ASSESSMENTS OF THE SYSTEM OF RICE INTENSIFICATION (SRI)

Proceedings of an International Conference held in Sanya, China, April 1-4, 2002

Organized by

Cornell International Institute for Food, Agriculture and Development
China National Hybrid Rice Research and Development Center

Co-sponsored by

Association Tefy Saina, Madagascar
China National Rice Research Institute

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INTRODUCTION

This conference on the System of Rice Intensification (SRI), held April 1-4, 2002, was a first attempt to assess cross-nationally the opportunities and limitations that are presented by this remarkable methodology developed in Madagascar for increasing rice production. By raising the factor productivity of land, labor, water and capital, SRI can give yields about twice the present world average without reliance on new varieties or agrochemicals.

A diverse group of participants from 18 countries — NGO workers, researchers, policy-makers, and farmers — gathered in Sanya, China, to share field experience and research findings in four days of reports and group discussions. The conference was organized by:

- **Cornell International Institute for Food, Agriculture and Development** (CIIFAD), which has been facilitating the evaluation and dissemination of SRI since 1994; and
- **China National Hybrid Rice Research and Development Center** (CNHRRDC), which began using SRI methods in 2000 and offered to host the conference.

It was co-sponsored by:

- **Association Tefy Saina** (ATS), the NGO in Madagascar that has pioneered SRI since 1990, carrying on the work of Fr. Henri de Laulanié, S.J., who had developed SRI over the preceding two decades; and
- **China National Rice Research Institute** (CNRRI), which has begun evaluating the methodology this past year.

The conference was supported by a grant to CIIFAD from the Rockefeller Foundation, which enabled the organizers to have wider international participation than otherwise possible.

We were pleased to have 45 international participants — 12 from non-governmental organizations, 11 from universities, 11 from government institutions, 7 from international organizations, 2 from the private sector, and 2 farmers — plus over 50 participants from China. These persons and their institutional affiliations are listed on pages 194-198.

SRI, as elaborated in these proceedings, is a methodology for giving rice plants growing environments that are conducive for more productive phenotypes from existing genotypes. The conference was convened to understand how SRI is being elaborated and modified under diverse conditions between and within countries, responding to different farmer constraints and various objectives.

The conference was expected to consolidate knowledge and clarify practices rather than to describe and evaluate something that is fixed and final. The task was to characterize and assess "a work in progress."

While SRI is very simple in many respects, it exemplifies the complexity of natural systems, bringing together multiple convergent factors. The concepts of interactivity and synergy are more illuminating for SRI than are any mechanical notions of causation and *ceteris paribus* effects.

The development and spread of SRI has been more practice-led than scientifically derived. This makes all the more necessary an appreciation of the dialectical relationship between knowledge and practice. The meeting was not convened to advocate SRI or to encourage competition for the highest yields. Rather, participants were asked to highlight the problems that they have found with SRI practice and adoption, not to emphasize accomplishments. Only objective, self-critical reporting and evaluation can make SRI more beneficial to large numbers of producers and consumers around the world.

These proceedings make available to persons who could not attend the Sanya conference what was reported there and what ideas and conclusions were generated by group discussions. Since this was a first international conference, the information here is more indicative than conclusive. We hope that this report will heighten others' interest in trying out SRI methods themselves and in contributing to a growing body of scientific explanations as well as to better farmer practices.

The papers have been edited for readability, given that most contributors normally write in some other language than English. We have not tried to homogenize the papers in terms of format or manner of presentation, leaving the differences in tone and style that reflect the diversity of professional and country backgrounds that the varied participants brought to this first international assessment of SRI.

We thank all the members of the international organizing committee whose names are listed on page 193. Special thanks go to Virginia Montopoli, CIIFAD executive assistant, who coordinated the travel and other planning arrangements and assisted at the conference itself. Without her tireless and always helpful support, the event could not have been so successful. We thank also Cally Arthur and Olivia Vent for their skilled assistance in producing these proceedings.

We appreciate very much the support of Dr. Ruben Puentes, Associate Director of the Rockefeller Foundation's Food Security Program. He has not only provided financial assistance for work on SRI but has been a good professional colleague helping to comprehend the potentials and reasons for SRI success. He was willing to give support and encouragement when there was only a fraction as much evidence to support the claims for SRI as there is now.

This conference has brought together a substantial amount of evidence from around the world that these claims should be taken seriously and evaluated further to understand the limitations and the full potentials of SRI. Both food security and the alleviation of hunger, on the one hand, and the intensification, diversification and modernization of agriculture, on the other, can be supported by this same methodology, which can also have positive impacts on the environment. Further, it appears that SRI could have relevance beyond rice production and for the beneficial agroecological practice of agriculture more generally. Thus we are pleased to share the following information with readers around the world, and we look forward to increasing production and exchange of knowledge about the theory and practice of SRI.

—*The Editors*

Participants at the International Conference on the System of Rice Intensification that was held in Sanya, China on April 1-4, 2002.

Communication from the International Conference on the System of Rice Intensification (SRI) Held in Sanya, China, April 1-4, 2002

Organized by the Cornell International Institute for Food, Agriculture and Development (CIIFAD) and the China National Hybrid Rice Research and Development Center (CNHRRD), co-sponsored by Association Tefy Saina (ATS), Madagascar, and the China National Rice Research Institute (CNRRI)

Reports from the 15 countries where SRI methods have been tried and from the Chinese participants who have done evaluations on SRI have shown that the principles and methods of SRI have:

- **much potential for raising rice yields**;
- under **many different circumstances**;
- in **environmentally friendly ways**;
- that are **particularly accessible to small farmers** to contribute to food security and poverty reduction; and
- that can substantially **raise the factor productivity** of land, labor and water for the benefit of households and countries.

The best uses of SRI methods involve **farmer skill, experimentation and learning** rather than promotion and adoption of a fixed technology. The system should contribute to human resource development as well as to rice production. Furthermore, SRI should **always continue to evolve and change:**

- to **suit the varied conditions** under which rice is grown; and
- to **incorporate new learning** from farmers and scientific researchers.

The participants will **assist the development and spread of SRI**:

- through scientific research to expand and deepen our knowledge of the principles and practices of SRI; and
- through NGOs and farmer organizations to spread and evolve the use of SRI methods.

The participants will cooperate to **advance the theory and practice of SRI** through:

- **national networks** of practitioners and researchers within their respective countries;
- **international networks** using electronic means of communication;
- **a website** to make information on SRI accessible worldwide;
- **sharing of extension materials and information on practices** as well as scientific reports and evaluations; and
- **international forums** such as the Latin American rice congress to be held in Havana, Cuba, in July 2002, and the international rice congress to be held in Beijing, China, in September 2002.

What is the System of Rice Intensification?

The System of Rice Intensification — in French, *le Système de Riziculture Intensive*; referred to as SRI in English and French and as SICA in Spanish — is quite literally a "system" rather than a "technology" because it is not a fixed set of practices. While a number of specific ***practices*** are basically associated with SRI, these should always be tested and varied according to local conditions rather than simply adopted.

With good use of these practices, it is usually possible to increase rice yields by 50 to 100%, and increases of 200 to 300% have been achieved where the initial level of production was low. Such increases can be attained without requiring farmers to change varieties or to use any purchased inputs. Only about half as much water is needed with SRI, so there can be substantial water savings from this method of production.

The ***principles*** that underlie SRI practices are more important than the practices themselves, and thus these principles should be considered first. The practices that follow from these principles differ dramatically from those that irrigated rice farmers have used around the world for decades, centuries and even millennia.

SRI grew out of insights gained by Fr. Henri de Laulanié from his three decades of work with rice and rice-growing farmers in Madagascar. He sought to learn how the best possible growing environment can be provided to rice plants. SRI practices were crystallized in 1983, but were not evaluated or disseminated very much for a decade.

Indeed, SRI methods were even not tried outside of Madagascar until 1999, first at Nanjing Agricultural University in China, and then by the Agency for Agricultural Research and Development in Indonesia. Since 2000, the evaluation and dissemination of SRI has spread to a dozen more countries, usually with good results and sometimes with spectacular results. There is thus growing interest around the world in this system for rice production.

The objective of SRI is not to *maximize yields* but rather to achieve *higher productivity* from the factors of production devoted to rice — land, labor, capital and water. Increases in productivity should be achieved in ways that benefit both farmers and consumers, especially poorer ones, and that are environmentally friendly if an innovation is to contribute to equity and sustainability.

The productivity of these four factors of production can be raised all at the same time with SRI practices, without tradeoffs among them. The exact yields obtained with the methods will vary considerably, since yields depend on the *skill* with which the practices are used as well as upon the *soil* and other growing conditions for the rice. So far, SRI methods have been able to raise the yields of any and all varieties used, both traditional and improved cultivars.

Principles

SRI practices derive from the following observations that come from the work and writings of Fr. de Laulanié:

1. **Rice is not an aquatic plant**. Although rice can *survive* when growing under flooded, i.e., hypoxic, oxygen-less, conditions, it does not really *thrive* in such a soil environment. Under continuous submergence, most of the rice plant's roots remain in the top 6 cm of soil, and most degenerate by the plant's reproductive phase.
2. **Rice seedlings lose much of their growth potential if they are transplanted more than about 15 days after they emerge in their nursery**. This potential can be preserved by early transplanting, before the start of the fourth phyllochron of growth, in conjunction with the other SRI practices.
3. **During transplanting, trauma to seedlings and especially to their roots should be minimized**. Stress, such as from the drying out of roots, delays the resumption of plant growth after transplanting and reduces subsequent tillering and rooting. This principle does not mean that one can get good SRI

results *only* with transplanting; it means that transplanting when done should be done very carefully. *Direct seeding* can also be used with SRI practices as it avoids root trauma entirely.

4. **Wide spacing of plants will lead to greater root growth and accompanying tillering**, provided that other favorable conditions for growth such as soil aeration are provided.
5. **Soil aeration and organic matter create beneficial conditions for plant root growth** and for consequent plant vigor and health. This appears to be the result of having greater abundance and diversity of microbial life in the soil, which helps plants resist damage from pests and diseases.

Practices

To give effect to these principles, SRI is communicated in terms of a set of practices or techniques. These should be understood as *starting points* for experimentation and for fitting SRI to local conditions.

1. **Start by transplanting *young seedlings***, preferably 8-12 days old and not more than 15 days, when the plant still has just two small leaves and the seed sac is still attached to the root. The nursery from which the seedlings are taken should have been cultivated like a garden, not kept submerged in standing water.
2. **Transplant seedlings *quickly and carefully***, allowing only 15-30 minutes between uprooting from the nursery and planting in the field
   a. Seedlings should be put 1-2 cm deep into soil that is muddy but not flooded.
   b. They should be laid into the soil with care, with roots lying horizontally so that their root tips are not pointing upward.
3. **Plant the seedlings *far apart***, with
   a. One seedling per hill and
   b. Relatively few plants per m^2.

   In some soils, 2 plants per hill may give more tillers per m^2 but certainly more plants in a hill will create inhibitions on root growth due to competition.
4. **Plant in a *square pattern* to facilitate weeding.** The most common SRI spacing is 25x25 cm spacing, but with good soil conditions, the hills can be up to 50x50 cm apart. With a square pattern, weeding can be done in perpendicular rows.
5. **Keep the soil *well drained* rather than continuously flooded during the vegetative growth period**. Then, after panicle initiation, keep only a thin layer of water on the field (1-2 cm) until 10-15 days before harvest, when the field should be drained. During the vegetative growth period of tillering, one can either:
   a. Apply *small amounts of water daily* — just as much as needed to keep the soil moist but never saturated, with no standing water. During tillering, the field should be left to dry out for several short periods (2-6 days), to the point of surface cracking; or
   b. *Flood and dry the field* for alternating periods of 3-6 days each throughout the period of vegetative growth.

   With either method, the objective is to avoid sustained hypoxic soil conditions that will cause the roots to form air pockets (aerenchyma) and begin to degenerate.
6. **To control weeds, there should be early and frequent weeding**. This is best done with a simple mechanical hand weeder often called a 'rotating hoe,' starting about 10 days after transplanting. Then weed about every 10 days, at least once more and if possible 2 or 3 times more, until canopy closure makes weeding difficult and no longer necessary. The purpose of any later weedings is more to *aerate the soil* than to remove weeds.
7. **Add nutrients to the soil, preferably in organic form such as compost or mulch.** This is optional since the above practices will increase yield in almost any soil, at least for several years. The best results with SRI come from soil that is rich in organic matter and microbial activity. SRI farmers often apply their compost to a preceding crop, such as potatoes or beans, rather than to the rice crop itself, to give more time for decomposition and microbial multiplication. Chemical fertilizers used with SRI practices raise yield, but they do not contribute as much over time to soil quality, which is a key factor in best SRI performance.

Approach

SRI is characterized as a methodology rather than as a technology because it is not to be presented to farmers as a set of practices to be simply *adopted*. The principles behind SRI should be explained so that farmers understand the reasons for the practices. Farmers should be encouraged to test, vary and evaluate the practices, *adapting* them to their own field conditions and taking factors like their labor constraints into account.

SRI was seen by Fr. de Laulanié as a strategy not just to increase rice production, but also to promote **human resource development**. Farmers, as a result of working with SRI, are encouraged to take more responsibility and more initiative for their own development. They see that traditional practices or even introduced modern ones do not necessarily give the highest yields.

Experimenting with spacing, water applications, weeding, etc. and making their own evaluations of what can work best for them encourages critical and independent thinking. SRI is thus intended to be more than just an agricultural innovation. NGOs working with SRI have found that it can be very motivating for farmers.

Tefy Saina — the name of the NGO that Fr. de Laulanié and a number of Malagasy friends established in 1990 to promote SRI as part of overall rural development in their country — means "to develop the mind" in the Malagasy language. Thus in any efforts to extend SRI, farmers should become **engaged as partners** in the evaluation of its practices and become **involved in farmer-to-farmer dissemination** of the opportunities that SRI can open up.

For many farmers, **the first year of SRI practice is difficult**, especially doing the careful transplanting of tiny, young seedlings. More labor time per hectare is required when first using SRI methods. But as farmers become familiar and skillful with the practices, they find that SRI can take less time. Eventually, the whole SRI operation can require less labor per hectare than do conventional methods. Changes in the human factor are as important as technical changes.

Also, farmers who are practicing SRI for the first time should be warned that for the first month and even up to 5 or 6 weeks, their field will look disappointing. There will be little green color to be seen as plants are small and sparse; and there will be no reflection of blue sky from standing water. One will see mostly mud. But once the exponential increase in tillering begins as a consequence of SRI's plant, soil, water and nutrient management practices, the field will fill rapidly with impressive green growth. The flag leaf usually remains green and upright up to harvesting. There is little senescence of the rice plant above — or below — ground.

SRI farmers often get asked: What is the new variety that you have planted this year? The answer: It is the same variety as last year, only new management practices are being used to bring out the plants' natural growth potential. This is the challenge of SRI, to achieve the full potential of rice by creating a growing environment for plants that is most conducive for vigor and production.

—Norman Uphoff, Cornell University,
Sebastien Rafaralahy and Justin Rabenandrasana,
Association Tefy Saina

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*

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Keynote Presentations

An NGO Perspective on SRI and Its Origins in MADAGASCAR

Sebastien Rafaralahy, Association Tefy Saina

Association Tefy Saina is a small NGO that works on training for rural development in Madagascar. It was established in 1990 with the assistance of Father Henri de Laulanié, S.J., a trained agriculturalist, in order to carry on and further develop his three decades of work for agricultural and rural development in Madagascar.

The name of our Association means "to develop the mind." This name indicates that development must involve, above everything else, the whole person, and not just certain skills but also the capacity for thinking, so that each person takes responsibility for himself, for others, and for his or her environment.

Since its creation, our Association has set itself the principal and urgent task of developing and diffusing the System of Rice Intensification in Madagascar which Father de Laulanié formulated over several decades of working with farmers to help meet people's food needs.

Rice—An Essential Food

Rice is the most important food crop in Madagscar. In our Malagasy language, we say "to eat means to eat some rice." Malagasy people think that unless you have eaten rice, you have not had a proper meal. So Madagascar has one of the highest levels of rice consumption per capita. However, this level has been declining. Sixty years ago, Malagasys had 150 kg of milled rice per capita each year; now they have no more than 110 kg. Such a decline could be due to increased affluence, but in Madagascar this reflects a growing population size and very low yields. Annual rice production needs are 2.5 million tons to feed 15 million inhabitants.

In rice farming, two methods coexisted in our country before the introduction of SRI. First, there were traditional methods, inherited from our ancestors and passed from fathers to sons without specific training. This system is characterized by planting randomly very mature seedlings, sometimes two or three months old, putting several seedlings in each hill, even up to 10 plants per hill. The paddies are kept always inundated with water.

In the past 60 years, improved methods known as le Système de Riziculture Ameliorée (SRA) have been introduced in the country: transplanting plants 3 or 4 weeks old in rows; 1 to 3 seedlings per hill; and into paddies kept similarly saturated with water. With these methods, it is strongly recommended to utilize chemical inputs like fertilizer. Even with the spread of SRA, however, the average national yield has remained only about 2 tons per hectare (t/ha), very low productivity.

The Discovery of SRI

SRI was developed mostly through the long and hard efforts of Fr. de Laulanié, but its crystallization was in fact partly by accident (Laulanié 1993). After coming to Madagascar from France in 1961, this wonderful and inspiring man worked very closely with farmers and with rice plants to try to help Malagasy peasants improve their agricultural practices and results.

Fr. DeLalaunié had trained in France before World War II at the Institut National Agronomique (INA) in Paris, but only after coming to Madagascar did he begin to learn about rice. He worked alongside farmers to learn what they knew about rice, without any preconceived ideas about how rice should be grown.

At first, he worked with the improved methods (SRA) described above and taught them to farmers. But being open-minded, he noted two things:

- Rice plants have very great tillering potential under the right conditions; and
- The best harvests of rice are obtained with soil aeration.

He started transplanting single seedlings per hill, which he saw practiced in some regions of the country, and he recommended that farmers follow this method. He also saw that some farmers did not keep their fields continuously flooded but rather they dried their fields out for certain periods of time, with beneficial effect. In order to utilize more fully the push weeder that extension agents were promoting at the time for row-planting, he tried planting rice plants in a square pattern. This way, the rotating hoe (*houe rotative*) could be used perpendicularly in two directions, and the wider spacing also encouraged plant growth.

In December 1983, at Antsirabe where he had established a training center for young peasants, Fr. de Laulanié made the breakthrough that launched SRI when he asked his students to plant seedlings that were only 15 days old. There was a prolonged drought that year, and when there was some rainfall, Fr. de Laulanié thought it would be less risky to transplant the tiny seedlings than to count on there being enough rain again when they reached the maturity that was normally used, 30 days. The students being young did not challenge the priest, but probably none of them believed that planting such young seedlings could be successful.

Father de Laulanié wrote later about this experiment: "The results struck like lightning as a technique that I had considered to be an exception became the rule for our paddy cultivation. I had never harvested so much rice before. The tillering reached 20-30 tillers per plant, which was fantastic." He subsequently recommended that rice farmers adopt this new method of transplanting very young seedlings, only 15 days old. He talked about this method to the government's research and extension services and to technicians at private training centers for rural development. But nobody was willing to believe him that this practice gave such good results.

Indeed, agronomists and other specialists in rice science said the reported results were not possible, that they were above the biological yield ceiling for rice. They rejected this new system without themselves ever undertaking any trials to test what he was suggesting. Peasants generally listened to the priest's talk in silence. He could feel that they did not want to change the long-standing practices in which they strongly believed, having inherited their accustomed techniques from their ancestors.

Father de Laulanié in making his recommendations at first did not have any theoretical justification to support his ideas. He had to wait until 1988 to give this system a solid scientific explanation, as discussed below. Mostly he had to rely on the cooperation of young peasants who had themselves seen the results of rice cropping with SRI methods, and on a few groups of isolated peasants here and there and on religious congregations of women who were willing to persevere with this system. The progress was very slow.

Father de Laulanié encouraged those working with him to undertake trials with seedlings even younger, only 12, 10, even 8 days old, with larger and larger spacings to see what would give best results. Those willing to make these changes in conventional practice were not disappointed, because the new methods could usually double their traditional yields and sometimes give even more. They initially called this new rice farming method "eight-days transplanting."

The Katayama Model of Rice Tillering

As noted already, a theoretical base of scientific explanation was missing for Father de Laulanié to convince those who challenged his empirical results. This unfortunate situation continued until 1988 when he happened to read a book on rice from France. In this book, Moreau (1987) presented a model of rice tillering that had been developed more than 50 years before by the Japanese researcher, T. Katayama (1951). According to this model, tillers emerge in a sequence that is governed by a sequential pattern, defined in terms of regular time intervals known as "phyllochrons." The duration (or length) of a phyllochron depends, among other factors, on temperature, the number of degree-days, and seed variety. For rice, a phyllochron varies from 5 or 6 days to 8 days or even more.

The Katayama model of tillering presented by Moreau is a genealogical table that is complex and not easy to understand.[1] So Father de Laulanié spent two years studying it and transforming it into a simplified table that is amenable to some statistical analysis. We refer to this now as the "Katayama-de Laulanié tillering model." It shows that three phyllochrons (growth periods) after the main tiller emerges, i.e., during the fourth phyllochron, a first primary tiller issues from the base of the main tiller, and then a second primary tiller emerges in the fifth phyllochron, etc.

Tillering development follows an exponential law that is evident once one understands the function of phyllochrons, though only with rice plants that are growing in aerated soil so that their roots are not dying back. It is this degeneration, common with continuously irrigated rice, that causes what is conventionally called "the maximum tillering stage" to precede panicle initiation. With SRI practices, maximum tillering and panicle initiation generally coincide.

[1] *The full Katayama table can be found on pages 223-226 in Volume I of the English translation of the Japanese encyclopedia of rice science edited by Matsuo et al. (1997).*

When growth is not constrained by sub-optimal environmental conditions, the total number of tillers will follow what is known in biology and mathematics as a Fibonacci series, where each stage's number equals the sum of the preceding two stages (see middle row of table below). This model operating through 12 phyllochrons of growth is summarized in Table 1. With ideal growing conditions, it is possible for rice plants to continue their tillering into a 13th and even 14th phyllochron of growth, exceeding 100 tillers or more.

Father de Laulanié wished to meet Katayama, and in 1992 he asked the Japanese Ambassador in Madagascar to help make contact so that he could explain this model of tillering development and get feedback and corrections from the originator of the model. Unfortunately, it turned out that Katayama had died several years earlier.

Agronomic consequences of model

For Father de Laulanié, the agronomical consequences from this model were evident:

1. The autonomy of tillers was reaffirmed. All of the tillers have their own leaves and their own roots.
2. There is evident solidarity among tillers: the formation of new tillers depends on the support of existing ones. Normally, five tillers can beget three new ones, with an average ratio of 5:3, or about 1.66.
3. A reasoned calculation of the best transplanting dates is possible with the tillering model. Transplanting should be done during the second phyllochron, or at latest during the third, to permit rice to recover more quickly from its trauma and stress of transplanting. Below are the transplanting dates worked out for Madagascar. Rice farmers can better schedule their work planning by using this table.

Transplanting dates

Altitude	0–500 m	500–1000 m	1000–1500 m
Best age of plants	6–11 days	7–13 days	8–15 days

Conditions for SRI Practices

Father de Laulanié considered two sets of conditions as defining SRI practice, recognizing that people are the most important factor for agriculture. Citing Fukuoka, Father de Laulanié liked to say: "Agriculture is an art. The farmer is an apprentice, and the plant is his teacher." He added: "Dear farmers, look at and listen to your rice, because it only knows truth [about how it can grow best], and only it can tell this to you."

Essential elements

The first essential part of SRI concerns *water management*. Given the fact that rice is not an aquatic plant, traditional water management, which is really minimum management because it tries to keep fields continously flooded, should be changed. SRI uses a minimum of water. The rice should have all the water necessary for its physiological and nutritive needs, but no more. Any excess of water is prejudicial. The best water for irrigating rice is rain water because it is oxygenated; if it is raining, there is no need to irrigate. To obtain greater profit, paddies should be kept drained during the day, with water added at the end of the day or at night as necessary to maintain soil moisture.

The second essential aspect is the *transplanting of very young seedlings* that still have only two tiny leaves, one by one, and with wide spacing. They should be transplanted very carefully so there is minimum trauma to the root. Rice farmers should determine the spacing that is best for themselves. They are advised to try the following distances: 25 x 25, 33 x 33, 40 x 40, and 50 x 50 cm, and then choose which is best for them under their soil and other conditions.

Additional elements

The following practices are beneficial for any crop and not only good for SRI:

- *Early weeding*: This activity should begin 8-10 days after transplanting and then be done every 10 days during the first month of vegetative growth. If farmers can do more weedings, they can often get even

Table 1. Katayama – de Laulanié model

Phyllochron	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Tillers/phyllochron	1	0	0	1	1	2	3	5	8	12	20	31
Total number of tillers	1	1	1	2	3	5	8	13	21	33	53	84

better results because this aerates the soil. However, farmers have to decide for themselves how many times to weed.

- *Fertilization*: Fr. de Laulanié was not against use of chemical fertilizers, but he found that using organic manures or compost, which are less expensive for cash-limited farmers, can contribute greatly to soil biological activity.

Competition for the Best Rice Yields

To launch more systematic efforts to promote SRI and to offer Fr. de Laulanié appropriate opportunities to train technicians on these methods and sensitize the authorities in charge of rice production in Madagascar, Association Tefy Saina organized six annual meetings between 1990 and 1995. The 1993 meeting recommended annual competitions to give awards for the best rice yields. These would be organized at two levels, national and regional, under government responsibility. Prizes should be awarded for the national competition by the President of the Republic. These competitions would be special occasions to boost SRI and to encourage small farmers to change their mentality vis-à-vis technological innovation, so they would more easily accept and adopt new profitable techniques like SRI. On such an occasion, the State would be honoring and giving more value to small farmer efforts. All that would promote development.

Fr. de Laulanié and we had a bet that these competitions could speedly increase rice production in Madagascar. But results were deceiving. Lacking the necessary support from the government and financial backers, these competitions have not reached their objectives. From 1994 to 2001, only 10 regional competitions were held, with 695 participants having yields ranging from 6 t/ha to 17.5 t/ha, which received the award. The average national rice yield in Madagascar is only 2 t/ha.

Training on SRI in Villages and in Schools

From 1990 to now, we have carried out itinerant training sessions on SRI in rural villages for small rice farmers. To diffuse this system of rice cultivation, Fr. de Laulanié did not hesitate to teach Katayama's model of tillering to small farmers, even if their reading, writing and arithmetic were not strong, so that there would not be any mystery about SRI effects. For us, this pedagogical approach has been always fruitful. Recently Catholic Relief Services in Madagascar has developed a set of illustrated cards to teach about SRI, working in seven dioceses across the country. They are hoping to be successful in this way.

Training sessions on SRI were given in rural schools in the Fianarantsoa region. The pupils learned the techniques rapidly, as if they were games, and without difficulty. Their first experiments in 1991 at Isorana were quite successful. They obtained easily 7.7 t/ha, which was truly unexpected by their parents and neighbors. Indeed such an yield was unheard of anywhere, so that students became the teachers of their parents. From these training sessions on SRI in rural schools, a Green Secondary School was created in the Isorana region after 1995. In October 2001, we were pleased when a "Laulanié Green University" was established in Antananarivo.

Research Confirmation

Tefy Saina began cooperating with Cornell University through CIIFAD in 1994, trying to help farmers in the peripheral zone around Ranomafana National Park find alternatives to the practice of tavy (slash-and-burn agriculture). This started a fruitful collaboration both gathering and analyzing data to understand what could be attained through SRI and why.

From 1997, the students from the Faculty of Agriculture (ESSA) at the University of Antananarivo began working on SRI through the interest and support of Prof. Robert Randriamiharisoa. His students in agronomy have undertaken SRI surveys covering many SRI factors. Up to now, five theses have been researched and written on SRI. This work has established that biological nitrogen fixation (BNF) in SRI is a reality.

Since 1999, Bruno Andrianaivo, a senior staff member of the agricultural research agency FOFIFA, has undertaken studies to evaluate SRI in farmers' fields around Fianarantsoa. He was the first government researcher to accept that SRI has something to offer the farmers of Madagascar. These were all important steps for gaining knowledge about SRI because from the early 1990s, scientists in our country were opposed to it, some vocally.

SRI Results

SRI has given some fantastic yields for farmers in Madagascar. The results we report come from all the country's regions including many different ecological zones (see Tables 2 and 3). SRI has worked very well everywhere in this diverse country. On the east and west coasts, two rice crops a year are possible. Moreover, around Fianarantsoa we have seen some success with ratooning, with results reaching 60-70% of the preceding harvest. This is very profitable as it saves labor for sowing and transplanting.

These are data for farmers from whom we could gather precise measurements. The exact number of SRI adopters in the entire country is unknown since collecting data is extremely difficult in Madagascar. Tefy Saina does not have the resources required to cover such a vast country (593,000 km^2) with its very deficient road system.

In 1992, we had the optimistic hypothesis that the number of adopters might double each year, through efforts to boost SRI. With 1,000 adopters in 1992, we should have reached 1,000,000 adopters by 2002. This would represent most of the rice-farmer population of the country. Unfortunately, the effort has not progressed that well because of a lack of financial means. It is hard to understand why financial backers have not been more interested in the method. Nevertheless, the Ministry of Agriculture estimates that about 10% of the rice farmers are now using SRI, which amounts to nearly 100,000 farmers.

Problems Suggested with SRI

Problems with SRI that are often expressed in Madagascar are given in Table 4 on the next page. Some are real, but others are not. The table suggests how Fr. de Laulanié would respond to these concerns and how he would propose dealing with them.

Conclusions

Given that SRI can considerably increase rice yields, it is unfortunate that its adoption has not been more rapid in the country of its origin, Madagascar. But we are glad to see it beginning to spread there more rapidly now, and to have more and more scientists gaining confidence in it, so farmers will be encouraged to take it seriously. The spread to other countries validates the worthwhile nature of the methods.

Table 2. Examples of yields above 15 t/ha

Farmer Nº	Localisation	Year	Surface (ha)	Spacing	Panicles/ hill	Grains/ panicle	Yield (t/ha)
1	Ampampana	1993	0.105	25x25	29	134	17.00
2	Bezaha	1993	0.25	25x25	26	130	15.00
3	Tsaranoro	1996	0.30	33x33	50	192	23.43
4	Soatanana	1998	0.13	50x50	70	260	21.00
5	Betafo	1998	0.10	30x30	33	172	16.60
6	Ambano	1998	0.12	25x25	28	152	16.18
7	Manandona	1998	0.25	25x25	31	111	15.23
8	Anjazafotsy	1998	0.03	25x25	29	138	15.23
9	Morondava	1999	0.50	25x25	30	130	17.50

Table 3. Some examples of SRI utilization on the High Plateau

	Harvest		
	1996	1998	1999
1. Region: Antsirabe			
Farmers (number)	47	47	data
Surface average (ha)	0.082	0.264	not
Harvest/farmer (kg)	541	2,724	collected
Yield average (kg/ha)	6,600	10,320	
2. Region: Antananarivo			
Farmers (number)	29	24	26
Surface average (ha)	0.113	0.165	0.153
Harvest/farmer (kg)	655	1,444	1,582
Yield average (kg/ha)	5,800	8,750	10,340

Table 4. Dealing with problems suggested with SRI

Problems	Responses
1. Soil depletion is a danger.	1. Research remains to be done on this. In the meantime we say: every year, please note your yields. If there is a pattern of decline, use more compost.
2. Water management and control is difficult for SRI.	2. In principle, it should be possible to make any area suitable for SRI if some investment is made for better control and drainage of water.
3. SRI is only feasible on a small scale and is really a "garden" kind of rice cultivation.	3. Actually, in Madagascar, most rice farmers have only 0.3-0.5 ha. Farmers who have such small land holdings need to find a way to get the very highest yield possible from what little land they have. Also, as the scientific bases for SRI become better understood, its principles and practices should be adaptable for larger-scale use.
4. SRI practices are very difficult for farmers to master.	4. In rural development, any technical skills can be acquired within several years. We must be patient. Increasing farmer skills is a goal of development.
5. SRI requires much labour intensity.	5. This is true, but only initially. In fact, SRI can become labour-saving after farmers have mastered the necessary skills.
6. SRI requires spending a lot of time in the fields, so a farmer who needs to hold down another job to earn money to support his family cannot do this at same time with SRI	6. This is also true. But if money is scarce in the rural economy, farmers should invest their limited labor time so as to get the highest possible returns from their land, labor and capital. SRI can help farmers accumulate capital, even little by little, because their labor productivity is higher.

We thank Prof. Norman Uphoff who has been helping us in spreading SRI outside Madagascar and salute his perseverance. If not for this, nobody else except Malagasy people will know about this method of wonderful rice cultivation. We thank also his CIIFAD colleague Glenn Lines for his persistent support to validate and extend SRI.

We thank most, of course, Fr. Henri de Laulanié. We in Madagascar are very grateful for his life and work. During all his life in our country, he devoted himself to improving the conditions of rural people. We are trying to carry on his efforts to advance and develop both the spiritual and material well-being of all the small farmers.

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A Scientist's Perspective on Experience with SRI in CHINA for Raising the Yields of Super Hybrid Rice

L. P. Yuan, China National Hybrid Rice Research and Development Center

The success in development of hybrid rice in China is a great breakthrough in rice breeding. It opens up an effective way to increase rice yields on a large scale. Many years of practice have proven that hybrid rice has generally a 20% yield advantage over modern semi-dwarf inbred varieties. In recent years, the planting area under hybrid rice in China is around 15 million ha, covering 50% of the total rice land and giving an average yield of 6.9 t/ha from hybrid varieties while that from inbred varieties is 5.5 t/ha.

Although research on commercial utilization of heterosis in rice has made tremendous achievements during the last 25 years, from a strategic point of view, the development of hybrid rice is still in its juvenile stage, since the great yield potential in hybrid rice has not been fully tapped yet. According to the estimates of most plant physiologists, rice can use about 5% of solar energy through photosynthesis. Even if this figure is discounted by 50 %, the yield potential of rice would be as high as 22-23 t/ha in temperate regions. So it can be seen that hybrid rice breeding possesses a very brilliant future.

In order to meet the food demands of the Chinese people in the next decade, a super rice breeding program was set up by China's Ministry of Agriculture in 1996 with the following yield targets, taking medium-duration rice as an example:

- Phase I (1996-2000): 10.5 t/ha on large scale
- Phase II (2001-2005): 12 t/ha on large scale

By 2000, through morphological improvement plus utilization of inter-subspecific (indica/japonica) heterosis, several pioneer super hybrid rice varieties had been developed that could reach the yield standard of phase I.

- For example, in 1999 a two-line hybrid variety, P64S/9311, was grown at 10 locations in Hunan Province with 6.7 ha (100 mu) each for demonstration. Out of these, the average yield in 4 locations was over 10.5 t/ha.
- Again in 2000, there were 18 locations with 6.7 ha each, and 4 locations with 67 ha (1000 mu) each, where the average yield was above 10.5 t/ha. The total planting area under this hybrid variety was 235,000 ha in 2000 and 1.2 million ha in 2001. Its average yields were 9.6 t/ha and 9.15 t/ha, respectively.
- Another two-line super hybrid P64S/E32 reached a record yield of 17.1 t/ha in an experiment plot (720 m^2) in 1999, and its yield is around 10 t/ha on commercial production.

In 2001, a newly developed three-line super hybrid, II-32/Min86, yielded 17.95 t/ha in an experiment plot (800 m^2). This is the new record so far in China. This hybrid also performed very well at a 7 ha demonstration location in Fujian Province last year. The average yield was 12.76 t/ha. This means that the yield standard set for the phase II has been basically met by this hybrid variety.

The yield levels mentioned above are obtained by using improved traditional cultivation methods that are commonly used for hybrid rice in China. Generally speaking, these include heavy application of chemical fertilizers; transplanting strong seedlings with many tillers, two seedlings per hill and with relatively dense spacing (20 X 20 cm); keeping the soil wet and flooding alternately; and using herbicides to kill weeds.

Experiments with SRI

Information about SRI reached me for the first time in late 2000. After reading a paper entitled "Questions and Answers about SRI" written by Dr. N. Uphoff, I was highly surprised and interested to know that the highest yield of rice that I have heard of, 21 t/ha, had been obtained by using the SRI method in Madagascar. Since then, Dr. Uphoff has been in contact with me very often and has given me more information about SRI. Thus my interest in this cultivation practice is increasing progressively.

To my thinking, if inbred varieties can reach such a high yield, it is quite possible that hybrid rice, especially our super hybrid rice, can yield even much more than that level by using SRI methods. This belief is based on two considerations. First, hybrid rice varieties have greater yield potential than inbred varieties under the same conditions. Second, old traditional Chinese cultivation methods were similar to SRI in some important aspects, such as application of organic fertilizers, wide spacing of plants, manual weeding instead of herbicide use, and keeping soil wet and flooding alternately.

The first trial of SRI was conducted at our Center's Sanya station from winter to spring 2000-2001. There were 8 combinations of practices, with plot size 100 m^2 each. The field management adopted was strictly according to typical SRI methods except a small amount of chemical fertilizer was used. That is to say, we transplanted tiny young seedling with two leaves, one seedling per hill, wide spacing (33 X 33 cm), large amounts of organic fertilizer (30 t/ha), manual weeding 3 times, keeping soil wet even to the point of cracking during the vegetative growth stage, etc. Among the 8 trials, only 3 varieties yielded above 10 t/ha (10.3-11.2 t/ha). Although the results were not as good as we had expected and hoped, their yield was still around 10% higher than TRC (conventional methods).

We continued SRI experiments with super hybrid rice at our Center's main station in Changsha in the summer of 2001. The results were better than in the previous experiment. Two varieties yielded 12 t/ha (plot sizes of 800 and 1000 m^2, respectively) and one variety yielded 12.9 t/ha (plot size 1000 m^2), which was a record yield for our Center so far.

A seminar report on SRI presented by Dr. Uphoff last April to our staff in Sanya and a paper on SRI translated by myself into Chinese, encouraged many Chinese scientists to conduct research in this area. There were 8 locations arranged by our Center to conduct SRI research with super hybrid rice in 2001. Of these, 5 locations got good results, with yield per ha over 12t.

Results from the Anqing Research Institute of Agricultural Sciences in Anhui Province show clear differences by comparing yield components between SRI and TRC (conventional methods) as shown in the next column. For these trials, fields were divided in half, using SRI and conventional methods side by side.[1]

	SRI	TRC
Spacing (cm)	33 x 33	16 x 26
Seedlings/hill	1	2
Panicles/hill	45.2	10.8
Grains/panicle	170.1	184.0
1000 grain weight (g)	25.5	25.2
Yield (t/ha)	12.15	10.02
Yield over TRC (%)	+21.3	—

Excellent results were also obtained in trials by a private sector company, the Meishan Seed Company in Sichuan Province. Using modified SRI methods, two experiment plots of 1,000 m^2 and 1,200 m^2 yielded 15.6 t/ha and 16 t/ha, respectively. Both are new records in Sichuan Province. The SRI yield components compared to those with TRC are shown below:

	Modified SRI	TRC
Variety	Super-I	Super-I
Panicles/m^2	337.5	283.5
Grains/panicle	185.3	159.6
1000 grain weight (g)	25.9	26.1
Yield (t/ha)	16.0	11.8
Yield over TRC (%)	+35.6	—

Preliminary Evaluation of SRI

1. SRI is a promising way to increase rice yield and to realize the yield potential of any variety regardless whether high-yielding variety (HYV) or local variety, but HYV can be expected to give higher absolute yield with SRI methods.
2. SRI methods can promote more vigorous growth of rice plants, especially the development of their tillering and root system.
3. Less insect and disease problems are observed during the vegetative growth stage.
4. There are definite varietal differences in response to SRI practices. Varieties with strong tillering ability and good plant type are more favorable for SRI cultivation.
5. SRI gives higher output with less input, but it requires very laborious manual work which makes it more suitable for small farms in developing countries that are well endowed with labor but have limited cropland.
6. SRI should be modified and wherever possible improved to be most suitable for local conditions.

[1] *A more detailed account of this research is given below on pages 112-115 in the section on Research Reports.*

Improvement of SRI

According to existing Chinese cultivation practices and preliminary experiences with SRI, we think that there are a number of ways in which SRI can be further improved, such as:

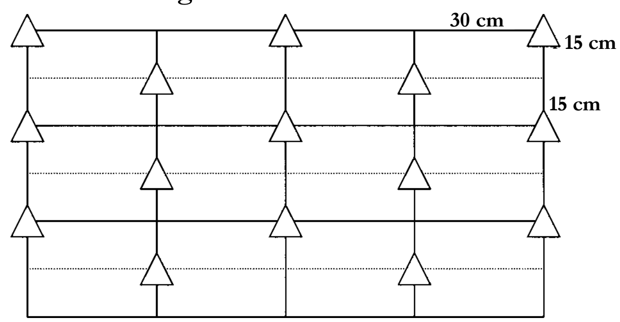
1. Use of tray nurseries to raise the young seedlings. The superiority of this method over flooded seedbeds is that there is no trauma when the young seedlings are transplanted and no shock after transplanting.
2. Application of herbicides to the field before transplanting. Weeds are a serious problem with SRI, especially during the early growth stage of rice. Weeding by hand or with weeding tools is not only hard work but it also causes injury to young plants.
3. Application of chemical fertilizers to promote vigorous plant growth when it is needed, especially at the beginning of the tillering stage.
4. Promoting tillering during the productive tillering stage but controlling tillering (mostly by water management practices) after that stage. Although SRI can promote rice plants to produce a great number of tillers, the percentage of productive tillers is relatively low. It can be seen from the following data provided by Tefy Saina (our results are similar to this):

Farmer's name	Yield (t/ha)	Tillers /hill	Fertile tillers /hill	Fertile tillers (%)
1. R. Albert	16.18	55	28	51
2. Ranaivoson	15.23	50	31	62
3. R. J. Donne	16.6	67	33	49
4. R. Henri	15.23	50	29	58
5. R. J. Claude	17.5	42	25	59
Average	16.2	52.8	29.2	55.3

Practical experiences have shown that the percentage of productive tillers in an high-yielding rice should be at least over 70%.[2] Too many nonproductive tillers waste nutrients, obstruct light penetration, cause pest and disease problems, and have adverse effects on the development of fertile tillers. Therefore, it is desirable to restrain the over-development of tillering. When the number of tillers reaches the targeted panicle number, it is the time to take measures to control tillering.

5. Making shallow furrows and raised beds in the field, keeping the soil at the bottom of the furrow between beds constantly wet during vegetative growth stage and maintaining a thin layer of standing water on the beds after panicle initiation. The raised bed can be alternately dried and wetted during the season. Such management of irrigation can contribute to soil aeration and at the same time meet plant needs.
6. Arranging hills in the triangular pattern shown below, transplanting 3 one-seed seedlings separately in each hill (Figure 1):

Figure 1: Pattern for transplanting single seedlings in separated triangular hills of three seedlings each



Such an arrangement has advantages over placing one seedling per hill in a square pattern. First, more fertile tillers per hill can be achieved this way; second, panicles are bigger and relatively more even because most of them are from primary tillers. The designer of this layout, Mr. Z. B. Liu of the Meishan Seed Company, who the person who achieved the record rice yield of 16 t/ha in Sichuan Province used this pattern of transplanting.

These ideas have come from our experimentation with and evaluation of SRI methods in a very short period of time. From a scientific perspective, SRI opens up many interesting questions for research and systematic study. We expect there will be many practical as well as theoretical advances in the years ahead.

Combining the insights from SRI management techniques with the genetic improvement work of rice breeders can help to meet the demand for rice that continues to grow. There are still many people in this world who are hungry and many others whose prosperity permits more consumption. Agricultural scientists will be challenged to keep ahead of the growing demand for food and feed grains with less water and less fertile land available to meet our production goals.

[2] *In the Anquing-Anhui trials referred to above, the rate of effective tillering with SRI methods was 72%.*

A Policy-Maker's Perspective on SRI from SRI LANKA

*Salinda Dissanayake, Member of Parliament, Government of Sri Lanka**

It is with great pleasure that I join so many SRI adopters and adapters from Asia, Africa and Latin America in this first international conference on the System of Rice Intensification. The review and sharing of experience and the deliberations undertaken here should be of great value for setting future directions to make SRI a more useful intervention for promoting sustainable agriculture in our countries.

My comments will be those of someone who has had responsibility for government policies in the areas of agriculture, lands and poverty reduction, and as someone who has personally practiced SRI. For me, SRI is not a matter of theory but of beneficial practice.

Rice is important not only because it is the staple food for millions of people, but also because it provides livelihoods for millions of people who employ substantial amounts of our natural and human resources in the production process. The land that is devoted to irrigated rice production cannot be put into some other use in the short run due to the ecological functions it performs and the specialized irrigation facilities already established. Increasing the productivity of the resources currently devoted to rice production is imperative for multiple purposes as development in the rice sector is development for land and for people.

The Rice Sector Situation in Sri Lanka

Sri Lanka possesses a long and proud history of utilizing its land and water resources effectively for paddy farming over most of the last 2,500 years. The country was called "the Granary of the East" in the ancient past, thanks to the magnificent irrigation systems developed and maintained with skill and commitment from the state leadership and the people. The scope and success of this agricultural endeavor are indicated by the more than 2,000 traditional varieties of rice possessed by our farmers.

However today, despite contributions of the Green Revolution of the 1960s and 1970s, Sri Lankan farmers face a spate of problems.

- The average paddy plot per household is less than 0.4 hectares, not enough to produce prosperity for the whole family given low levels of productivity.
- Farmers have a problem of water scarcity as the amount available for cultivating their small plots is diminishing year by year.
- Farmers experience problems with their soil, whose quality has been deteriorating due to the excessive use of chemical fertilizers and agro-chemicals.
- They frequently have difficulties in getting good seed of an appropriate variety in the required quantities at the needed time.
- Farmers also have constraints of labor availability due to the present unattractiveness of paddy cultivation with its low returns to family members and the high cost of hired labor.
- Specifically, many farmers have problems of land preparation due to the high cost of farm machinery and the declining rearing of farm animals.
- There is limited investment capital available due to the low returns on investment in the rice sector.
- When they do have a good harvest, farmers commonly have problems of storage and even lower prices.
- Finally, with unattractive prices for their production, rice growing has become an unprofitable venture.

Although the Green Revolution with its high- yielding varieties succeeded in increasing rice production, that was made possible with considerable environmental

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cost. The use of chemical fertilizers and pesticides affected the character of traditional integrated farming systems and compromised the biodiversity that provided sustainability to local systems of paddy farming. In Sri Lanka, there is an increasing incidence of suicide by farmers who find their situation without hope, and the dissatisfaction expressed by farmers over crop losses, indebtedness and other social pressures has become a matter of great concern for the political leadership of the country.

The Introduction of SRI in Sri Lanka

We have found that the System of Rice Intensification provides an alternative approach to rice production that addresses most of the problems that are being encountered by our farmers. Information on SRI first came in 1998 from Prof. Norman Uphoff who had been working in Madagascar but no action was taken until Mr. Joeli Barison from Madagascar visited Sri Lanka at a time when I was launching a program of desiltation and rehabilitation for minor reservoirs in the dry zone district where I come from. Our aim was to increase the cropping intensity of the minor irrigation systems by bringing back their water-holding capacity to original levels along with several other complementary interventions.

In January 2000, Barison talked with farmers, researchers and officials about SRI, and I arranged for him to explain this system on national television. As a farmer myself, I could grasp the basic principles behind SRI and had no difficulty in becoming convinced about its potential to make significant changes in our rice fields.

Having brought SRI to the attention of the top management, agricultural scientists, and rice researchers of our Ministry of Agriculture, we formed a small team to present information on SRI to groups of farmers, comparing these new practices with those that are presently being used by farmers. Farmers listened carefully, raising questions about root growth, tillering, nutrient absorption, water use, use of the mechanical weeder, and the practical application of a low-input, high-return model. They wondered about the adaptability of the method under the different dry zone and wet zone conditions in our country. They were inquisitive about how farmers in Madagascar did their land preparation, made and applied compost fertilizer, and managed water sparingly.

The first time that farmers practiced SRI on their own farm fields was to test its viability in the yala (dry) season in 2000. Staff of the Ambepussa Agriculture Training Center of the Western Provincial Council did trials to compare SRI with the conventional system. In these efforts it was clearly demonstrated that yields can be doubled by using SRI.

Personal Experience

I have my own rice field, a little more than two acres, located in Kurunegala District adjoining the national government's main rice research station at Batalagoda. I have practiced SRI on my field there for four seasons now using seeds of various different varieties, traditional and improved, to see which will respond best to SRI practices.

The highest yield reached so far was 17 t/ha, with BG 358, a variety developed by Sri Lankan rice researchers on the adjoining station. I have gotten some equally impressive yields, exceeding 8 t/ha and as high as 13 t/ha, with local varieties such as *Rathhel* and *Pachchaiperumal*. These are usually much lower yielding, just 2 t/ha or so. But these traditional varieties produce a very tasty, high quality rice for which the market price is two to three times higher than for standard rice and for which there is export potential. Reaching 8 tons or more is thus very profitable. These high yields are supported in part by my using the Effective Micro-organism technology (EM) on my field which contributes to better soil microbial dynamics.

Taking Advantage of the Opportunities from SRI

These achievements compelled us to present information on SRI to a wider rice-farming community countrywide, allowing farmers to practice it by themselves in small plots to test its potentials. The farmer response has been impressive with greater yields reported by farmers from 18 districts who generally have gotten a doubling of the yield they are used to getting.

These yields were obtained with less water, less seed, less chemical fertilizer, and less cost of production per kilogram by farmers who voluntarily tested SRI in their farm plots. Among SRI users, we find people of many different income and educational levels and different social standing, including many poor farmers having only small plots of land, farmers with moderate income, some agricultural scientists, and a few administrators, businessmen and political leaders who practice it with their own convictions.

The Department of Agriculture's Rice Research Institute at Batalagoda is now testing SRI before it makes its formal recommendation. The Department is the formal organization accountable for official approval of new practices and technologies, so it is usual practice for researchers to test any innovation on their research station and subsequently on farmers' fields before issuing a formal recommendation.

Since SRI is completely environmental friendly with no requirement of imported seed or increased inputs, and since SRI is based on practices that farmers are already accustomed to, we expect that there will soon be an adequate body of knowledge and experience generated by farmers to predict that when SRI is more widely utilized, the people and the country will benefit from this. There is no reason to be worried about at least trying it out.

There are various other reasons to promote SRI that are important to policy-makers. Our government is anxious to serve better the economic interests of rice producers.

- One farmer who two years ago led a group of fellow farmers in a much-publicized fast against the government to protest the low prices that farmers were receiving is now playing a leading role in promoting SRI, having become a SRI farmer himself and getting very attractive yields. The method gives farmers a more positive attitude toward their opportunities and profession.
- In the Western Province where paddy cultivation has been declining due to high labor costs and very low yields, we are seeing farmers taking up SRI in increasing numbers, season by season, because this new method lowers their costs of production. In some cases, paddy land that was previously abandoned because farmers could not have any profit growing rice is being cultivated again using SRI methods in expectation that paddy can once again become profitable.
- A group of Sri Lankan farmers practicing SRI has recently started to export some high-quality traditional rice varieties to Europe as "eco-rice." These receive a premium price as organic produce from consumers since no pesticides have been used, and their yield is very favorable using SRI methods.

Although Sri Lanka is nearing self-sufficiency in rice, still there is need to import a substantial quantity of rice, 300,000 metric tons, about one-seventh of our consumption, to fill the gap between production and requirement. There is also the need to prudently use the available land and water resources by tapping the maximum potential where such utilization is profitable. The farmers presently cultivating paddy on nearly 750,000 hectares in my country are of many different categories of land assets and capabilities so there will surely be a large number for whom SRI is attractive and practical.

The contribution of this conference to our greater understanding of SRI will be of utmost importance to enlighten many others who would need such information for action. We are very much interested to hear from professionals from other countries about their experience in applying SRI in their environments, the problems encountered, and the opportunities ahead.

If these initial efforts can grow to such magnitudes that they increase productivity, quantity and quality of the staple food for millions of people, this will go a long way toward reducing hunger, poverty and social unrest in our countries. I wish the conference all success in producing knowledge and insights for directions in promoting the System of Rice Intensification for greater benefits to all.

A Farmer's Perspective on SRI from SRI LANKA

H. M. Premaratna, Ecological Farming Center, Mellawalana, Bopitiya, Sri Lanka

I am very happy to have this opportunity to present my views as a farmer who practices SRI at this very important conference. I learned paddy cultivation during my childhood from my father. Then I learned its science at school and tried to practice it according to the recommended methods. Having experienced financial losses with conventional rice-growing methods, I turned to the practice of environmentally friendly paddy cultivation, seeking both to save production costs and to preserve ecological values.

I first came to know about the System of Rice Intensification during early 2000 from reading a newspaper article by Dr. Gamini Batuwitage, who was interviewing Joeli Barison from Madagascar who visited Sri Lanka on behalf of CIIFAD and was hosted by the Ministry of Agriculture. Since then I have been practicing SRI in all of my paddy fields.

Not only have I obtained some remarkable yields hitherto not produced in those fields—10 to 15 t/ha—but also I have been getting as high satisfaction from my farming as a person can have in this profession. I feel that my relationship to the ecosystem and to my fellow farmers and human beings is now more fulfilling.

At this time of crisis in paddy farming in Sri Lanka arising from problems of economic profitability and environmental effects, I voluntarily manage a training centre that offers extension information to farmers from all around the island for the expansion of SRI and the use of other ecologically favorable practices, while operating my paddy farm of 1.5 hectares.

During the past 13 years we have been trying to find environmentally friendly solutions for paddy farming in Sri Lanka, and we have indeed been able to get some good results from such approaches. However, it has not been possible to obtain yields from such efforts that are comparable to the results that we could get so far from SRI.

Why do I accept SRI as a farmer? From my experience, I have observed that the rice plant becomes a healthier plant once the basic SRI practices are adopted. There is nothing that brings more satisfaction to the farmer than the sight of a really healthy paddy field. At present, the excessive use of agrochemicals is making rice production less attractive to farmers the world over, both in terms of cost and in terms of health. However, not seeing alternative, it has been difficult to reduce the use of chemicals. The yields we obtained during the past 13 years when not using agrochemicals were low. We can change this now by practicing SRI. SRI is giving us promising outcomes, showing that the use of pesticides can be avoided. We use the principles of biodynamic farming and practice timely cultivation with SRI.

Evident Advantages of SRI

The favorable results that we have obtained from using SRI methods include:

1. Greater stability of production, getting a better harvest in water-stressed seasons with SRI even when other farmers do not get any significant yield. This is more important to farmers than maximum yields.
2. Use of less water, thereby reducing demands on the ecosystem and reducing conflicts among farmers.
3. Opportunity to use the best quality seeds, and ones most appropriate to local conditions, since SRI requires very few seeds and we can be very selective.
4. Growing rice in ways that are completely environmentally friendly.
5. More reliance on organic fertilizers, and
6. Improved soil biological conditions which have increased the macro- and micro-organisms in the soil, facilitating land preparation and even reducing its cost.

Beyond this, SRI has made it possible for us farmers to build up a network of country expertise and methodologies for its extension, as well as to participate in a network of information-sharing that goes beyond the boundaries of Sri Lanka. These are gratifying developments.

Problems for Farmers

We in Sri Lanka are facing several serious problems as paddy farmers. First, there is the high cost of production, which continues to rise. Much of our expenses are for purchase of external inputs. Also, the inability to maintain biodiversity at an optimal level in our rice paddies is another serious problem, contributing to greater occurrence of pests and diseases. There are various other problems also created by the use of agro-chemicals and the use of poor or defective farming methods.

Another problem arises from the inability in paddy farming to deal with changing weather conditions and risks. Paddy farmers suffer from these conditions and from pest attacks growing to epidemic proportions. We need systems of production that are robust and not dependent on large amounts of water. There are also considerable losses that farmers experience caused by the deteriorating quality of rice produced, increased rates of unfilled grains, and poor storage.

In the present methods of farming, there is no protection for the micro and macro organisms in the soil environment. Serious damage is caused by the use of weedicides in soil preparation, by those types of chemicals that kill all weeds before planting, and other weedicides that are used for selective killing of weeds after planting.

It is true that the SRI system of farming does not have 100% solutions to all of these problems. But it has been established through our own experience that the SRI farming system has more solutions than do any other systems.

As to the question of increased labor requirements with SRI, except for weed control we find that this system can be actually labor-saving compared to others. If we stop spending so much time doing chemical sprayings of the crop, we then have time available for doing the requisite weeding. The time demands for weeding can be minimized by using the most appropriate types of hand weeders that are suitable to different soil conditions and by making certain adjustments and adaptations in their use. We should count as a plus the increase in yields that result from more frequent and better weeding, rather than see this activity only as a cost.

Methods of Dissemination and Research

The methodology adopted in Sri Lanka for extending SRI to farmers is one of farmer-to-farmer sharing of information, supporting free interaction among participants. We offer detailed practical training, on demand, regarding every operation of SRI at our Ecological Farming Center in Mellawalana. We are grateful for support from CIIFAD to make audio-visual equipment available with which presentations of field operations can be made more effective.

The popularity of SRI methodology is now going beyond the current capacities of our farm, as we are called upon to respond to requests for practical training and interactions with farmers from almost all the districts in the country. With visitors now coming from abroad to visit us, our work in innovative farming and training has become recognized by several agencies and in publications with information published about our work.

We should reconsider the present approach to most agricultural research being conducted on paddy rice. At the result of most of this research is recommendations that call for increased use of inputs and lead to more and more mechanization or use of chemicals. In contrast, the fundamental principles applied with SRI fit nicely with the dynamics of nature. This system helps us to make farming more compatible with natural processes, which is one reason why SRI can lower the costs of production.

In Sri Lanka and in many other countries, the availability of food and the food security of millions of people around the world will continue to depend heavily on what happens in paddy farming. I strongly believe, as a farmer, that moving back to a more natural and sustainable, low-cost approach in paddy farming is an essential part of any effort to create a better world for all people.

SRI Results Reported

Summary from Conference Reports

E. C. M. Fernandes and Norman Uphoff, Cornell University

Most SRI experience is very recent. Three years ago, the only country where SRI was known and was being practiced was Madagascar. At this conference in April 2001, there were reports from 17 countries on SRI experimentation and often extension, from:

- **China** in East Asia,
- **Indonesia, Philippines, Cambodia, Laos, Thailand** and **Myanmar** in Southeast Asia,
- **Bangladesh, Sri Lanka, India** and **Nepal** in South Asia,
- **The Gambia, Madagascar** and **Sierra Leone** in Africa, and
- **Cuba, Peru** and the **U.S.** in the Western Hemisphere.

It is understandable that most of these countries are from Asia since about 90% of the world's rice is grown in that region. Most of the reports give evidence of quite positive results from SRI methods; however, several do not show the expected effects.

As most of the knowledge about SRI is quite recent, conclusions about it must remain for now provisional, pending more years of experience and wider utilization of SRI in a greater variety of circumstances. The initial results are, however, mostly very positive and give reason to suggest that more countries and more farmers should have an opportunity to evaluate SRI for themselves.

Constituent Practices

As confirmed by the reports from the various countries, the set of practices that can give much increased rice yields when they are combined includes:

- Careful transplanting of young seedlings — with just two leaves, usually less than 15 days old and preferably 8-12 days old;[1]
- Planting 1 seedling per hill, though under some soil conditions, 2 seedlings may produce better than single seedlings;
- Avoiding soil saturation of the field during the vegetative growth phase, either by applying only small amounts of water daily, or by alternately flooding and draining/drying the field;
- Early and frequent weeding that aerates the soil as it removes weeds; and
- Application of compost.

This last practice, which promotes nutrient cycling and soil biological activity, reduces nutrient mining from the farm. In the short run, however, it may be considered as a means to improve yields beyond what the other practices can achieve rather than as being a required part of SRI.

Advantages

Numerous benefits associated with SRI practices were reported in the papers, the most important being an increase in **total factor productivity**. Specific advantages reported included:

- **Increased yields** — higher production of rice per unit of land.
- **Increased returns to labor** — although more labor is usually required with SRI, at least when first practices, there is greater productivity per day or per hour of work. There were several reports that SRI can be **labor saving** once farmers have mastered its techniques.
- **Water saving** — less water is generally used with SRI practices, an important consideration whenever water is not abundant; with higher production achieved, the productivity per unit of water applied becomes greater.
- **Improvement of soil quality** — greater root growth contributes to better soil quality as does the application of organic sources of nutrients.

[1] *However, if prevailing temperatures are colder, as in Nepal, "young plants" can be a few days older than 15 days because biologically they are less mature than plants grown in a warmer climate.*

- **No requirement of external inputs** — there are increased returns per unit of capital invested to the extent that purchased inputs are unnecessary while output increases.
- **Reduced requirement of seeds** — 5-10 kg/ha of seed are used rather than 5-10 times this amount with usual practice.
- **Lowered cost of production** — contributing to higher income for farmers.
- **Accessibility for smaller and poorer farmers** — since no purchase of agrochemicals is needed; the only capital requirement is a rotary weeder.
- **Better food quality** — associated with reduced or no application of agrochemicals to the crop.
- **Environmental benefits** — resulting from reduced demands for water and less or no use of agrochemicals that can affect both ecological and human health.[2]

Disadvantages

These include:

- **Requirement of good water control**, to be able to apply small amounts of water on a regular basis rather than maintain continuous flooding of fields, or to practice alternate wetting and drying throughout the growth period. Farmers who do not have such control or reliable access to water will get less or little benefit from SRI practices.
- **Requirement of more labor**, at least in the first year or two, as skills are learned for using the SRI practices quickly and confidently. This can be a barrier to adoption, even for poor households that are relatively more endowed with labor. These must use their available labor power to earn daily income, even if this is less than they could get by investing their labor in SRI methods.
- **Requirement of greater skill** on the part of farmers, expecting them to do their own trials and evaluations to adapt SRI practices to their own conditions for best effect. This can be considered as a benefit with SRI, however, rather than just as a cost.

Review of Reports

- **Yields:** Three-fourths of the cases confirmed that there is a significant **yield advantage** with SRI practices. Average yields up to 8 t/ha or at least 20-50% increases were usually reported. Table 1 summarizes yield reports and gives simple arithmetic averages. The super-yields reported from Madagascar have not been obtained elsewhere, but some farmers in Cambodia and Sri Lanka have come close to these. Interestingly, often with SRI methods, higher yields have been obtained on farmers' fields than on research stations. This is something worth investigating.

  There were a number of reports of yields over 10 t/ha. We should identify and quantify the driving factors that give such results. Clearly some varieties give better yield responses to SRI methods than do others. It may be that 120-140 day varieties respond most productively, but more evaluation is needed on this. Yields are most often best at 35x35 cm spacing, though the best spacing will always vary according to soil quality and rice plant type. Very wide spacing, e.g., 50x50 cm, is not recommended to begin with, and 25x25 cm is probably best to start off, evaluating alternative spacings as soil quality improves. With poor soil, 20x20cm may give best results.
- **Labor:** An increased requirement of labor was widely reported, though three country reports mentioned the possibility of less labor being needed over time. Extra labor is most needed in land preparation (leveling), transplanting, and weeding.
- **Water:** Almost all of the reports agreed that there can be water savings with SRI methods.
- **External inputs:** There was most variation on this factor in the reports, as in some countries, farmers are finding they can get increased yields without using any chemical fertilizer or insecticides or other agrochemicals, while in other countries, chemical fertilizer is being used with SRI, and often with good results. *Not using external inputs should be seen more as an opportunity than as a requirement with SRI.*[3]
- **Soil and roots:** Unfortunately, little information on soil chemical and physical properties (especially texture) was contained in the reports, which makes interpreting crop responses to SRI management practices more difficult. For example, there are conflict-

[2] *No research has been done on reduction of greenhouse gas emissions with SRI practices, but when paddies are not kept continuously flooded, methane productioin should be reduced. Rice paddies are a major source of methane. With alternate wetting and drying of paddies, production of nitrous oxide could increase due to increased nitrification and denitrification. Nitrous oxide is more powerful as a greenhouse gas than methane. However, if inorganic N is not being applied in large amounts to rice fields, the amount of N to be converted to NO_2 is less. More field data are required for drawing any conclusions about this.*

[3] *The question was raised whether heavy use of N fertilizer with SRI might have an adverse effect on effective tillering through some impact on root development. This should be examined through systematic research.*

ing results on the beneficial effect of drying the soil until it cracks before rewetting it. Soil characteristics surely play a role in this. Soil biology is probably the key to the synergy that is seen with SRI practices, but this remains a hypothesis to be evaluated. There is little information on native soil fertility, and nutrient balance budgets should be constructed to understand soil dynamics over time with SRI management.

- **Seeds:** There was wide agreement on the possibilities for significant savings on seed requirements as plant populations can be greatly reduced with good effect when using SRI practices.
- **Food and environmental impacts:** There is a desire in some countries to use SRI methods as a way to produce healthier food and to reduce adverse impacts on the environment, including production of methane gas from flooded paddies.
- **Socio-economic analysis:** More work needs to be done on the economics of SRI, particularly on costs of production and net income improvements possible. Several country reports had data on this that were very encouraging, but more systematic information is needed. Also, how readily the poor can use SRI methods needs to be studied. A study in Madagascar found that the poorest households adopted SRI less than better-off ones (which in Madagascar are still not very well-off) because of their need to earn income daily during the cultivation season.

Data Needs

The information reported from various countries represented a wide range of experience. It will be helpful if future reports provide better descriptions of trial plots or farmers' field — who did what where? There is still huge variability in results, so there should be adequate replication of trials to provide more robust results and better estimates of variability.

Particularly we would like to know what is special about the sites where much higher yields than usual are achieved. Basic site data such as GPS coordinates, elevation, soil and climate information would be invaluable for developing a more systematic understanding of the variable SRI responses across sites.

While researchers appreciate the reports from NGOs and farmers, they would like to see more standardization of reporting across regions so that inferences and conclusions can be more reliably drawn. SRI experience to date suggests that these methods offer an unusual opportunity for 'win-win' outcomes in agriculture. But to have confidence in this, there is need for more and more detailed reports on the use and results of SRI as well as the yields for best-recommended practice based on local research, e.g., the Chinese SRI trials with hybrid rice varieties.

Since this was the first international meeting to report and share results, it was still more exploratory than conclusive. It is hoped that within a year or two with more experimentation and more communication of information, a broader and deeper understanding of SRI — its opportunities and its limitations — can be achieved and disseminated.

Summary of Data from Conference Reports

It was not possible to get complete or always comparable data from all of the countries. What appears in Table 1 is a compilation of data extracted from the various country, NGO and research reports that follow in these proceedings. The data have been put into parallel format to provide an overview what the presently available data on SRI show. Simple arithmetic averages are shown for those countries where more experience with SRI has been accumulated and the reports give enough data to indicate approximate yield levels.

As often as possible, comparable or control measurements of yield are shown in the middle column whenever these were provided in the report. Comparisons with national averages are usually too gross to be very meaningful, so we show in the middle column only yield data that the persons making the report considered to be valid standards for comparison. As the same criteria would have been used for both numbers, relative comparisons (ratios) should be reasonably valid even if there are questions about the absolute numbers.

The unweighted average for all the comparison/control yield figures is 3.9 t/ha, which is very close to the current world average for rice production. The average for all the SRI yields reported is 6. 8 t/ha, and the average of highest reported yields is 10.5 t/ha. Figure 1 on page 39 was constructed from the data in Table 1 to give an overview of the variations reported.

Table 1. Summary data from conference reports on SRI and comparison yields

	Season[1]	No. of Farmers (F) or Trials (T)	Reported Average SRI Yield (t/ha)	Compar-ison/ Control Yield (t/ha)	Highest SRI Yield (t/ha)	Comments
BANGLADESH						
CARE	D2000	F (29)	6.53	5.0	NR	Kishorganj district
“	D2001	F (99)	6.25	5.0	7.2	“
Dept. of Agric. Exten.	D2000	F (53)	7.5	5.0	9.5	“
“	D2001	F (80)	7.5	5.0	NR	“
BRRI	D2000	Trials	5.4	4.4	NR	Comilla station
“	W2000	Trials	NSD	NR	NR	Gazipur HQ
“	D2001	Trials	NSD	NR	NR	“
BRAC	D2001	T (10 acres)	5.9	4.7	NR	Own fields
Syngenta	W2000	T (0.2 acre)	5.25	NR	5.61	“
“	W2001	T (0.2 acre)	5.7	NR	6.15	“
Average			**6.3**	**4.8**	**7.1**	
CAMBODIA						
CEDAC	W2000	F (28)	5.0	2.0	13.7	
“	W2001	F (393)	3.4	2.0	14.0	Bad drought year
“	W2001	F (6)	6.0	4.0	10.00	Recessional cultivation
Average			**4.8**	**2.7**	**12.9**	
CHINA						
Nanjing Agric. Univ.	1999	Trials	9.7	NR	10.5	Used 50% less water
CNHRRDC	w2001	Trials	NR	NR	11.2	Hybrid varieties
“	S2001	Trials	NR	NR	12.9	Hybrid varieties
Anqing Res. Institute	2001	Trials	12.15	10.02	17.56[2]	Hybrid varieties
Hunan Agric. Univ.	2001	Trials	11.67	NSD	13.1	Hybrid varieties
Meishan Seed Co.	2001	Trials	15.8	11.8	16.0	Hybrid varieties
Average			**12.4**	**10.9**	**13.5**	
CUBA						
Council of Churches	2001	F (1)	8.8	5.8	NR	From a manual
Sugar Cooperative	2001	Trial (1 ha)	9.5	6.6	NR	“
“	2002	Trial (1 ha)	11.2	6.6	NR	“
Sugar Mill	2001	Trial	5.2	2.8	NR	“
Average			**8.7**	**5.6**	**NR**	
THE GAMBIA						
National Agricultural	2000	Trials	6.8	2.0	8.3	Managed by
Research Institute	2001	F (10)	7.4	2.5	9.4	Mustapha Ceesay

NR = Data not reported or comparison not relevant; NSD = No significant difference; specific data not reported

[1] D=Dry season, W=Wet season; S=Summer season; w=Winter season

[2] Theoretical yield calculated for that SRI crop

Table 1. Summary data from conference reports on SRI and comparison yields (continued)

	Season[1]	No. of Farmers (F) or Trials (T)	Reported Average SRI Yield (t/ha)	Compar-ison/ Control Yield (t/ha)	Highest SRI Yield (t/ha)	Comments
INDIA						
Tamil Nadu Agr. Univ.	2001	Trials	6.3	6.4	7.6	Used 56% less water
INDONESIA						
AARC	D1999	Trials	6.2	4.1	NR	Sukamandi
"	W2000	Trials	8.2	NR	9.3	"
"	W2000	Farmers	6.5	NR	10.3	"
"	D2000	Trials	8.3	NR	9.7	"
"	W2001	Trials	8.4	6.7	9.1	"
"	D2001	Trials	7.3	4.8	8.7	"
IPM Program	D2001	F (3)	6.8	4.5	7.0	Ciamis
ADRA Program	D2001	F (7)	11.6	4.4	13.8	West Timor
Average			**7.8**	**4.9**	**9.7**	
LAOS						
Oxfam/CAA	W2001	F (3)	3.6	3.0	4.55	Seed:harvest ratio up from 1: 43 to 1: 203
MADAGASCAR						
ATS/CIIFAD	1994	F (39)	8.25	2.0	15.0	400 farmers doing
Ranomafana	1995	F (70)	8.04	2.0	16.0	SRI by 1999
French studies - HP[3]	1996	F (108)	7.7	3.6	14.0	With Min. of Agric.
Morandava	W1998	F (280)	4.38	Tradl 2.15	5.58	"SRA" = improved
"	D1998	"	6.92	SRA 3.49	9.11	system w/ inputs
French project data	1994-99	F (>2000)	8.55	Tradl 2.36	14.0	SRA = 3.77 t/ha
Cornell thesis - Station	2001	Trial	6.26	2.63	NR	SRI 10.2 t/ha in pre-
Farmer survey	"	F (108)	6.36	3.36	15.0	vious station trial
ATS "best farmer"	1999	F (1)	NR	NR	21.0	Not a sampled yield
U of Tana theses	2000	T/poor soil	6.40	2.48	6.83	Factor trials N = 288
"	2001	T/good soil	8.35	2.52	10.25	Factor trials N = 240
CRS - 20-40% SRI	2001	F (420)	2.4	1.5	3.2	Limited use of SRI
60-80% SRI	"	F (493)	3.7	1.5	7.5	Partial use of SRI
100% SRI	"	F (139)	4.2	1.5	15.0	Full use of SRI
			7.2	**2.6**	**12.8**	
MYANMAR						
Metta Foundation	2000	Trials	2.35	2.5	2.73	Planted 1 mo. late
"	2001	Trials	5.5	2.5	NR	On very poor soil
"	2001	F (~300)	5.75	2.5	6.5	Participants in Farmer Field Schools

NR = Data not reported or comparison not relevant; NSD = No significant difference; specific data not reported

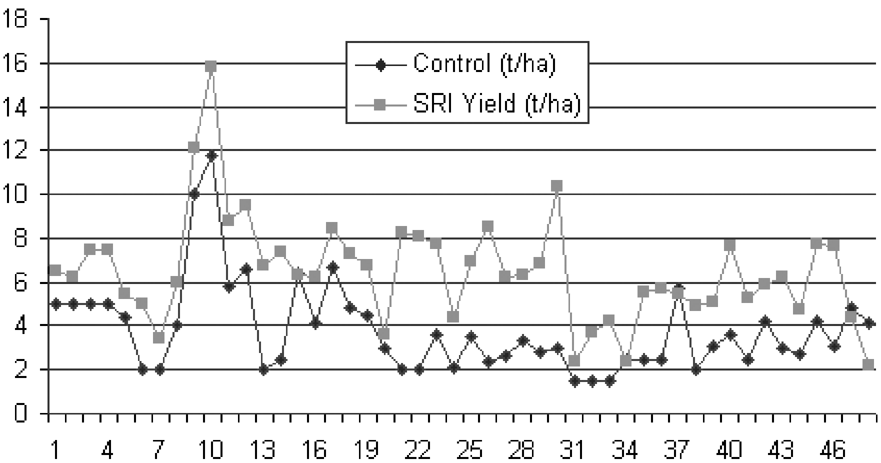
[3] High Plateau: 108 farmers in the regions around Antananarivo and Antsirabe

Table 1. Summary data from conference reports on SRI and comparison yields (continued)

	Season[1]	No. of Farmers (F) or Trials (T)	Reported Average SRI Yield (t/ha)	Compar-ison/ Control Yield (t/ha)	Highest SRI Yield (t/ha)	Comments
NEPAL						
Khumaltar RARS	1999	Trials	Lower yields compared		NR	No water control
"	2000	Trials	to usual methods		NR	Poor water control
Tarahara RARS	2001	Trials	NR	NR	8.0	More water control
Bairahawa RARS	2001	Trials	5.4	5.7	6.2	Poor water control
Sunrise Farm	2001	F (1)	NSD	NR	NR	Good plant growth
PHILIPPINES						
CDSMC	1999	F (10)	4.95	2-2.5	NR	Farmer volunteers
"	2000	F (10)	4.28	2-2.5	13.45	"
BIND	1999-01	T (10)	6.9	NR	NR	"
"	S2001	Trials	5.4	NR	7.3	"
"	W2001	F (26)	5.1	3.1	7.6	"
Agric. Training. Inst.	2001	F (1)	7.6	3.6	NR	ATI employee
Average			**6.0**	**3.0**	**9.4**	
SIERRA LEONE						
World Vision	2002	F (160)	5.3	2.5	7.4	Tradl. max. = 3.2 t/ha
SRI LANKA						
Ambepussa ATC	D1999	Trials	5.9	4.2	NR	
"	W2000	Trials	6.2	3.0	NR	
Wet Zone	W2001	F (135)	4.7	2.7	13.1	
Intermediate Zone	D2001	F (112)	7.7	4.2	15.2	
Dry Zone	D2001	F (10)	9.2	NR	NR	Measured by Dept. of Census & Statistics
3 agroecological zones	D2001	F (17)	7.6	3.1	11.4	
H. M. Premaratna	2000-01	Farmer	8-12	4.0	15.0	
Salinda Dissanayake	2000-01	Farmer	9-13	4.2	17.0	Measured by DC&S
Average			**7.8**	**3.6**	**14.3**	
THAILAND						
CMU/MCC	D2001	Trials	4.35	4.81	NR	No SRI effect has
"	W2001	Trials	2.19	4.16	NR	been seen here

NR = Data not reported or comparison not relevant; NSD = No significant difference; specific data not reported

Figure 1: Line plot of rice yields reported where data are available on both actual SRI yield and comparison/control yield



Note: Not all data from Table 1 are included because of missing values.

Factorial Trials Evaluating the Separate and Combined Effects of SRI Practices

Robert Randriamiharisoa, University of Antananarivo, and Norman Uphoff, Cornell University

In 2000 and 2001, Jean de Dieu Rajaonarison and Andry Andriankaja, graduating students in the Faculty of Agriculture (ESSA) at the University of Antananarivo in Madagascar, conducted complex sets of trials evaluating six different factors that affect rice production. Their field research was supervised by the first author, at the time director of research for ESSA, with support from CIIFAD and a grant from the Rockefeller Foundation.

It was anticipated that carefully controlled trials might show that one or more of the SRI practices would not contribute much to higher yield so that the set of SRI practices could be simplified without much loss, making SRI easier to practice. In fact, however, the trials showed a high degree of ***synergy*** among practices. Although "young seedlings" were found to be the most important practice in both sets of trials, none could be discarded without some loss of yield. The trials also showed that the ***same pattern*** of increases in yield could be seen in two very different agroecosystems.

The first location was on the fields of the Centre de Baobab, an agricultural improvement center near Morondava on the west coast of Madagascar. The second was on farmers' fields in the village of Anjomakely, 18 km south of the capital Antananarivo, in the center of the country on its high plateau.

At Morondava, one of the factors evaluated was **rice variety**, comparing results from SRI vs. conventional practices using a high-yielding variety (2798) on half of the 288 trial plots and a common local variety, *riz rouge*, on the other half (see Table 1). All were planted on poor sandy soil near ***sea level*** in a ***tropical climate***. At Anjomakely, the effects of **soil quality** were evaluated, using *riz rouge* as the variety for all 240 trial plots. Half of the plots were better clay soil and the other half, poorer loam soil. The area is at ***1200 m elevation*** with a ***temperate climate*** (see Table 2).

The four SRI practices evaluated in both sets of trials were:

- Use of **young seedlings**, transplanted at 8 days of age, compared to 16 or 20 days (at Anjomakely with its higher elevation and colder temperatures, 20 days of seedling growth was equivalent to 16 days at Morondava with its higher more tropical climate).
- **Water management**, comparing practices that maintained soil moisture but avoided saturation (aerated soil, AS), with continuous flooding (saturated soil, SS).
- **Plant density**, with one seedling per hill vs. 3 seedlings per hill; and
- **Fertilization**, using compost, made from plant biomass, vs. NPK (16-11-22) in the recommended dosage vs. no fertilization as a control.

The variable of **spacing** was not really tested because both of the spacings used—25x25 cm vs. 30x30 cm—are within the SRI range, not conventional practice. There turned out to be no difference in average yields between the two sets of plots differentiated by spacing at Morondava (each N=144), and only 0.08 t/ha difference at Anjomakely (each N=120), with each set containing equal numbers of SRI and non-SRI practices with regard to seedling age, water management, density, etc. Since there was no real difference observed for this (narrow) range of spacings, the spacing trials were combined. Thus, instead of having three replications of each of 96 or 80 combinations in the experiment, all the averages reported below are based on ***at least six replications***. The factor of **weeding** was not evaluated as this would have required a doubling of trials, to 576 and 480, respectively, beyond the researchers' means.

All trial plots were 2.5x2.5m, laid out according to a modified Fisher bloc design. The main bloc at Morondava was divided by **water management** (AS vs. SS) because plots with these treatments could not be randomly irrigated (or not), given that water applied to an individual plot will permeate into adjoining plots. These main sub-blocks were divided into sub-blocs for **fertilization practice** to avoid any effects of sub-surface movement of nutrients. While this is not as serious a problem as sub-surface movement of water, it should be avoided as much as possible. Within these sub-sub-blocs, then, plots were randomized for different combinations of **plant age, plants per hill, spacing,** and **variety**.

For the Anjomakely trials, two nearby locations on farmers' fields were identified as having **better** or **poorer soil**. The first had more clay content, the latter was more loamy soil. These were close enough that there were no climatic differences. Within these two main blocs, there were sub-blocs for **water management** and within these, sub-sub-blocs for **fertilization**. Within these, randomized combinations of **plant age, plants per hill,** and **spacing** were established, all with the same variety (*riz rouge*).

More detailed information on soil characteristics and the design and trials themselves is available in the theses (*memoires de fin d'etudes*) written by Rajaonarison and Andriankaja, including tests of statistical significance. These theses, in French, are available in electronic form from CIIFAD. The summary presentation below is concerned with any **patterns of difference in yield** according to the different combinations of practices, SRI or non-SRI, and the different extents to which SRI practice were used (zero SRI, 25% SRI, 50% SRI, 75% SRI, or 100% SRI—see Tables 3, 4, 5 and 6).

For both sets of trials, data were gathered also on the number of tillers, number of panicles, panicle length, root length, and root density (the latter measured by a pull test of root system resistance to uprooting). The patterns for these measurements of yield components and plant characteristics mirrored those reported below for yield. Statistical analysis shown in Tables 2 and 3 shows the differences to be quite significant. The differences in Tables 5 and 6 are even larger, but significance tests have not been calculated for those yet.

With growing conditions controlled, using all SRI practices—young seedlings, one per hill, aerated soil, with compost added—gave yield increases of 140% to 245%, compared to plots where only non-SRI practices—more mature seedlings, three per hill, saturated soil, with NPK fertilizer applied—were used. In both sets of trials, the increments to average yield generally increased as a larger ***proportion*** of SRI practices was used, with the largest increase in both sets of trials coming when the combinations went from 75% SRI to 100% SRI. This added almost 2 t/ha to yield in these trials. (The factor of weeding might have added even more to yield, but this was not tested in these experiments.)

Absolute and relative yields will vary, possibly considerably, across different sets of factorial trials as differences in soil, climate and variety will affect the outcomes from any particular set of practices. However, that these two sets of trials, under very different soil and climatic conditions, showed such a **consistent pattern** of results, based on averages for 6 rather than just 3 test plots, suggests that the relationships reported here are reasonably robust.

This analysis should be seen, however, not so much as a set of conclusions as an invitation for others to undertake similar sets of factorial trials to assess the effects of SRI practices both separately, other things being equal, and collectively, in different combinations.

Table 1. Factorial trial results comparing high-yielding and traditional variety responses with SRI methods vs. non-SRI methods, Morondava, 2000

Yield figures below in tons/ha are all averages from 6 replicated trial plots. Conventional results are *italicized* and SRI results are **bold faced**. Two different varieties were used in these trials; the soil type for all was *sable roux* (rough sand).

	CONTINUOUS FLOODING				SRI WATER MANAGEMENT			
	16-day plants		8-day plants		16-day plants		8-day plants	
	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill
MODERN VARIETY (2798)—RIZ BLANC								
No Fertilizer	1.68	1.90	2.28	2.31	1.69	1.92	2.61	3.47
NPK	*2.84*	2.79	4.08	4.50	4.04	4.10	5.75	6.62
Compost	2.69	2.73	3.35	3.85	4.18	3.82	4.42	**6.83**
TRADITIONAL VARIETY—RIZ ROUGE								
No Fertilizer	1.49	1.77	2.01	2.46	1.91	1.95	2.46	3.14
NPK	*2.11*	2.28	3.09	3.65	2.64	2.89	3.34	4.29
Compost	2.67	2.47	4.50	5.18	3.10	2.88	4.78	**5.96**

Table 2. Factorial trial results comparing yield responses on clay and loamy soils with SRI methods vs. non-SRI methods, Anjomakely, 2001

Yield figures below in tons/ha are all averages from 6 replicated trial plots Conventional results are *italicized* and SRI results are **bold faced**. A traditional variety (*riz rouge*) was used for all trials, with soil type as a variable.

	CONTINUOUS FLOODING				SRI WATER MANAGEMENT			
	20-day plants		8-day plants		20-day plants		8-day plants	
	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill
CLAY (BETTER) SOIL								
No Fertilizer	2.26	2.78	3.09	3.75	4.82	5.42	5.65	6.25
NPK	*3.00*	5.04	5.08	6.07	7.16	8.13	8.15	8.77
Compost	3.71	4.50	6.72	7.45	6.86	7.70	9.32	**10.35**
LOAM (POORER) SOIL								
NPK	*2.04*	2.78	2.60	3.15	3.89	4.36	4.44	5.00
Compost	2.03	2.44	3.41	4.10	3.61	4.07	5.17	**6.39**

Table 3. Factorial trial results, yield in tons/ha, evaluating effects of using greater numbers of SRI methods, Morondava, 2000

N of trials in parentheses; SRI practices shown in **bold face**

	Variety		
	HYV	Traditional	Average
Conventional			
SS/16/3/NPK	2.84 (6)	2.11 (6)	2.48 (12)
1 SRI Practice			
SS/ 16 / 3 / **C**	2.69 (6)	2.67 (6)	
SS/16/**1**/NPK	2.74 (6)	2.28 (6)	
SS/ **8** /3/NPK	4.08 (6)	3.09 (6)	
AS/16/3/NPK	4.04 (6)	2.64 (6)	
	3.34 (24)	2.67 (24)	3.01 (48)
	[+0.50 t]	*[+0.56t]*	*[+ 0.53 t]*
	(p=.021)	(p=.007)	
2 SRI Practices			
SS/16/ **1** / **C**	2.73 (6)	2.47 (6)	
SS / **8** / 3 / **C**	3.35 (6)	4.33 (6)	
AS/16/**1**/NPK	4.10 (6)	2.89 (6)	
AS/16/ 3 / **C**	4.18 (6)	3.10 (6)	
SS/ **8** /**1**/NPK	5.00 (6)	3.65 (6)	
AS/ **8** /3/NPK	5.75 (6)	3.34 (6)	
	4.28 (36)	3.24 (36)	3.78 (72)
	[+0.94 t]	*[+0.62 t]*	*[+0.78 t]*
	(p=.000)	(p=.000)	
3 SRI Practices			
SS/ **8** / **1** / **C**	3.85 (6)	5.18 (6)	
AS/16/ **1** / **C**	3.82 (6)	2.87 (6)	
AS/ **8** / 3 / **C**	4.49 (6)	4.78 (6)	
AS/ **8** /**1**/NPK	6.62 (6)	4.29 (6)	
	4.69 (24)	4.28 (24)	4.48 (48)
	[+0.41 t]	*[+ 0.99 t]*	*[+0.70 t]*
	(p=.000)	(p=.000)	
All SRI Practices			
AS / 8 / 1 / C	6.83 (6)	5.96 (6)	6.40 (12)
	[+2.14 t]	*[+1.68 t]*	*[+1.92 t]*
	(p=.000)	(p=.000)	

Table 4. Factorial trial results, yield in tons/ha, evaluating effects of SRI methods used without any fertilization, Morondava, 2000

N of trials in parentheses; SRI practices shown in **bold face**

	Variety		
	HYV	Traditional	Average
Conventional			
SS / 16 / 3	1.51 (6)	1.49 (6)	1.50 (12)
1 SRI Practice			
SS / 16 / **1**	1.90 (6)	1.77 (6)	
SS / **8** / 3	2.36 (6)	2.01 (6)	
AS / 16 / 3	1.69 (6)	1.91 (6)	
	1.93 (18)	1.89 (18)	1.91 (36)
	[+0.42 t]	*[+0.40 t]*	*[+ 0.41 t]*
	(p=.0036)	(p=.007)	
2 SRI Practices			
SS / **8** / **1**	2.31 (6)	2.46 (6)	
AS /16/ **1**	1.92 (6)	1.95 (6)	
AS / **8** / 3	2.61 (6)	2.46 (6)	
	2.28 (18)	2.28 (18)	2.28 (36)
	[+0.35 t]	*[+ 0.39 t]*	*[+0.37 t]*
	(p=.0003)	(p=.0003)	
All SRI Practices			
AS / 8 / 1	3.47 (6)	3.14 (6)	3.30 (12)
	[+1.19 t]	*[+0.86 t]*	*[+1.02 t]*
	(p=.000)	(p=.000)	

SS = saturated soil
AS = aerated soil (SRI)
16 = 16-day seedlings
8 = 8-day seedlings (SRI)
3 = 3-day seedlings
1 = 1 seedling per hill (SRI)
NPK = chemical fertiizer
C = compost (SRI)

Table 5. Analysis of factorial trial results, with soil differences, Anjomakely, 2001

N of trials in parentheses; SRI practices shown in **bold face**

	Clay	Loam	Average
Conventional			
SS/20/3/NPK	*3.00* (6)	*2.04* (6)	*2.52* (12)
1 SRI Practice			
SS/ 20 / 3 / **C**	3.71 (6)	2.03 (6)	
SS/20/**1**/NPK	5.04 (6)	2.78 (6)	
SS/ **8** /3/NPK	7.16 (6)	3.89 (6)	
AS/20/3/NPK	5.08 (6)	2.60 (6)	
	5.25 (24)	**2.83** (24)	**4.04** (48)
	[+2.25 t]	[+0.79t]	[+1.52 t]
2 SRI Practices			
SS/20/ **1** / **C**	4.50 (6)	2.44 (6)	
SS / **8** / 3 / **C**	6.86 (6)	3.61 (6)	
AS/20/**1**/NPK	6.07 (6)	3.15 (6)	
AS/20/ 3 / **C**	6.72 (6)	3.41 (6)	
SS/ **8** /**1**/NPK	8.13 (6)	4.36 (6)	
AS/ **8** /3/NPK	8.15 (6)	4.44 (6)	
	6.74 (36)	**3.57** (36)	**5.16** (72)
	[+1.49 t]	[+0.74 t]	[+1.12 t]
3 SRI Practices			
SS/ **8** / **1** / **C**	7.70 (6)	4.07 (6)	
AS/20/ **1** / **C**	7.45 (6)	4.10 (6)	
AS/ **8** / 3 / **C**	9.32 (6)	5.17 (6)	
AS/ **8** /**1**/NPK	8.77 (6)	5.00 (6)	
	8.31 (24)	**4.59** (24)	**6.45** (48)
	[+1.57 t]	[+1.02 t]	[+1.29 t]
All SRI Practices			
AS / 8 / 1 / C	**10.35** (6)	**6.39** (6)	**8.37** (12)
	[+2.04 t]	[+1.80 t]	[+1.92 t]

Table 6. Analysis of factorial trial results on clay soils with no fertilizer or compost applied, Anjomakely, 2001

N of trials in parentheses; SRI practices shown in **bold face**

	Clay (Better) Soil	
Conventional		
SS / 20 / 3	*2.26* (6)	
1 SRI Practice		
SS / 20 / **1**	2.78 (6)	
SS / **8** / 3	4.82 (6)	
AS / 20 / 3	3.09 (6)	
	3.56 (18)	[+ 1.30 t]
2 SRI Practices		
SS / **8** / **1**	5.42 (6)	
AS /20/ **1**	3.75 (6)	
AS / **8** / 3	5.65 (6)	
	4.94 (18)	[+1.38 t]
All SRI Practices		
AS / 8 / 1	**6.25** (6)	[+1.31 t]

Trials without any fertilizer or compost were not conducted on the poorer loam soils at Anjomakely as this did not appear to the researcher worth the effort to manage an additional 48 plots on top of the 240 plots laid out in the design.

The effect of "young seedlings" was very pronounced on this better clay soil when neither fertilizer nor compost was added.

SS = saturated soil
AS = aerated soil (SRI)
20 = 20-day seedlings
8 = 8-day seedlings (SRI)
3 = 3-day seedlings
1 = 1 seedling per hill (SRI)
NPK = chemical fertiizer
C = compost (SRI)

Table 7. Comparisons of factor effects, Morondava

The yield differences reported here are with all other factors being equal; averages were calculated with an equal number of SRI and non-SRI practices for each of the other factors [N = 144 for each average reported, except for fertilization, for which each N = 96].

Young seedling effect		*+1.40 t/ha*		
8 days old	3.96 t/ha	vs.	16 days old	2.56 t/ha
Water management effect		*+0.85 t/ha*		
Water control	3.71 t/ha	vs	. Flooding	2.86 t/ha
Fertilization effect (average for clay/loam soils)		*+.027 t/ha*		
Compost	3.96 t/ha	vs	NPK fertilizer	3.69 t/ha
Plants per hill effect		*+ 0.46 t/ha*		
1 plant/hill	3.51 t/ha	vs.	3 plants/hill	3.05 t/ha
Spacing effect (note: both distances are within SRI range)		*+0.00t/ha*		
30 x 30 cm	3.28 t/ha	vs.	25 x 25 cm	3.28 t/ha

Table 8. Comparisons of factor effects, Anjomakely

The yield differences reported here are with all other factors being equal; averages were calculated with an equal number of SRI and non-SRI practices for each of the other factors [N = 120 for each average reported, except for fertilization, for which each N = 96].

Young seedling effect		*+2.48 t/ha*		
8 days old	6.28 t/ha	vs.	20 days old	3.80 t/ha
Water management effect		*+1.41 t/ha*		
Water control	5.75 t/ha	vs	Flooding	4.34 t/ha
Fertilization effect (average for clay/loam soils)		*+1.01 t/ha* [1, 2]		
Compost	5.49 t/ha	vs	NPK fertilizer	4.48 t/ha
Plants per hill effect		*+ 0.78 t/ha*		
1 plant/hill	5.43 t/ha	vs.	3 plants/hill	4.65 t/ha
Spacing effect (note: both distances are within SRI range)		*+0.08 t/ha*		
30 x 30 cm	5.08 t/ha	vs.	25 x 25 cm	5.00 t/ha
Soil effect (averaged for equal number of trials with compost and NPK fertilization)[2]				
Clay (better) soil	6.75 t/ha	vs.	Loam (poorer) soil	3.72 t/ha

[1]*These results are for a traditional variety, which is expected to be less responsive to the application of NPK and conversely, relatively more responsive to compost.*

[2]*Average yield on clay (better) soil without either compost or NPK amendments was 4.25 t/ha*

Table 9. Summary comparisons of factorial trials, Morondava, 2000, and Anjomakely, 2001

	Standard Practices (t/ha)	SRI Practices (t/ha)	Increase (%)
	16- or 20-day seedlings 3 plants per hill Standing water Fertilizer (NPK)	8-day seedlings 1 plant per hill Water control Compost	
Morondava#			
HYV (2798) (N=144)	2.84	6.83	140%
Traditional (riz rouge) (N=144)	2.11	5.96	182%
Anjomakely*			
Good (clay) soils (N=120)	3.00	10.35	245%
Poor (loam) soils (N=120)	2.04	6.39	213%
Seedling Age	16/20 days	8 days	
Morandava	2.61	3.96	+1.35 t/ha#
Anjomakely	3.80	6.28	+2.48 t/ha
Water Management	Flooding	Water control	
Morandava	2.86	3.71	+0.85 t/ha#
Anjomakely	4.34	5.75	+1.41 t/ha
Plants per Hill	3 seedlings	1 seedling	
Morandava	3.05	3.51	+0.46 t/ha#
Anjomakely	4.65	5.43	+0.78 t/ha
Fertilization	NPK	Compost	
Morandava	3.69	3.96	+0.27 t/ha#
Anjomakely	4.48	5.49	+1.01 t/ha*

**All Anjomakely trials were done with traditional variety (*riz rouge*) whereas Morandava trials were half with traditional variety, half with improved, high-yielding variety (2798).*

*#All Morondava trials were carried out on poorer sandy soils (*sable roux*) than on the soils available at Anjomakely.*

Country Reports

Experience with SRI Methods in BANGLADESH

A. M. Muazzam Husain, Bangladesh Rural Advancement Committee[1]

In Bangladesh, meeting the food needs of a growing population of 129 million is a continuous challenge to the government and the farmers of our country. The climate is dominated by typical monsoon weather pattern with high to fairly high rainfall and equable temperature. Eighty percent of Bangladesh's land area consists of flat alluvial flood plains with more elevated hilly areas located in the northeast and east. Agriculture is the primary economic sector employing around two-thirds of the labor force, and rice, the staple crop, occupies 75% of the total cropped area.

Over the last three decades, the production of rice has doubled, and yield has increased with greater adoption of the modern technology with high-yielding varieties (HYVs). However, with population growth and consequent shrinking of cropped area, the arable land per capita is declining. The growth rate for rice production needs to be further enhanced to meet the growing demand for food and to release labor, land and water resources for other uses. The dependence of HYV technology on chemical fertilizers and pesticides raises production costs and also leads to ecological problems that pose a threat to the sustainability of agriculture in the country.

Spreading Institutional Involvement with SRI

A number of different institutions in Bangladesh have come to know about the System of Rice Intensification (SRI) developed in Madagascar either through literature on SRI or through direct contacts. **CARE/Bangladesh** first learned about SRI through its participation in a conference on sustainable agriculture at Bellagio, Italy, in April 1999 where Prof. Uphoff presented a paper on SRI. This paper was subsequently circulated by CARE within Bangladesh, and it reached the government's **Department of Agricultural Extension** (DAE) whose director-general encouraged DAE district directors to try out the new methodology.

The **Bangladesh Rice Research Institute** (BRRI), the government's agency for improving rice production, was encouraged by DAE to take up SRI trials, and **Syngenta Bangladesh Ltd.**, a private company, in turn learned about SRI from the director-general of BRRI. The **Bangladesh Rural Advancement Committee** (BRAC) learned about SRI from Prof. Uphoff when he visited its headquarters in December 2000 and talked to agricultural staff about the new methods, also giving this talk on SRI to CARE staff in Dhaka and to BRRI researchers at their headquarters in Gazipur.

The SRI technique attracted the interest of a number of researchers, extension personnel and NGO practitioners. The first trials evaluating the performance of SRI began in the 1999-2000 *boro* (dry) season through CARE. It was already conducting farmer field schools in different parts of the country to improve irrigated rice-based farming systems with an IPM component. Adding SRI evaluation to its ongoing program of farmer-centered research and dissemination was easy. These trials were conducted in Kishoregonj and Rajshahi districts, with efforts extended subsequently to Mymensingh district. DAE also initiated trials in 1999-2000 with 54 farmers in Kishoregonj, and it has plans to involve farmers in 20 other districts.

BRRI started trials at its Comilla station in the 2000 *aus* (middle) season and then on its research farm in Gazipur later in that year. Syngenta encouraged trials with contract seed growers in the district of Bogra during the 2000 *aman* (wet monsoon) season and continued its trial during the next year. BRAC began its trials during the 2000-2001 *boro* season in Habigonj and ex-

[1] *This report was prepared by the Senior Advisor for Agriculture for the Bangladesh Rural Advancement Committee (BRAC), in consultation with Mr. Mir Ataur Rahman, CARE/Bangladesh; Mr. Wasiuzzaman Akonda, Department of Agricultural Extension; Dr. Sirajul Islam, Bangladesh Rice Research Institute; Mr. J. C. Saha Choudhury, Syngenta BD Ltd.; and Mr. Taslim Reza, BRAC.*

tended its trials on some of its own farming area in Faridpur and Gopalgonj districts during 2001-2002 *boro* season. It hopes to go for farmers' field trials from next year.

CARE and DAE have done all of their evaluations of SRI in farmers' fields. Only Syngenta and BRRI have conducted trials during the wet *aman* season. Others have conducted their trials during the dry winter *boro* season when irrigation control is better, considering this essential for SRI. All these organizations expanded their trial areas during 2001-2002 due to the favorable initial results obtained.

Evaluations

Summary information is presented in Table 1 on these various trials, including information on practices followed, area cultivated, the number of farmers involved if any, period of trials, seasons, and varieties used. Generally, evaluations started by using the recommended set of SRI practices, but later specific components were tried and their results evaluated. CARE started by trying out general SRI practices, comparing the results with those of local farmer practices. Then during the next year, farmers evaluated certain components of the SRI method: seedling age, and spacing. In trials on the effect of seedling age: 10-, 15- and 20-day-old seedlings were tested at 30x30 cm spacing; in spacing trials: 30x30 cm, 35x35 cm and 40x40 cm spacings were tested with seedlings aged 12-15 days. In its evaluations, DAE promoted use of the standard set of practices of SRI on farmers' fields in order to see the resulting yields and other advantages of SRI.

BRRI at Gazipur has not been evaluating the SRI practices as a package but has focused on just some of them, varying seedling age and spacing. This can miss the synergistic effects possible when the full set is used. BRAC has followed the set of practices recommended for SRI to evaluate their results, including yield gains and relative costs and returns of SRI. Both BRAC and Syngenta have decided to go for farmers' trials during the ensuing cropping season. The trials in Bangladesh have been done on a variety of plot sizes and most without replications, so from a scientific point of view, no consistent or reliable estimates can be made yet about the overall performance of SRI in the country.

Results

Overall yield performance of the different trials during the *boro* season has been encouraging. Yield improvements ranged from 30-40% in the case of farmers working with DAE, 11-34% for farmers working with CARE, and 26% for BRAC on its own fields. Only BRRI experiments have not found any significant yield increases with SRI over other practices. Yield per hectare varied from trial to trial and from area to area. Seed and irrigation costs were generally less under SRI practice. According to BRAC figures, irrigation costs under SRI practice were 28% less than with traditional methods of cultivation.

Learning

- Farmers have found it difficult to pull up very young seedlings from the seedbed and to transplant them. Further trials are being carried out to improve this part of the cultivation process.
- During the winter *(boro)* season, seedling growth is very slow. So young seedlings less than 10 days old face more damage than older seedlings. In cold areas, recommended seedling age may thus may to be raised to 10-15 days for SRI practice. Farmers in some areas have transplanted seedlings accordingly.
- Water management during the monsoon *(aman)* season is difficult due to flooding caused by heavy rains. During this season, SRI could be tried only in high and medium high lands that have good drainage systems and in regions with less rainfall, such has Rajshahi and Jessore regions. Having good water control will remain a problem for SRI use in many parts of Bangladesh.
- Availability of adequate organic matter has been a problem in introducing SRI practices. The awareness of farmers of the value of such inputs needs to be increased, and training and motivation provided, to get more preparation and use of organic matter in SRI rice fields.
- Wide spacing and periodic drying of the field led to high weed growth. Cost-effective, ecologically sound and acceptable methods of weed control need to be evolved and practiced.

Prospects

- Encouraging results of the trials conducted in Bangladesh and gradual expansion of trial areas indicate that there are favorable prospects for adoption and use of SRI in Bangladesh
- The trials so far conducted cannot be termed as conclusive. Well planned, coordinated sets of trials and evaluations need to be undertaken. At a workshop 14 January 2002, organized at the initiative of Prof. Uphoff and hosted by BRAC, the participants from all the organizations working with SRI resolved to form a Working Group that would coordinate, facilitate and strengthen future programmes of SRI activity in the country.

- A five-member Steering Committee was formed to act on behalf of the Working Group which can plan and coordinate the conduct of ongoing trials and evaluation on SRI. At the January workshop, the IRRI representative in Bangladesh who is managing the DFID-funded PETRRA project encouraged preparation and submission of a proposal to fund evaluation research on SRI by the group.
- A concept note is being prepared on behalf of the Working Group for submission to the PETRRA project to support evaluations of SRI techniques to determine the most suitable methods for an improved and sustainable agricultural production technology that will raise incomes, improve livelihoods, and contribute to poverty elimination in rural Bangladesh. The evaluation research will seek to enhance the productive potential of rice-based farming systems in Bangladesh.

Table 1. Results of SRI practices when used by different organizations in Bangladesh, 1999-2001

Institution	Season	Area	Seedling age (days)	Spacing (cm^2)	Farmers	Variety	Fertilizer	Yield
CARE								
Kishoregonj and Rajshahi	1999-2000 *boro*	0.21 acres	–	–	21 farmers	12 HYVs	Chemical fert.	6.53 t/ha (av.)
	2000-2001 *boro*	1 acre	10-20	30x30 to 40x40	99 farmers	HYVs	Same	6.25 t/ha (av.) (4.8-7.2 t/ha)
DAE								
Kishoregonj	1999-2000 *boro*	2 acres	9-18	30x30 to 50x50	53 farmers	HYVs	Chemical fert.	7.5 t/ha 30-40% higher (5.2- 9.5 t/ha)
2000-2001 *boro*		increased	14-17	35x35	80 farmers	Same	Same	Similar
BRRI								
Gazipur	2000 *aman*	$80m^2$	15	40x40 to 50x50	Own research plots	HYV, HR	Chemical fert.	No significant yield variation observed
	2000-01 *boro*	$180m^2$	15	Same	Same	Same		
Comilla	1999-200 *boro*		15	NR	Same	Same	Chemical fert.	5.4 t/ha. vs. 4.4 t/ha with same variety & usual methods
Syngenta								
Bogra	2000 *aman*	0.2 acre	12	20x15 to 50x50	Own research plots	HYVs	Chemical fert.	4.9-5.61 t/ha
	2001 *aman*	same	12	20x15 to 30x30	Same	HYV	Same	5.25-6.15 t/ha
BRAC								
Habigonj	2000-01 *boro*	10 acres	15	25x25	Own farm	HYV	Chemical fert.	5.9 t/ha; 26% higher

Experience in CUBA with the System of Rice Intensification

Rena Perez, Ministry of Sugar [1]

In March 2000, the Scientific Commission of the National Geographic Society held its annual meeting in Havana, and among those participating was Dr. David Pimentel, who had been my professor of insect ecology in 1957 while I was studying at Cornell. Dr. Pimentel spoke of work that CIIFAD was doing with a rice methodology from Madagascar and got me in contact with its director, Dr. Norman Uphoff. Soon, five papers and reports on SRI, in English, that we received from him were condensed into a brief Spanish summary.

Two thousand copies were distributed throughout the country, first to farmers working in the 1,600+ sugar cane cooperatives and 156 sugar mills of the Ministry of Sugar (MOS), and later to others associated with Low-Input Rice (LIR) initiatives and the Rice Research Institute (RRI) of the Ministry of Agriculture (MOA), the Urban Agriculture (UA) program, the Cuban Council of Churches (CCC), the Cuban Association of Small Farmers (CASF), and the National Institute of Agricultural Sciences of the Ministry Higher Education (NIAS/MHE).

Evaluations

The first information on how to improve yields and other SRI-related issues began to circulate only during the last trimester of 2001. There are results to report from: (1) a resource-limited farmer (associated with the CCC) cultivating a small family plot in the central lowlands susceptible to sea-water flooding; (2) one hectare on a sugar cane cooperative of the Sugar Ministry in the western-most province (Pinar del Rio); and (3) an experiment inspired by SRI to study planting distance of direct-sown rice on the incidence of the mite/fungus complex, S*teneotarsonemus spinki* and *Sarocladium oryzae*, conducted by RRI.

Farmer experiment

Age of seedlings: 15 days, transplanted within 15-20 minutes after extraction from nursery

Number of seedlings/hill: 1

Variety: Caribe 1

Area: 20 x 20 m

Fertilizer: none

Planting distance: 35 x 35 cm, in water up to one-half the height of the seedling

Management practices:
No further water was added after transplanting; after 15 days the plot was dry, then it was left another 15 days with no water until the soil showed signs of cracking. Water and some rain kept the soil moist. Twenty days after planting, there were 2 tillers; at 90 days there were 50-60 tillers, and the rice was one meter or more in height.

Previously, the farmer had planted up to 10 plants/hill on this plot, 35 day-old seedlings that often were more than one-day old from the nursery, at a spacing of 20 x 20 cm.

Sugar cane cooperative

Date of planting: February 2001; harvest April-May 2001

Variety: VN 2084, short grain

Distance: 30 x 30 cm

Age of seedlings: 12-15 days

Soil: alluvial brown clay soil

Fertilizer applied prior to transplant: phosphorous and potassium 0.2 t

Fertilizer during vegetative stage: urea 0.4 t

Area: one hectare

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Management practices:
- Water was removed from the terraces 24 hours prior to planting, which meant that the seedlings were transplanted into very humid soil, but without any standing water.
- Precaution was taken so that the root and stem of the single seedling were not planted at right angles, but rather straight.
- The day following planting, and every 72 hours thereafter, enough water was applied to cover the seedlings during 20-24 hours. Beginning with the third watering, the seedlings were not covered with water.
- After 15 days, when the rice plants were 30 cm tall, the water was completely removed for a period of 12 days after which time the soil was cracked and the plants showed definite signs of stress due to lack of moisture. (Soil moisture should not be interpreted in terms of number of days, but rather in terms of soil cracking.)
- At that time, after the 12th day without water, 0.4 t/ha of urea was applied, followed immediately by water, which was left there during 6 days. At that time, there was an estimated 15% weed infestation.
- On the 18th day, i.e., six days later, a herbicide was applied to eliminate any weeds that protruded through the water. The area used was not considered very weedy.
- Five days after applying the herbicide, the water was removed. Thereafter, every 72 hours, water was provided for a period of 24 hours until the rice flowered and the grains were visible.

Institute of Rice Research

Presently, the most serious rice pest/disease problem in Cuba is the mite/fungus association, responsible since 1997 for a 30% reduction in yield. Chemical control is difficult, and five research institutes are actively engaged in developing an Integrated Pest Management Program to combat this problem. The traditional row distance for machine-seeded rice, both low-input rice (LIR) cultivated by farmers and high-input rice (HIR) grown in the public sector, is 15 cm. For this spacing, the seed requirement is 100-120 kg/ha.

Scientists at RRI, after analyzing data on SRI from Madagascar on the correlation between fewer plants and higher yield, hypothesized that one major SRI feature, increased distance between plants, if applied to direct sowing, might increase the exposure of mites to sunlight and wind flow, two mortal enemies, and thus reduce mite presence. The treatments were:

T_1 in rows, east to west, 15 x 45 x 15 cm (50 kg seed/ha);

T_2 in rows, north to south, 15 x 45 x 15 cm (50 kg seed/ha);

T_3 broadcast, 100 kg seed/ha; and

T_4 broadcast, 50 kg seed/kg

Results

Farmer experiment

These methods produced 21 5-gallon cans of paddy rice, equivalent to 5.8 t/ha. The first trial with SRI yielded 32 cans, which is the equivalent of 8.8 t/ha.

The next season, he increased the number of plots to 12, and a neighbor planted three. However, all of these were lost due to seawater intrusion during Hurricane Michelle in October 2001. This farmer now has a pump and is “cleaning” his land of salt to begin all over again.

Sugar cane cooperative

This co-op, considered by the Ministry of Sugar as one of the best for rice yields, has always transplanted its rice, planting between 13-14 ha yearly. In 2000, the yield was 6.6 t/ha. The first hectare planted according to the SRI methodology gave these results:

1. A 44% increase in production with SRI methods, reaching 9.5 t/ha the first season, and 11.2 t/ha the next season, a 70% increase;
2. Important savings in seedlings, seeds and water;
3. Less labor required for transplanting because of fewer and smaller seedlings;
4. Impressive early root development which meant that the water was more efficiently used in the period of greatest development of tillering, flowering, panicle formation, and in the initial stages of maturation; and
5. The co-op found that it can do two plantings/year and will double the area planted to SRI in 2002.

Institute of Rice Research

The results in Table 1 show that with wider row distance, inspired by SRI thinking, and an east-west row orientation (T_1), the incidence of mites was reduced by approximately two-thirds, fungus affectation was only about one-half, there were fewer infertile grains, and improved yield performance.

These preliminary results led RRI scientists to examine, in the presence of extreme mite infestation, the relationship between population density and yield. Their findings, supporting SRI concepts, were the following:

Plants/m²	Yield
21-25	9.3 t/ha
37-44	8.5 t/ha
70	8.5 t/ha
Over 80	4.2 t/ha

Learning

We have encountered various obstacles or resistances to getting SRI tried out. In the sugar cooperatives where 20,000 ha of rice traditionally been sown by machine or airplane, the introduction of SRI has meant that the workers for the first time must learn to transplant rice and set out seedbeds adjacent to the terraces. They are accustomed to planting sugar cane but not rice. However, with the prospect of increased yields with SRI, which could make more money for them, farmers are becoming interested. Various other observations have been made:

1. The use of small seedlings and the need to develop an appropriate substrate for growing them makes some farmers anxious about using a mixture of filter-press mud and cane trash ash in the nursery. The possibility of substituting commercial sources of potassium and phosphorous for filter-press mud and cane trash ash should be examined.

Table 1. Number of mites, associated fungus infestation, and yield performance related to different planting methods and plant densities *

Treatments	Total no. panicles**	Infertile grains (%)	Grains with fungus (%)	Mites per plant	Yield (t/ha)
T_1	1190a	24c	6	94	6.57a
T_2	1006b	31b	10	265	6.53a
T_3	1049b	40a	10	295	5.97b
T_4	1055b	31b	11	240	6.30b

**J. L. Hernández, P. J. Gómez, M. Vega, E. Botta, J. Martínez, M. Socorro, and J. Horsfford, 2001. Efecto del marco y la dosis de siembra sobre la incidencia de S. Spinki* Smiley en el cultivo del arroz. *Forum Ciencia y Técnica*, 2001, Habana (unpublished).
***Data refer to 10 panicles.*

2. The manipulation of small seedlings is easier with smaller fingers to transplant, which might mean engaging women and children in this activity.
3. The lack of a culture of intensive cultivation for rice means that new attitudes are necessary, including the need to question tradition and accept discipline with implementing careful practices.
4. There is need to convince certain persons who categorically deny the possibility of producing rice profitably that this can be done with SRI.
5. There is need to learn how to make compost and to compare the results of using organic with inorganic fertilizer.
6. A lack of workers available to control weeds has led some farmers to associate SRI with wider row spacing and a return to oxen for cultivation, which may be feasible.
7. Finally we have to deal with the concern of one functionary who objective that with SRI there will be insufficient workers to harvest because SRI will produce more rice!

The RRI has emphasized, correctly, that rice transplanting culture is relatively new in the country. Since the mid-90s, farmers have begun to accept transplanting because:

1) It saves on seed.
2) Farmers, in contrast to the state farms, cannot acquire herbicides and must rely on water to control weeds.
3) Transplanting produces higher yields, meaning that less land is required.
4) Less water is used with intermittent flooding compared to immersion.
5) There are fewer insect pests with intermittent flooding.

RRI has openly and enthusiastically supported evaluation of the new SRI methodology, although it also recognizes that with SRI, unless farmers can learn to level their terraces correctly, there can be problems with using such small seedlings, with the wider distances between plants, and without using herbicides.

Prospects

The country requires 650 TMT of rice yearly. The present average yield of paddy LIR and HIR is 3.25 and 3.6 t/ha, respectively. Before the present economic crisis, all rice was HIR and machine- or airplane-sown. The country produced half its requirements, and rice was never transplanted. Beginning in 1996, a national movement known as LIR was created to produce rice locally, on smaller-scale holdings compared to HIR which was begun in the early 60s. Presently, 42% of LIR is transplanted while 58% is still direct-planted. By 2001, the production of LIR had increased to 195 TMT, or, two and a half times more than HIR.

Low-input rice

The movement to reduce rice imports has become so important that the government recently decided to create 13 provincial LIR bureaus, as well as assign a specialist in rice to each of the 157 municipal agricultural delegations. The first results with SRI in Cuba, more than 9 t/ha, have fortuitously coincided with this new development, and SRI will immediately be incorporated in a national program (RRI/MOA) to compare existing LIR technologies in the three principal rice-growing regions of the island. Also, with SRI, some farmers have already expressed an interest to study having three rice harvests from two plantings, i.e., after the harvest in August, harvesting a second or ratoon crop in November. This would leave one month to fertilize and prepare the soil.

Ministry of Sugar

In the sugar cane sector, beginning in March 2002, in the two westernmost provinces, 30 cane co-ops will plant a total of 70 plots (each 400 m^2). Two cane co-ops have already planted two hectares each, and one sugar mill has, for the first time, switched to transplanting 26.8 ha, which is 10% of the 268 ha required to provide rice for its workers.

Research sector

The RRI, which sets the standards and monitors the production of both HIR and LIR throughout the country, has recognized that SRI, in addition to having the prospect of improved yields, has opened up a whole new line of thought for controlling mites. The Institute will immediately (3/2002) initiate an extension trial of 2 ha. to compare T_1 (rows east to west, 15 x 45 x 15 cm, sowing 50 kg/ha) with broadcast planting (100 kg/ha). The rice experiment station for Ministry of Higher Education (NIAS/MHE) is already studying the possibility to produce rice plants commercially for SRI in Urban Agriculture, using seeding blocks and mycorrhiza. Finally, information has been received to the effect that some farmers, only recently exposed to SRI methodology and with their rice already planted, have begun to let their fields dry up once a week and are already observing better results!

Experiments with the System of Rice Intensification in The GAMBIA

Mustapha M. Ceesay[1]

The Gambia is a small country in West Africa of 11,700 km², surrounded on three sides by Senegal, situated between 13.2 and 13.7° N latitude. The country is a 50-km-wide ribbon of land that extends eastwards 475 km from the coast and bisected by the River Gambia. It lies within the Sahelo-Sudan climatic zone with 900 to 1400 mm of average annual rainfall, with the rainy season extending from late May to early October.

In The Gambia, the rice production systems can be grouped into five categories: upland, lowland rainfed, irrigated (pump and tidal), freshwater swamps, and seasonally saline mangrove swamps. Production constraints differ naturally from one environment to another, and accordingly, farmers need a variety of technological alternatives.

Rice is the staple food in The Gambia, with average annual consumption per capita of 70 to 110 kg. Domestic production lags behind consumption by 60%, with the balance needing to be met by importation. National average yields of rice are only 2 t/ha.

SRI was introduced to The Gambia in the rainy season of 2000 as part of a thesis research project for a PhD program in Crop and Soil Sciences currently being undertaken by the author at Cornell University. Farmers were invited to visit the first SRI trial site at the Sapu station of NARI, and the positive interest that they expressed after seeing the new potentials of their local varieties made it possible to conduct a series of on-farm trials in 2001.

Evaluations

On-station trials

During the first year of experimentation with SRI, three different plant population densities were investigated with several varieties. Yields ranged from 5.4 to 8.3 t/ha. In 2001, in addition to a plant population-density trial, there were also SRI trials with fertilizer variations and on-farm trials involving 10 farmer households. The on-station SRI trials were conducted under pump irrigation, and on-farm trials under tidal irrigation.

The plant population densities investigated were of the following spacing distance:

- 20 x 20cm
- 30 x 30cm
- 40 x 40cm

Two rice varieties IET3137 and ITA306 were used in the trial.

The SRI fertilizer trials assessed the following fertilizer treatment rates:

- 70-30-30 NPK (the national recommended rate)
- 140-30-30 NPK
- 280-30-30 NPK

The objective of these trials was to find out if the available nutrients in The Gambian lowland soils are a limiting factor for maximising yields under the SRI production system. The SRI components used in these trials were 30 x 30cm spacing, water control, and young seedlings (age assessed by leaf stage). IET3137 and ITA306 rice varieties were used in the experiment.

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On-farm trials

The SRI on-farm trials were farmer-managed and researcher-supervised. SRI results were compared to those with farmers' practice. Farmers transplant much older seedlings, 28-40 day-old seedlings. Three or four seedlings are transplanted per hill, with 30-35 seedlings per m^2. Older seedlings are preferred because they are taller and can be transplanted in uneven fields with poor water control and thus a lot of flooding.

Results and Discussion

On-station trials

Spacing: Differences in population density gave relatively similar grain yields between 20 x 20cm and 30 x 30cm spacing. Stover yield increased with an increase in spacing, but this did not correspond to an increase in grain yield. Spacing at 30x30cm is more economical in terms of seed and labor requirements; it is much faster than transplanting at 20x20cm spacing. Transplanting at 40x40cm spacing gave the highest stover mass, but the lowest grain yield. Spacing at 30x30cm is thus being recommended to farmers in The Gambia.

Fertilizer Applications: These trials indicated that under SRI management, the nationally-recommended fertilizer application rate of 70-30-30 NPK is as effective as doubling the rate. While tripling the rate gave higher yields, this is not economically profitable.

On-farm trials

These gave exciting results, showing *a tripling of yield* compared with the production using farmers' present practices. The trials were conducted in a communal tidal irrigation scheme. Other non-participating farmers had the opportunity to observe the trials.

The most acute problem facing farmers in their effort to adopt SRI in The Gambia is land preparation. Extra effort had to be put into land preparation in order to prepare the fields for SRI. For some farmers, this will be a problem for undertaking these new methods.

Farmers in The Gambia still do not have a well developed culture of water control. Fields are simply kept flooded after transplanting until the rice plants reach maturity. Fertilizer application and weeding are done under submerged conditions. So these practices would conflict with adoption of SRI.

Table 1. Grain yields from SRI on-farm trials, The Gambia, 2001

Farmer	Farmers' Practice (T/ha)	SRI Practice (T/ha)
1	3.7	8.5
2	2.0	7.8
3	2.5	9.3
4	1.8	9.4
5	1.6	9.0
6	1.4	8.0
7	2.8	6.0
8	2.5	7.0
9	3.8	7.6
10	2.5	1.8
Average	2.5	7.4

In one instance (Farmer No. 10 above), the bund between the area with the farmers' own practices and the SRI half of his plot gave way, submerging the 1-week-old SRI seedlings and resulting in seedling mortality and retarded growth. All the other SRI plots performed much better than those with conventional practices, averaging a little more than 8 t/ha.

Prospects

High returns from SRI practices were clearly demonstrated to farmers in The Gambia. Prospects are that farmers will start utilizing at least one or two SRI components in their production systems and reaping its benefits. However some fundamental factors will limit utilization of several or all SRI components effectively.

Policies in The Gambia and Sahel region regarding extensification of irrigation schemes is to a great extent influenced by the amount of water available to support production, taking into consideration the massive demand of current production systems. In the more arid regions of the Sahel, rivers are already failing to fully support irrigation schemes.

Land preparation under SRI in more intensive, and although SRI gives three times more grain yield than current practices, adoption of SRI will to a great extent depend on access to extra man-days of labor for land preparation or power-tiller time.

The System of Rice Intensification in INDONESIA

Anischan Gani, Triny S. Kadir, Arti Jatiharti, I. P. Wardhana, and Irsal Las, Research Institute for Rice, Agency for Agricultural Research and Development [1]

Initial "rice intensification" efforts in Indonesia started in 1959 when the government established a network of local rice centers (*Padi Sentra*), which organized farmers for rice production and provided them with credit. Rice intensification was undertaken because we needed to produce more rice to feed the ever-increasing population in Indonesia.

After the initial program was evaluated, a "mass guidance" program known as BIMAS was established in 1965, with the addition of more components, to cover almost all irrigated areas in the country.

Following BIMAS, there were other modifications in the program for rice intensification. Starting in 1986, it was extended to become SUPRA-INSUS, the supra-intensification system. The components of this program included use of certified seed of recommended varieties, integrated pest management, balanced fertilization, and credit availability. The program was implemented throughout the irrigated rice areas in Indonesia.

Starting about 1995, it was realized that the existing rice intensification program could no longer support the needs of the rice sector. New production technology was failing to keep pace with food demand. SUPRA-INSUS could not reach the expected production levels.

To make matters worse, the technologies (especially the use of chemical inputs) have been upsetting the ecological balance in irrigated rice systems. Rice production and productivity was seen to be leveling off, stagnant, and in some places even declining.

Thus, despite many years of experience with rice intensification efforts, the rice production system in Indonesia appears to be less and less sustainable. Intensification programs that once made Indonesia one of the leading rice-producing countries, with self-sufficiency achieved for a short period after 1984, had to be improved. The country's strategy to increase rice production and secure sufficient food for its population needed to be repositioned.

Encouraged by a presentation on the System of Rice Intensification (SRI) by Prof. Norman Uphoff in October 1997 in Bogor, his first presentation on SRI made outside of Madagascar, AARD started to evaluate this system and to revise its rice intensification efforts.

After a full assessment of our past programs (involving expertise from IRRI), it was concluded that there was indeed something to be learned from SRI methods. Starting in 1999, AARD undertook evaluations of SRI at its Research Institute for Rice (RIR) in Sukamandi and found that a higher level of production could be attained with this method.

Since 2000, we have been thinking through, developing, and evaluating a new combined strategy for rice intensification that includes SRI practices with integrated pest management (IPM) practices, as well as other local-specific means to increase rice production. It is called the *Integrated Crop and Resource Management* (ICM) system for irrigated rice areas and has been evaluated on farmers' fields in 8 provinces of Indonesia.

Before and during program implementation, ICM ideas were introduced and spread with local staff and farmers in a decentralized and participatory manner. During the development and evaluation of the program, a participatory, farmer-centered approach has been used. This is important as the process should upgrade our human resources in agriculture, which are the key to success.

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Evaluations

With millions of people depending on irrigated rice ecosystems for their food and income, any drop in rice production could have serious implications for food security. Therefore, the Rice Institute, in accordance with its national mandate, has to find the ways to provide farmers with the knowledge and skills needed to improve their rice production and productivity in a sustainable manner. The strategy depends heavily on farmers' empowerment and on maintaining and improving soil fertility.

These efforts aim at regaining rice self-sufficiency, increasing farmers' welfare, and sustaining the system of rice production. Much hopes are hanging on this ICM approach to irrigated rice. It is expected to bring back self-sufficiency in rice as well as to sustain the rice production system.

The ICM system has three main components: intermittent irrigation to save water and improve soil quality, transplanting single younger seedlings, and increasing soil organic matter. The three components go to the heart of rice crop production thinking, relative to the conventional flooded systems. For maximum production in a given area, these components should be applied together. Other components should be promoted as far as socio-economic and environmental concerns are supportive.

Evaluation and development of ICM were undertaken during 2001 in 5-ha irrigated rice areas at 16 selected villages. Superimposed and component technology trials were conducted as well. The concept of integration is a broad one, including many levels, i.e., institutions, crops and resources, scientific personnel, and farmers, all linked analytically and operationally. Through this ICM approach, aside from increasing production levels, we expect that the quality of resources in wetland rice production systems could be maintained or improved.

All 5-ha demonstration plots and super-imposed trials in each of 16 villages were monitored and supervised by facilitators from the Assessment Institutes for Agricultural Technology (AIATs) in the respective provinces, as well as by researchers from Research Institute for Rice (RIR).

Results

Demonstration trials at Sukamandi

Dry and wet seasons of 1999 and 1999/2000

The first trials with ICM (modified SRI) for irrigated rice ecosystems were carried out on the main RIR experiment station at Sukamandi. In this study no P or K fertilizers were applied. The rate of N fertilizer was 200 kg urea/ha (normally farmers apply as much as 250-300 kg urea), and the timing of applications was determined based on leaf-color chart readings.

On average, the rice yield obtained from plots practicing ICM principles in the dry season of 1999 was 6.2 t/ha, or 51% higher than on plots with farmers' standard management practices (4.1 t/ha). These practices included transplanting 21-day-old seedlings, 3 per hill, with no application of organic matter, continuous flooding, and application of N-P-K fertilizer.

The grain yields in the wet season of 1999/2000, obtained from 6 demonstration plots (1,500 m^2 each) at Sukamandi, ranged from 7.2 to 9.3 t/ha, with *return-to-cost (R/C) ratios* of 1.63 to 2.08 (see Table 1). The average rice productivity using SRI methods under farmers' management was 6.5 t/ha (R/C value 1.61). Several rice samples, harvested from plots 10 x 10 m^2, had grain yield reaching 103 kg, which is the equivalent to 10.3 t/ha yield. This was the first time that rice yield in this area had reached 10 t/ha.

Dry and wet seasons of 2000 and 2000/01

ICM demonstration plots in the dry season at Sukamandi in this second year of trials, yielded 6.9 to 9.7 t/ha (R/C values = 1.83 to 2.39), averaging 8.3 t/ha. This was 30% higher than the 6.4 t/ha (R/C = 1.98) that farmers using conventional methods achieved. Moreover, in the wet season of 2000/01, the ICM plots yielded 7.7 to 9.1 t/ha (R/C values = 2.00 to 2.48), averaging 8.4 t/ha. This was a production increase of 29% more than on farmers' fields (6.5 t/ha, with R/C value = 1.97) (Table 2).

Dry and wet seasons of 2001 and 2001/02

In the dry season 2001, the response of three rice varieties was evaluated. Due to differing yield potentials of the three varieties, there were different yield responses to ICM methods: Ciherang yielded 7.3 to 7.7 t/ha, IR-64 gave 6.8 to 6.9 t/ha, and Way Apo Buru produced 7.4 to 7.6 t/ha. At the same time, farmers nearby using conventional methods achieved only 4.7, 4.9 and 5.7 t/ha with IR-64, Way Apo Buru and Ciherang, respectively. Irrespective of variety, ICM gave higher R/C values than those with conventional production methods (Table 3).

Table 1. Results of ICM demonstration plots using Way Apo Buru variety, Sukamandi, dry and wet seasons, 1999-2000

	Plot A	Plot B	Plot C	Plot D	Plot E	Plot F	Farmers Fields
Dry Season 1999							
Yield (t/ha)	6.2	–	–	–	–	–	4.1
R/C	2.40	–	–	–	–	–	67
Wet Season 1999-2000							
Yield (t/ha)	7.2	7.8	8.3	8.4	9.3	9.2	6.5
R/C	1.63	1.72	1.85	1.88	2.05	2.08	1.61

Table 2. Results of ICM demonstration plots using Way Apo Buru variety, Sukamandi, dry and wet seasons, 2000-2001

	Plot A	Plot B	Plot C	Plot D	Plot E	Plot F	Farmers Fields
Dry Season 1999							
Yield (t/ha)	8.0	8.2	8.0	6.9	9.7	9.0	6.4
R/C	2.11	2.07	1.98	1.83	2.39	2.16	1.98
Wet Season 2000-2001							
Yield (t/ha)	8.2	9.1	8.6	8.2	8.5	7.7	6.5
R/C	2.36	2.11	2.48	2.00	2.52	2.35	1.97

Table 3. Results of ICM demonstration plots using different varieties, Sukamandi, dry season, 2001

	Variety		
	Ciherang	IR-64	Way Apo Buru
ICM Methods			
Yield (t/ha)	7.3-7.7	6.8-6.9	7.4-7.6
R/C	2.35	2.46	2.48
Conventional Methods			
Yield (t/ha)	5.7	4.7	4.9
R/C	2.18	1.96	2.01

Table 4. Results of ICM demonstration plots using different varieties, Sukamandi, wet season, 2001-2002

	Variety		
	Way Apo Buro	IR58025A-IR53942 (Hybrid Variety)	BP364R-MR-33-3-MR5-4 (NPT)
ICM Methods			
Yield (t/ha)	7.0-8.3	5.9	5.8
R/C	2.04-2.27	1.76	1.74
Conventional Methods			
Yield (t/ha)	5.5	–	–
R/C	1.87	–	–

Starting in November 2001, the same fields were used with ICM methodology, and some farmers followed the ideas by themselves, for comparison. This season, one hybrid and one New Plant Type (NPT) cultivar were being tested, with Way Apo Buru as the standard variety for comparison (Table 4).

Way Apo Buru, an inbred variety, responded well to ICM in comparison to conventional methods, in terms of yield and R/C ratio. On the other hand, hybrid rice (IR58025A-IR53942) and the NPT variety (BP364R-MR-33-3-MR5-4) did not respond so well to ICM in comparison to Way Apo Buru. It seemed that the spacing of 25x25 cm was too wide for these two cultivars as they produced fewer tillers and panicles. In addition, the percentage of filled grains for the two cultivars was much lower than with Way Apo Buru.

Farmer evaluations

IPM Program in 2001

SRI has also been evaluated by the Farmers' Science Group in Ciamis district, West Java, that is associated with Indonesia's Integrated Pest Management (IPM) program. The group was supported and facilitated by Mr. Enceng Asikin and Mr. Koeswara, IPM program alumni. Farmers got the idea of testing SRI from the FAO Community IPM Program.

This study was conducted on farmers' fields at Sindang Kasih village, Cikoneng sub-district, between February and early May 2001. Grain yields on the SRI fields were 6.7 and 7 t/ha compared to 4.5 t/ha on an adjacent field using regular methods, an increase of 49-56% over farmer practice. The yield improvement was associated with increased numbers of tillers and productive tillers. Also, the incidence of stem borer seemed to be lower with SRI (3%) compared with conventional methods (8%).

Evaluation of ICM in 8 provinces during 2001

Starting in the dry season 2001, two villages in each of 8 provinces in Indonesia were chosen for ICM development and evaluation. More than 4 ha irrigated lowland rice area were used as a test location in each village, having 10-20 farmers as cooperators. The program was planned for three years. According to different growing seasons among villages, the harvest time differed among villages and test locations.

Average rice yields in all of the ICM plots as part of this 8-province evaluation were found to be higher than the yields obtained by farmers in each of the participating villages. The subsequent results have been quite impressive, with rice yields with ICM methods being 7.1 to 33.3% higher (average = 16.4%) than those with farmers' usual practices.

Lower yield responses to ICM in some places were associated with the incomplete practice of its main components, especially not doing intermittent irrigation but rather keeping fields continuously flooded. In Bojongjaya, West Java, lower yields were due to flooding; ICM with its younger seedling gave a 3.3% yield reduction (Table 5). There is often not the willingness or the means to change age-old irrigation practices.

In the second season of evaluations at village level, the yield response to ICM was higher than in the first. Table 6 shows that ICM methodology produced 2.7 to 51.4% (average 28.4%) more grain in comparison with conventional methods. Lower yield responses to ICM methods at Kliwonan and Gunungrejo were due to reduced water availability toward the end of the dry season.

Farmers using ICM saved 15-40 kg seed and 140-200 kg of urea per hectare, lowering substantially their costs of production. As a result, the R/C values for ICM methodology were higher in most ICM trials (2.06 to 3.28, average 2.77) than with conventional methods (1.71 to 3.42, average 2.36).

Farmer evaluation under ADRA project in 2002

The most recent data on SRI evaluation in Indonesia has come from the ADRA Mother and Child Health and Agriculture (ADRA MCHA) project. Following a visit from Mr. Roland Bunch of COSECHA in November 2001, ADRA tried SRI methodology with farmers on their own fields in Kupang, West Timor. This NGO worked through farmer groups, involving more than 100 local farmers. In the trials, farmers practice transplanting single and younger (8 to 10-day-old) seedlings, 25x25 cm spacing, improved drainage during the vegetative growth stage, and 1-2 cm flood water during the reproductive stage. They gave small amounts of urea in addition to organic compost. The trials were conducted from January to May 2002.

SRI methods gave remarkably higher yields, from 8.6 to 13.8 t/ha, with an average of 11.6 t/ha, compared to yields with farmers' usual methods averaging 4.4 t/ha. Most farmers used IR-64 variety. Even a traditional variety, Si Putih, yielded 11.6 t/ha. More numerous tillers and panicles produced with SRI methods accounted for the higher yields in these trials.

Learning

Some possible constraints for the spread of ICM have been encountered since the first demonstration plots at Sukamandi in 1999 and during the implementation of the project in eight provinces. In general, the constraints were specific for certain areas. For example, in areas where the golden snail is endemic, farmers were afraid to use ICM because they feared that once the pest comes, the tiny seedling will disappear. In such areas we recommended using 2 to 3 seedlings per hill, although we found in our first tests in 1999 that intermittent flooding actually reduced the populations of golden snail.

Difficulties that have been faced in disseminating SRI methods so far are:

- Irrigation management and water control are not easy to maintain. As a result the optimal effects from increased soil aeration were often not realized.
- Labor requirement was higher than with the traditional practice, at least to begin.
- Many constraints limit the use of younger, single seedlings.
- Some pests and diseases attacked younger seedlings more after transplanting.
- It is not easy to handle and cultivate a tiny single seedling, at least until farmers gain skill and confidence in this method.
- Farmers are afraid of running greater risks with younger and single seedlings.
- Improvement of soil organic matter is often difficult in situations like on Java where often farmers do not own the land that they cultivate. So they hesitate to invest in improving the soil, even when they know that there will be benefits from this, even in the short run.
- Because not all farmers understand the ICM methodology equally well, and there are always some variations in bio-physical conditions, there were many differences among villages in how completely and how well they applied these methods. Not all farmers/villages utilized the main components completely. This means that there is still scope for further improvement of yields.

Prospects

Analyzing the trends and development of rice intensification in the world, particularly in Indonesia, we see the conditions that we have to keep pace with. There are major emerging global issues concerning water scarcity and environmental degradation. There are concerns about maintaining and improving land productivity as a key factor for the success of any intensification program for rice over the long run. We expect these problems can be addressed through ICM implementation throughout the country as it makes fewer demands on water and aims to build up soil quality and health.

Table 5: Rice yields and R/C values with ICM methodology and farmers' practice, dry season, 2001

Location Province/	SRI Yield (t/ha)	Conventional Yield (t/ha)	Production Increase (%)
North Sumatra			
Aras	6.0	5.0	20.0
Tanjung Kubah	6.1	5.0	22.0
West Sumatra			
P. Pakandangan	4.7	3.8	24.0
West Java			
Sukasenang	5.0	4.6	8.7
Bojongjaya	5.9	6.1	-3.3
Central Java			
Sugihan	7.5	7.0	7.1
Kliwonan	6.4	4.8	33.3
East Java			
Gunungrejo	9.3	7.4	25.7
Tembalang	8.5	7.3	16.4
West Nusa Tenggara			
Jangala	7.4	6.5	13.9
South Sulawesi			
Matoanging	6.5	5.8	12.1

This methodology that is being developed and evaluated, to raise lowland rice production within different agro-ecological zones, has to be continually improved with a farmer-centered approach, to evolve specific systems for rice intensification that are most effective, in site-specific ways, for a given agro-ecosystem.

The good and healthy performance of our ICM crop has attracted the interest of hundreds of farmers around the study areas. Local staff and cooperating farmers have become highly impressed with ICM. From this point on, the future development and spread of this methodology will depend very much on the farmers themselves.

With better handling of the main components of ICM, much higher rice productivity can be achieved than at present. It is expected that the current rice yield ceiling can be lifted by utilizing available technologies and practices within our ICM framework. Although rice yields have been stagnant in Indonesia for the past 5-7 years, we now see a way to resume their growth.

Table 6. Rice yields and R/C values with ICM methodology and farmers' practice, dry season, 2001, and wet season, 2001-2002

Province/Location (Season)*	SRI Yield (t/ha) [R/C in brackets]	Conv. Yield (t/ha) [R/C in brackets]	Production Increase (%)
West Sumatra			
P. Pakandangan (W)	5.3 [2.98]	3.5 [1.71]	51.4
Central Java			
Kliwonan (2nd D)	8.0 [na]	7.6 [na]	5.3
East Java			
Gunungrejo (2nd D)	7.6 [2.06]	6.8 [1.91]	11.8
Tembalang (2nd D)	8.4 [2.59]	5.7 [2.08]	47.4
Bali			
Petiga (2nd D)	7.6 [2.59]	5.7 [2.08]	33.3
Tunjuk (D)	6.9 [na]	5.7 [na]	21.1
West Nusa Tenggara			
Tanjung (W)	7.1 [3.28]	5.7 [3.42]	24.6
Balo (D)	5.9 [2.92]	4.3 [2.22]	37.2
South Sulawesi			
Pinrang (D)	8.0 [3.00]	6.5 [3.08]	23.1

In some villages, due to available irrigation water, lowland rice is cultivated twice in the dry season (2nd D); otherwise season is denoted by D for dry and W for wet.

Pleased with the ICM results so far, starting in the dry season of 2002, three more provinces, Bengkulu, Lampung, and Yogyakarta District, are being included as additional sites for ICM development. Senior officials in the Indonesian Ministry of Agriculture, including the Minister himself, upon learning about ICM during their visits to Sukamandi station have taken great interest in getting ICM evaluated and introduced in all major rice-growing regions.

Acknowledgment

The data from IPM farmer group trials in Ciamis, West Java, supplied by Mr. Enceng Asikin and Mr. Koeswara, and from the ADRA Mother and Child Health and Agriculture Project in West Timor, supplied by Mr. Bruce Ewart, were highly appreciated.

Experience with the System of Rice Intensification in NEPAL

Chris Evans, Appropriate Technology Asia; Scott Justice, CIMMYT; and Shyam Shrestha, Sunrise Farm

SRI work has not progressed very far in Nepal; however there have been some small but interesting evaluations. In 1998, some initial work on SRI was begun by Chiranjivi Adhikari, an agronomist at the government's Khumaltar Research Farm near Kathmandu. The trials were sponsored by the Soil Management Collaborative Research Support Program funded from the U.S. Agency for International Development and managed through Cornell University. Though Adhikari has since been transferred to the Regional Agricultural Research Station (RARS) at Tarahara in eastern Nepal, his work on SRI continues.

In summer 2001, after some lengthy discussions between the first author and CIMMYT, two more sets of trials were begun, one at Sunrise Farm, an independent farm at Sitapaila near Kathmandu, owned and managed by the third author, and the other on the RARS at Bhairahawa in Rupandehi District. At that time, neither Evans nor CIMMYT knew about Adhikari's work.

About the time that the work on SRI began at Sitapaila and Bhairahawa, Scott Justice of CIMMYT learned from Prof. John Duxbury, Cornell's manager for the Soil Management CRSP about the previous work done on SRI. It was agreed then that there should be some coordination so as not to "reinvent the wheel" and waste resources. What follow are brief accounts of the evaluations to date.

Regional Agricultural Research Station Trials

In 1998, a small feasibility study on SRI was conducted as on-farm research at Sipaghat in Naldung, Kavre District. Three transplanting spacings (20x20, 30x30 and 40x40 cm), with three seedling ages (10, 20 and 30 days old), were transplanted on farmers' field. Very high tillering was observed at 40x40 cm spacing, but because the site was very far from Khumaltar, not all of the necessary data were collected. Also, it was not possible to maintain proper water control in the field as expected with SRI.

In 1999, evaluations were conducted both on-station at Khumaltar RARS and at two on-farm locations at Bhaktapur. At Khumaltar, two varieties that are popular in Kathmandu valley (Khumal-4 and Taichung-176) were used, while in Bhaktapur district, Khumal-4 was planted in Bageshori village and Taichung-176 in Nangkhel village. Three plant spacings (20x20, 30x30 and 40x40 cm) and three seedling ages (10, 20 and 30 days old) were used, and all detailed data were recorded.

Tillering was as high as 60 tillers per hill. However, the yield data showed the highest grain yield was achieved with 20-day-old seedlings using 20x20 spacing. The highest leaf area index (LAI) was also observed at 20x20 spacing. Thus, these first trials did not show the predicted SRI effect of better plant performance with younger seedlings and wider spacing. There were still difficulties during the tirals in maintaining SRI water management.

In 2000, the study was continued with slightly modified SRI practices used again at Khumaltar and in farmers' fields at Bhaktapur. Three popularly grown varieties were used in this study (Khumal-4, Khumal–6 and Taichung –176). At Khumaltar, the trials were planted with three spacings (20x20, 20x15 and 15x15), while at Bhaktapur, only one spacing (20x20 cm) was used. Again the result showed that 20x20 spacing produced the highest grain yield, this time compared to narrower spacings, below what is recommended with SRI. Farmers preferred this 20x20 spacing for its higher tillering and good grain size.

In 2001, further evaluation was conducted at RARS Tarahara and on a farmer's field in its command area. Of the SRI practices, only single seedlings were used. They were not very young (20 days old) and with 20x20 cm spacing. The popularly grown variety Mansuli was planted. Very high tillering (as high as 65 tillers per hills) was observed in the farmer's field. Grain yield as high as 8 t/ha was observed. One important characteristic of the plants grown this way was that there was no lodging, because of stronger plants and greater root growth. The same variety of rice when planted with the usual practices lodged while the single-seedling plants did not.

Sunrise Farm, Sitapaila, Kathmandu

In 2001, the authors coordinated a small trial on this farm located on the edge of Kathmandu Valley. The seedlings used were 8 days old, planted at three spacings: 15x15, 30x30 and 50x50 cm. The yields were only average and the 15 cm spacing was best. Shrestha's wife found the planting easy, and the extra time spent planting individual plants carefully was saved by the low planting density.

Weeding was, as expected, labor-intensive but it was reduced by sowing a green manure crop of mustard at transplanting time. This kept weeds down for 2-3 weeks. The first author has produced a brochure for farmers on SRI in Nepali which the NARC scientists have remarked was very helpful for them in formulating their trials. (Copies were made available at the conference.)

Regional Agricultural Research Center/ Bhairahawa and CIMMYT

Here there had been numerous participatory technology development (PTD) investigations undertaken and new advances in tillage and crop establishment (TC&E) technologies, such as surface seeding and reduced and zero tillage in wheat, in connection with the Rice-Wheat Systems consortium program. This work has been supported by CIMMYT.

The need to identify new TC&E technologies for rice had been noted for some time. Prior to summer 2001, RARS/Bhairahawa scientists J. Tripathi and M. R. Bhatta had been discussing recent SRI papers with Scott Justice (CIMMYT). They found the claims interesting and worth taking a closer look. It was decided that the work should not only evaluate SRI but should attempt to find germplasm that might have high tillering tendency.[1]

[1] *This is an offshoot of work done earlier, on bed-planted wheat, where wheat on raised beds of up to 70 cm in height, with 50 cm separation between outer rows, can give higher yields with lower seeding rates, due to the higher number of tillers and longer panicles*

At the Bhairahawa research farm, two preliminary experiments on SRI, funded by CIMMYT, were conducted in the rice season of 2001-2002 to study the feasibility of these techniques for the local environment and also to examine their economics. The experiment was simply laid out in RCBD with three methods of rice transplanting (two SRI and one conventional) and two rice varieties (Rampur Masuli & Radha 4) (See Table 1).

After transplanting, severe weed infestation appeared to be a serious problem, so two weeding practices (rotary weeder and manual weeding) were adopted in the experiment. Thus, all together three factors were included in the experiment but replicated only twice. Thirty centimeter spacing was used in SRI 1, and 40 cm spacing in SRI 2, while 10-day-old seedlings were transplanted with both SRI methods; for the conventional practice (CP), 20-day-old seedlings were transplanted at a distance of 20 cm apart.

The overall results of the experiment did not show any significant SRI yield increase over the conventional practice. However, data analysis revealed that the longer-duration variety produced a higher yield with SRI 1, whereas the shorter-duration variety did better with conventional practice. It was noticed that the SRI experiment suffered from heavy rains just a few days after transplanting and from severe weed problems, which contributed to poor crop growth.

Overall crop performance was poor for some weeks with SRI, but later it recovered surprisingly well and gave very good impressions. From the field observations, it was seen that growth performance was not uniform with SRI methods. In some patches the crop was so good that it produced up to 70 tillers /hill.

Future Plans

An SRI workshop was held mid-April in Kathmandu at the National Agricultural Research Council (NARC) headquarters to share data and experiences between scientists and farmers. At RARS/Bhairahawa, scientists have decided, based on their observations during the last crop season, to continue this experiment. In fact, they wish to formalize the experiment by developing and submitting a new proposal for NARC funding.

At Sunrise Farm, Shrestha and his wife consider that the method certainly has promise and plan to expand their area under SRI as well as continue evaluating its use with green manures and mulch to try to reduce weeding costs. Shrestha also plans to combine SRI with the Fukuoka no-till system (a rice-wheat-clover rotation) which is already working well on his farm.

Table 1. Experiments at Regional Agricultural Research Station, Bhairahawa

Treatments	Plant height (cm)	Panicle length (cm)	Maximum tillers/m^2	Effective tillers/m^2	Filled grains	Unfilled grains	Total grain weight (g)	Yield (kg/ha)
Effect of variety:								
R. Masuli	115	23	300	211	172	20	19	5665
Radha-4	112	23	244	185	136	24	25	5192
Effect of SRI methods:								
S1	111	23	259	196	155	21	22	5368
S2	115	24	268	193	162	23	22	5204
CP	115	22	288	205	146	22	23	5713
Effect of weeding practices:								
WP1	113	23	273	199	154	22	22	5453
WP2	113	23	270	197	154	22	22	5404
Variety x SRI methods:								
RMxS1	115	24	297	219	180	26	19	5905
RMxS2	115	24	295	207	184	23	19	5465
RMxCP	115	22	308	206	153	11	19	5624
R-4xS1	106	23	222	174	130	15	25	4832
R-4xS2	114	24	241	179	140	24	25	4942
R-4xCP	115	22	269	203	138	32	26	5802
Variety x weeding practices:								
RMxW1	115	23	305	214	172	20	19	5739
RMxW2	115	23	295	208	172	20	19	5590
R-4xW1	112	23	241	185	136	24	25	5166
R-4xW2	112	23	246	186	136	24	25	5218
SRI methods x weeding:								
S1xW1	111	23	260	200	155	21	22	5494
S1xW2	111	23	259	193	155	21	22	5243
S2xW1	115	24	272	193	162	23	22	5152
S2xW2	115	24	264	193	162	23	22	5256
CPxW1	115	22	288	205	146	22	23	5713
CPxW2	115	22	288	205	146	22	23	5713
Variety x SRI methods x weeding practices:								
RMxS1xWP1	115	24	301	227	180	26	18.5	6193
RMxS1xWP2	115	24	306	208	184	23	19	5402
RMxS2xWP1	115	22	308	206	153	11	19	5624
RMxS2xWP2	115	24	293	212	180	26	18.5	5618
RMxCPxWP1	115	24	285	205	184	23	19	5529
RMxCPxWP2	115	22	308	206	153	11	19	5624
R-4xS1xWP1	106	23	218	173	130	15	25	4795
R-4xS1xWP2	114	24	238	178	140	24	25	4902
R-4xS2xWP1	115	22	269	203	138	32	26	5802
R-4xS2xWP2	106	23	226	174	130	15	25	4869
R-4xCPxWP1	114	24	244	180	140	24	25	4983
R-4xCPxWP2	115	22	269	203	138	32	26	5802

SRI Experience in the PHILIPPINES

Robert Gasparillo, Broad Initiatives for Negros Development [1]

In the Philippines, knowledge on SRI came through various channels of information. Some got it through international networks like the International Institute for Rural Reconstruction (IIRR) while others encountered it through agricultural publications, such as the ILEIA Newsletter. Broad Initiatives for Negros Development (BIND), an NGO based in Negros Occidental, began SRI farm trials in 1999 using a draft document from CIIFAD downloaded from an internet website.

The Philippines has mostly maritime tropical climate with temperature variations reflecting differences in elevation. There are two pronounced seasons—wet and dry—with an average of 20 tropical typhoons annually during the rainy season, especially from June to December. Monthly rainfalls average 300–400 mm at the maximum and decrease to 100–200 mm at the minimum. Philippine lowlands usually have clay, sandy clay to sandy clay loam soils, while the uplands have clay to clay–loam.

In the Philippines, current rice yields in irrigated lowland average about 3.5 tons per hectare, using conventional farming methods, with considerable use of HYVs and agrochemicals. The two dominant cultural practices for irrigated rice are transplanting seedlings either 10–12 days old or 25–30 days old, usually closely spaced, and in clumps of 3–4 seedlings per hill.

During the vegetative phase, rice fields are usually irrigated with 10 to 20 cm of water to contain weed growth as well as provide water. Using early-maturing rice varieties is common practice, enabling farmers to attain five crops within a span of two years.

Initial Evaluations

SRI evaluations are just beginning in the Philippines. In one of the first trials, the Consortium for the Development of Southern Mindanao Cooperatives (CDSMC) began evaluating SRI in 1999. The 10 farmers working with this NGO got an average yield of 4.95 t/ha, which compared well with the usual yields of 1.5-2.5 t/ha there. The next year the average with SRI was 4.28 t/ha, but with one farmer reading 13.45 t/ha. In subsequent years, other NGOs including a farmer NGO for use of organic methods of agriculture, MASIPAG, started working with these methods. In 2001, a staff member of the Agricultural Training Institute (ATI) reported a yield of 7.6 t/ha with SRI compared to a previous yield on his field of 3.6 t/ha, using a mestizo hybrid variety (e-mail communication from Edwin Acoba to Norman Uphoff, CIIFAD, March 6, 2002).

BIND Evaluations

BIND has conducted 13 SRI on–farm trials in various farming communities since 1999, both in irrigated lowland and upland areas. As an NGO working at the grassroots to promote sustainable agriculture and food security, the farmers whom we mobilize participate in all stages of program activity. Thus, 26 BIND-assisted farmers have been involved in all aspects of the SRI experimentation—from land preparation and conducting trials to data gathering and data processing. This approach, aside from providing farmers with basic skills in conducting experimentation, aims to broaden farmers' agricultural knowledge of the whole system of food production.

Using randomized design, a method that farmers can easily comprehend and relate with in their farming experiences, BIND has conducted on-farm trials in 8 communities involving three towns and cities in the province of Negros Occidental. Of the 13 SRI on-farm trials, 11 focused on different planting distances that

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ranged from 15x15 to 40x40 cm (see Table 1). Another was a varietal study, and the other was more than a trial, being scaled up on an actual farm, comparing SRI to non-SRI methods, involving 3,044 square meters. For soil fertilization, a gallon of Free-Grow, a seaweed-based organic foliar fertilizer, and two tons of chicken manure were applied, based on soil analysis, to give 60 kg of pure N.

BIND Results

Based on almost three years of on-farm trials with SRI, we can report a maximum yield of 7.5 t/ha and an average of 6.9 t/ha based on trials between November 2000 and March 2001. Further trials from July to November 2001 gave a maximum yield of 7.3 t/ha and an average of 5.4 t/ha. All these trials were planted with M-44, a farmer-bred rice variety (Table 1).

A maximum yield of 7.4 t/ha, with an average of 5.1 t/ha was attained from the comparative study between SRI and non–SRI (Table 2). In the comparative varietal study, both M-44 (VAR 1) and Bordagol-1 (VAR 4) reached a maximum yield of 4.6 t/ha with averages of 4.1 t/ha and 4.5 t/ha, respectively (Table 3).

Reasons Why SRI is Found Interesting

Aside from its yield potentials, SRI works well with organic rice production methods:

1. Using a hand push-weeder for soil oxygenation as well as weed control gives farmers a good alternative to using herbicides.
2. Planting single seedlings in a large square space gives a good response to organic fertilizers, particularly to composted plant biomass and animal manure, in terms of plant growth and yield.
3. SRI requires less water during the season, and fewer seeds for planting, as little as 10%.
4. The wide spacing with SRI is a good way to help manage crop pests. Farmers observed that the conventional spacing in non–SRI fields had rat trails and signs of damaged plants, but they saw none of these in the SRI field. Rats shy away from wide-open spaces.
5. Not only rats were checked, but also brown and green leafhoppers—carriers of the deadly rice tungro virus. Wide spacing in plots allows more sunlight to penetrate even the base of the plant, exposing the hoppers to sunlight, which they detest and avoid.
6. SRI also can promote growing of other food and crops in the paddies, as the use of toxic chemicals—herbicides, pesticides, fungicides and others—is reduced.

Constraints and Learning

Much of the difficulties that most SRI farmer–practitioners have encountered is in transplanting. Planting single seedlings in large square spaces takes about 25 farm laborers to finish one hectare. This has a corresponding labor value of P2,500 ($50) at P100 per person. Possibly this cost will come down with experience, but at present it is an obstacle for starting up SRI.

Another problem can be golden snail infestation and damage, to which young seedlings are vulnerable in a newly transplanted field. This problem is often encountered in not very well leveled paddies where draining of water is difficult. If the paddies are kept dry, this can reduce golden snail infestation.

To reduce seedlings' stress during uprooting from the nursery and their movement to the field, both farmers and BIND research staff have made some modification, like planting the seedlings on lengths of split bamboo instead in a permanent seedbed. This allows farmers to carry the bamboo with the seedlings inside to the field for transplantation.

Prospects

Although SRI has already shown its yield potential, there is definitely ample room for further experimentation to utilize more efficiently the synergy of various factors in the paddies—rice variety, soil fertilization, spacing, altitude, moisture level, etc. Farmers' indigenous knowledge and participation in all levels is critical in realizing this goal.

There is now a planned collaborative effort between BIND and a local government research agency to conduct SRI farm trials in selected towns and municipalities in Negros Occidental. At the national level, a consultation workshop on SRI was planned for April 12, 2002 to involve NGOs and farmer organizations from all over the country. This workshop, among other efforts, should consolidate and share various research findings of SRI practitioners in the country where there is growing interest in these methods.

Table 1. SRI yield comparisons of different spacing trials, 1999–2002, calculated in t/ha

				Yield (in t/ha)											
				Minimum				Maximum				Average			
Dates of Trials	Rice Variety	Area (sq m)	Soil Type	15 cm	25 cm	33 cm	40 cm	15 cm	25 cm	33 cm	40 cm	15 cm	25 cm	33 cm	40 cm
Nov 01– Jul 02	M-44	150	CL[2]	4.6	**4.7**	3.5	2.7	5.0	**5.6**	3.9	3.1	4.7	**5.1**	3.5	2.7
Jul 01–Nov 01	M-44	150	C[2]	4.1	**4.3**	**4.3**	3.0	**7.3**	5.4	4.7	4.0	**5.4**	5.1	4.4	4.0
Jul 01–Nov 01	M-44	80	C[1]	**2.8**	**2.8**	2.5	2.3	5.8	**6.5**	4.5	3.5	3.8	**4.4**	3.4	2.7
Jul 01–Nov 01	M-44	90.25	CL[1]	4.7	4.8	**4.9**	4.7	5.0	5.0	**5.3**	5.1	5.5	4.9	**5.8**	4.5
Jul 01–Nov 01	M-44	150	SCL[2]	2.2	2.5	**2.9**	1.8	4.2	3.4	**5.7**	2.7	2.2	4.9	**5.8**	4.5
Jul 01–Nov 01	M-44	150	SCL[2]	3.2	3.3	**3.7**	3.2	**6.2**	5.0	5.7	5.0	**5.3**	4.1	4.7	4.3
Nov 00–Mar 01	M-44	80	CL[1]	3.1	**4.2**	4.0	4.0	4.2	5.0	**5.2**	5.0	3.6	4.4	**4.6**	4.4
Nov 00–Mar 01	M-44	80	CL[1]	4.0	2.9	**6.0**	2.5	5.5	7.0	**7.5**	5.3	5.0	5.7	**6.9**	4.4
Nov 00–Mar 01	M-44	80	C[1]	2.2	2.0	2.2	**2.3**	2.5	3.3	**4.3**	3.2	2.3	2.8	**3.0**	2.6
Nov 00–Mar 01	M-44	150	SCL[2]	1.4	2.6	**5.1**	3.0	2.7	3.1	**6.1**	4.6	2.2	2.9	**5.6**	3.6

Note: Highest yield in each set is **bold-faced** *for easier comparison.*
Legend: C=clay, CL=clay loam, SCL=sandy clay loam.

Table 2. Comparison of SRI vs. non–SRI Methods in lowlands, calculated in t/ha

				Yield (in t/ha)					
				Minimum		Maximum		Average	
Dates of Trial	Rice Variety	Area (sq. m.)	Soil Type	SRI	Non-SRI	SRI	Non-SRI	SRI	Non-SRI
Jul 01–Nov 01	M-44	3,044	SCL	**3.8**	3.0	**7.4**	5.6	**5.1**	3.1

Legend: SCL = sandy clay loam.

Table 3. Study of SRI Methods with varietal variation in uplands, calculated in t/ha, with spacing 33 x 33 cm

			Yield (in t/ha)											
			Minimum				Maximum				Average			
Dates of Trial	Area (sq m)	Soil Type	Var 1	Var 2	Var 3	Var 4	Var 1	Var 2	Var 3	Var 4	Var 1	Var 2	Var 3	Var 4
Jul 0–Nov 01	90.25	CL	4.3	2.5	2.5	4.3	4.6	3.8	3.3	4.6	4.1	3.4	3.4	4.5

Legend: Variety 1 = M–44, Variety 2 = Bingawan, Variety 3 = 99–C, Variety 4 = Bordagol–1; CL = clay loam.

Adaptation of the System of Rice Intensification in SRI LANKA

Gamini P. Batuwitage, Ministry of Agriculture[1]

The ideas for SRI were introduced by Professor Norman Uphoff, Director of CIIFAD, at a farmer meeting in September 1998 in Gal Oya, a large irrigation settlement in a remote district in Sri Lanka. After this, communication continued and information was shared with the political and administrative leadership of the Ministry of Agriculture and Lands. This led to a visit in January 2000 by Joeli Barison, a Malagasy student at Cornell who had a good understanding of SRI, to provide more information directly to researchers, officials and farmers.

At that time I was Senior Assistant Secretary in the Agriculture Ministry. A Deputy Director in my office, U. G. Abeygunawardane, joined me in organizing the dissemination of SRI information. We had the support of the Deputy Minister of Agriculture and Lands (later the Minister of Lands, Land Development and Export Agriculture), the Hon. Salinda Dissanayake, who himself tried SRI methods on his own farm and got involved in promoting SRI countrywide because he saw its good results.

The Ecological Farming Center at Mellawalana operated by a farmer H. M. Premaratna, the Mihidiya Foundation for Research and Development, and several NGOs and farmer groups supported by a small team of officers in the Ministry of Agriculture continue to disseminate information on SRI. The first systematic testing to evaluate SRI was undertaken already in 1999 at the Ambepussa Agricultural Training Centre in the Western Province. SRI evaluation has now been undertaken by the Rice Research and Development Institute of the Department of Agriculture at Batalagoda.

Farmers knowledgeable about rice farming are investing their own resources and assuming any risks themselves to assess the productivity of their land, labor, capital and water inputs using SRI methods. They have sent records of crop yield and cost of production data to my office in the Division for Export Agriculture in the Ministry of Agriculture so that information on SRI can be accumulated and shared.

More than 3,000 farmers in 18 districts are now estimated to be practicing SRI in small plots, about 0.2 ha on average. SRI practice is most prominent in Kurunegala District where the Deputy Director of the Agricultural Development Authority collects information on SRI practice and continues observations. In other districts, officers of different agencies give leadership in disseminating information among farmers according to their own interest since there is no formal directive from the Ministry's extension service to undertake SRI promotion, extension or supervision.

Sri Lanka lies in two agroecological zones (AEZs): AEZ 2 is characterized as warm subhumid tropics, and AEZ 3 as warm humid tropics. It has a tropical monsoon climate, with two monsoons during the course of a year: a southwest monsoon from mid-May to September, and a northeast monsoon from December to February. There are two distinct rice-growing seasons, locally called *maha* (October to February) influenced by the monsoon starting in December, and *yala* (March to September) influenced by the monsoon that begins in May. The latter only covers the southwestern quadrant of the island, leaving the rest of the country mostly dry during this part of the year.

SRI is practiced in all three locally defined AEZs, the dry zone, the wet zone, and an intermediate zone. Average annual rainfall in the dry zone varies from 500 mm to 900 mm, from 900 mm to 2160 mm in the intermediate zone, and from 1260 to >3175 in the wet zone. Average temperatures range from 26 to 28° C in the plains and from 14 to 24° C in the hilly areas.

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[1] *Additional Secretary (Export Agriculture), Ministry of Agriculture and Livestock. This report is a personal one since the Ministry has not yet officially approved of SRI practices. E-mail address: batuwita@sltnet.lk.*

The majority of irrigated and drought-prone rainfed lowlands are in the dry and intermediate zones. Ricelands in these zones are located mainly on floodplains and valley bottoms where soils are clayey and the water table is high. Rice is grown mainly in the low humic gley soils and in some parts of the wet zone in half boggy soils. In the wet zone, ricelands are situated mainly on terraced slopes and narrow inland valleys of the highly dissected middle peneplain.

Of the 860,000 ha of riceland, 321,000 ha (42%) are irrigated. The remainder are rain-fed lowlands, with about 25,000 ha of tidal rice along the southwestern coast. Approximately 17% of the rain-fed lowlands are of a favorable type, 74% are drought-prone, and 6% are submergence-prone or submergence-and drought-prone (www.riceweb.org).

Farmers have tried both improved varieties and traditional varieties under SRI. The highest yield recorded so far during the last three years came from the improved variety of BG-403, a four-month variety (15.8 mt/ha) and from *Rathhel*, a traditional variety (9.6 mt/ha).

SRI is not yet been formally accepted by the Department of Agriculture, which is now testing it in one of its agricultural research stations. The Ministry of Agriculture and Livestock takes the view that farmers can try SRI if they want and should decide upon continuation according to the results they achieve. The Ministry is awaiting evaluations from its research station. Meanwhile there is considerable farmer enthusiasm and experimentation. Other government agencies such as the Irrigation Department, Ministry of Lands, the Mahaweli Authority, Agricultural Development Authority, and Ceylon Electricity Board are cooperating in SRI trials throughout the country.

Results

Wet zone (75% expectancy value of annual rainfall >1270 – >3175 mm)

The Agricultural Training Center at Ambepussa, as noted above, did the first trials to compare SRI and the conventional system using a three-month variety of local improved seed in the *yala* season 1999 and a four-month variety in *maha* season 1999/2000. The yala yield achieved was 4.2 t/ha under the conventional system using all prescribed inputs, and with SRI, a low-input methodology, it was 5.9 t/ha. The *maha* SRI yield was 6.2 t/ha, twice the average rice yield for the province under the conventional system, 3.0 t/ha.

In the wet zone district of Colombo where paddy farming has been declining due to low returns and high labor requirement, 135 farmers practiced SRI during maha 2000/2001 and only two farmers got yields lower than what they used to get under the conventional system (communication at a review meeting with data from the Deputy Director, Agricultural Development Authority, Colombo District). Data from a sample of 16 farmers showed the following results:

	Average Yield	Minimum	Maximum
Before adopting SRI	2.7	0.6	6.6
With adoption of SRI	4.7	0.6	13.1

Intermediate zone (75% expectancy value of annual rainfall >900– >2160 mm)

The first SRI yield recorded at the Mellawalana Ecological Farm operated by farmer H. M. Premaratna in yala 1999, using BG-403, a four-month improved variety from Batalagoda Research Station, was 15.8 t/ha. This encouraged him to begin training other farmers in this methodology because of its environmental as well as economic advantages.

Yields reported by 112 farmers in seven Agrarian Service Center Areas of Badulla district in the intermediate zone were as follows:

Average Yield	Minimum	Maximum
7.7 mt/ha	5.7 mt/ha	15.2 mt/ha

Dry zone (75% expectancy value of annual rainfall >500 – >775 mm)

The Agriculture Division of the Department of Census and Statistics confirmed the following results from a crop-cut survey on 10 SRI farm plots in Kurunegala District in the northwestern dry zone.

Table 1. Average yield with SRI system, Kurunegala District, Yala 2001 (N=10)

SCHEME	Average Yield	Std. Error	95% Confidence limit Lower	95% Confidence limit Upper	Sown Area (ha)
Major Irrigation	9.2	1.2	6.9	11.5	2.4

Agriculture Division, Department of Census and Statistics

Island-wide results

Reports from 17 farmers in five districts falling in all three agroecological zones (dry, intermediate and wet) during *yala* 2001 produced the results in Table 2.

For purposes of comparison, consider that the country's current average yield (2002) is 3.8 t/ha. Under major irrigation schemes in the Mahaweli System, average yields of 4.5 to 5 t/ha have been achieved.

Table 2. Anuradhapura, Polonnaruwa, Puttalam, Kegalle and Matara Districts (t/ha)

	Average Yield	Low	High
Before SRI	3.1	0.9	4.1
With SRI	7.6	4.1	11.4

Costs of Production

In Sri Lanka, the average cost of production of a kilogram of paddy in 2000 has been calculated as Rs. 10.58 with conventional practices, which include considerable application of inorganic fertilizers and agrochemicals. SRI farmers have reported that their cost of production is usually less than Rs. 5 per kilo. Some of the savings come from using less seed paddy (10 kg/ha, instead of 100 to 250 kg/ha with conventional practices), from not having to plaster their bunds to retain water (a saving of Rs. 4,200/ha), and from not applying biocides, either weedicides or insecticides, a very costly operation. Their extra cost of hired labor for SRI was compensated by these other cost savings.

In 2000-2001, a group of farmers at Namalthalawa in the rice growing area of the Eastern Province did measurements and calculations comparing their observed SRI performance with that of alternative cultivation methods. With their usual practices, the yield was 2.9 t/ha; with the government recommended package of practices, utilizing new varieties and fertilizers, 4.7 t/ha, and with SRI, 8.5 t/ha. The average depth of rooting they measured as 2, 3 and 9 inches for rice grown under the three systems, respectively. Their costs of production per kilogram of rice were calculated to be 6 Rs. for usual practice, Rs. 5.65 with the government package, and Rs. 3.00 with SRI. A farmer in Kurunegala District compared his costs of production and found that with SRI they were Rs. 4.35/kg, while they were 9.35 Rs/kg with the conventional system.

Since the **quality** of paddy under SRI grown without biocides is considered higher, using much less chemical fertilizer and with a higher filled-grain ratio, farmers have reported that they can sell their paddy as seed which fetches a higher price. Recently, we have reports that millers are offering a higher price per bushel for SRI paddy and some are even offering to buy a SRI crop while still standing in the field. A recent development is that farmers adopting SRI are using traditional seed varieties of rice which have better taste and aroma and also red rice with bran for export to Europe as "eco-rice." These farmers report receiving Rs. 40 to 60 per kg of rice, compared to the current market price (wholesale) for rice of Rs. 25-30/kg.

Water Use

Water use with SRI is quite evidently less, and most farmers report it to be less than 50% of the conventional system. A group of farmers in Moneragala District reported that the SRI plot experimented used only 13 irrigation turns of water while the farmers using conventional practices needed 26 turns of water.

Labor

Farmers use more labor days in certain operations with SRI, mainly in transplanting and weeding at the beginning of their adoption. However, they use less labor with SRI once they get experienced with these operations. Transplanting fewer seedlings, even carefully, can take less time than standard transplanting practice once farmers have gained skill and confidence in SRI techniques. One farmer who tried both systems recorded his experience during yala 2001 as follows:

	Conventional System		SRI	
	Labor (days)	Cost (Rs.)	Labor (days)	Cost (Rs.)
Raising bunds and plastering	5	1000	-	-
Transplanting	15	2250	15	2250
Weeding	15	2250	16	3200
Total	35	5500	31	5450

If one counts the saving of labor from not having to spray agrochemicals (as many as four sprayings a season when following recommended practice), the difference becomes greater. His returns to labor become much greater with SRI. With the conventional system, his production was 2,205 kg of paddy, valued at Rs. 28,665, whereas his production with SRI was 3750 kg, valued at Rs. 49,140. The increased labor cost for the main SRI operations was 14%, but the total return from SRI was 71% higher than with conventional practice.

Farmers' own data has shown that by adopting SRI in Sri Lanka, there are potential increases in roots, tillers, nutrient uptake, plant growth, plant resistance (less attractiveness to pests), grain filling, and higher yield under a broad range of agro-ecological conditions compared to what they can produce with the conventional system. How SRI could be practiced on a larger scale is to be demonstrated by farmers who have gained experience with the methods.

Information extracted from data collected from 135 farmers adopting SRI on small plots in 18 districts during *yala* 2000 revealed that they are planning to extend the area under cultivation in 2001 in all but one district. The land that these farmers had under SRI in *yala* season was 51.4 ha; they planned to put 80.1 ha under SRI in *maha* 2001/2002. This indicates that SRI has become attractive and practical to those farmers who practiced it on small parcels of land on a voluntary experimental basis.

SRI evaluations in Sri Lanka have come mostly from farmers since the research stations would not undertake systematic evaluations of SRI in the absence of a formal directive. Dissemination of SRI has accordingly been through farmer-to-farmer communication and promotional work by a small team of officials working with farmers for development communication. This team has been well supported by numerous officers at various levels in the districts and sub-districts who have seen the benefits achieved by farmers who practiced SRI.

Learning

Since there was no formal extension service supporting SRI in the districts, the biggest difficulty that SRI farmers report is **obtaining weeders** at the time they need to weed. Although more than 1,000 weeders have been produced and distributed, some farmers who adopted SRI using information from a newspaper article or pamphlet experienced difficulties in using it correctly. However, farmers now report getting over such difficulties by practice. Two farmer companies and local craftsmen are producing and distributing weeders at present.

A new weeder design developed by H. M. Premaratna is producing an implement that can weed much more quickly. A hectare can be weeded in as little as 2.5-4 days, instead of 20 days or more, because it does not get clogged with mud and can be simply pushed down the rows, not requiring a pushing and pulling movement. This could be a technology advance that will make SRI much more adoptable by farmers of all sizes.

A second problem of farmers who cultivate in major irrigation schemes is **inadequate time for land preparation** and to raise seedlings due to the short notice they are given on water issues from the irrigation system. Getting adjusted to the agreed irrigation interval, however, has not been a problem for them.

Some farmers who cultivate under rain-fed conditions experience **difficulties in following the required water management practices**. They tend to be reluctant not to take as much water as possible when it is available, feeling uncertain about future water availability. Over the past four seasons, however, farmers have found their own solutions to these problems.

Farmers' own solutions show that SRI can be adapted by them to the conditions under which they operate. These changes include **direct seeding** where time and labor was thought to be a problem; **changing plant spacing** depending on their ability to drain their fields as required; the **type of seed** used; using **various combinations of chemical fertilizer and compost**; and the using various **preparations of plant extracts to repel pests**. The latter cost less and are better for the environment and human health by avoiding synthetic chemical applications. In general, farmers who practiced SRI have tried to follow the principles to the extent possible.

The most important gain from SRI as farmers have understood and used it has been its **resilience to the vagaries of weather** that farmers have to face every season. Under drought conditions as well as under flooded conditions, farmers have found that SRI gives them at least some production even when rice fields cultivated conventionally fail due to the deeper root structure that SRI practices promote, absorbing moisture and nutrients from a much larger rhizosphere. A comparison of SRI and non-SRI fields side by side during a period of drought dramatically favors the former. Recently, two farmers have demonstrated the possibility of saving SRI crops under drought conditions by using sprinklers with a small volume of water.

By weeding and aerating the soil, SRI allows farmers to give a boost to plant growth and tillering. Farmers also see the advantage of maintaining biodiversity in their fields, increasing predator populations so that the use of biocides can be avoided and the use of chemical fertilizer can be reduced. A healthy plant gives a healthier, cleaner product, something that farmers now believe that they can achieve with SRI.

If there is formal recognition and approval by the Department of Agriculture, dissemination of SRI can be accelerated several-fold in the country. At present, dissemination is carried out with few resources, depending mostly on farmers' own resources. This has made it difficult to undertake systematic evaluation on certain aspects of SRI relevant to scaling up production with these methods.

Prospects

Rice is the staple food of Sri Lankans, and the country has been importing a declining quantity every year to meet food security needs. Rice production provides livelihood to thousands of farm families who make up the 40% of the population engaged in agriculture. The annual per capita consumption of rice is about 100 kg, which represents 75% of total grain consumption. Some 40% of total calories are derived from rice. Rice farmers derive about 50% of their total income from rice cultivation.

Yield stagnation and the high cost of external inputs have made rice production an unattractive venture to be engaged in full-time. There is need for practices that reduce costly inputs and increase the productivity of land and water so that paddy can be grown profitably. SRI addresses these needs by demonstrating to farmers that they can increase the productivity of their water, land, labor and capital simultaneously without sacrificing any one factor to gain from another. Also, farmers have realized that by using SRI, they can increase the yields of traditional varieties of high quality for which there is an increasing export market. SRI farmers in Sri Lanka have already started exploiting this market. This will help to maintain the biodiversity of rice species within the country.

Information on SRI practices of Madagascar farmers, and later by Sri Lankan farmers in different agro-ecological regions, has been presented as part of development comunication efforts through pamphlets, through the Ministry's newspaper publication distributed in 18 districts, and through live telecast in national TV twice and live broadcast over national radio twice. Call-in radio shows have been most interesting medium for communication as SRI users have spoken out very strongly in its favor.

The most effective means of communication have been presentations of the principles and practices of SRI using multi-media presentations at farmer meetings and farmer-to-farmer interactions promoted mainly through the Ecological Farm of H. M. Premaratna who has provided training on SRI to more than 3,000 farmers.

Support of the political leadership was gained from a realization of the benefits farmers could get from SRI. It was presented to the scientific community through several national-level seminars and national newspapers. Premaratna's Ecological Farm was provided with display equipment for information dissemination and my efforts with Mihidiya Foundation for conducting a national seminar on SRI were supported by CIIFAD.

In January 2002, the Sri Lanka Association of Advancement of Science (SLAAS) conducted a national seminar on SRI sponsored by its Agriculture Division. A large number of public officials are working closely with farmers on a voluntary basis to support information dissemination and to provide assistance within their capacities. Several NGOs and farmer groups continue to share information and experience among farmers. The Mellawalana Farm takes the lead in this.

The present Minister of Agriculture and Livestock has recognized that the continued adoption of SRI by small farmers will increase productivity on small plots and supports farmer efforts with emphasis on producing organically grown traditional rice ("wild rice" or "eco-rice") for export. The Ministers of Lands and Irrigation and of Mahaweli Development have also been supportive.

Since there is no formal approval for SRI yet from the Department of Agriculture (DOA) and since the Department is the agency responsible for any effects of such recommendations, there is no officially supported extension effort yet. The DOA is awaiting a recommendation from its Rice Research Institute. This institute takes the position that SRI would not be practical for farmers due to its water management requirements for intermittent wetting and drying during the growth period which could cause difficulties to farmers given uncertainty in the rainfall pattern. It also holds that SRI is not practical due to the high labor requirements for transplanting, weeding, and crop care.

These are empirical questions, however. They will be answered ultimately with experience gained by farmers on their own fields. New methods for gaining control over water are being devised by farmers, and some are now finding that once they master its techniques, SRI can be a labor-saving methodology. The biggest impediment at present is a lack of support to undertake participatory action research that systematically evaluates SRI in farmers' fields and that documents results so that more projections and adaptations can be made for SRI in Sri Lanka.

Experience with the System of Rice Intensification in Northern THAILAND

Phrek Gypmantasiri, Multiple Cropping Center, Chiang Mai University

The paddy rice ecosystems in the upper north of Thailand can be broadly classified into lowland paddy and highland paddy ecosystems, with elevations ranging from 200 m to 1,000 m above mean sea level. The highland paddy ecosystem is rainfed and produces subsistence rice. Increasing rice yield is an important strategy to overcome rice deficits and to reduce slash-and-burn practice. Lowland rice farmers, both irrigated (25% area) and rainfed (75% area) produce quality rice for home consumption and for cash.

Over 80% of rice land is planted to photoperiod-sensitive varieties in the rainy season, and among these 80% are glutinous rice. Dry-season rice, less than 5% of total rice planted area, is cultivated to supplement rice requirements and to lesser extent as a cash crop. The yield of photoperiod-sensitive rice varieties under the present cultivation practice ranges from 3.5 to 5.0 t/ha in the irrigated area. The yield of rainfed lowland rice is highly variable and much lower. Only 30% of farm households achieve rice yields greater than 3.75 t/ha. Therefore, bridging the yield gap and stabilizing rice productivity with low external inputs is essential to improve the situation of rainfed lowland rice farmers.

Information on the principles and practices of SRI was first introduced in Chiang Mai in late 2000 by Klaus Prinz of the McKean Rehabilitation Center (MRC). He had participated in a workshop organized by the International Institute for Rural Reconstruction (IIRR) in the Philippines where SRI was discussed. This information was passed to the Multiple Cropping Center (MCC) of Chiang Mai University in late 2000, where an on-station study was initiated. Further contacts with CIIFAD at Cornell and Association Tefy Saina in Madagascar were established by the MRC and MCC to get more details on SRI.

It is envisaged that the practice of SRI could add value to the on-going work of the MCC on green manure crops in rice farming. Evaluation of SRI was first attempted by MCC in an on-station study in order to gain experience with the methods and to use the experimental plot as a demonstration for farmers who participated in MCC's green manure research program.

Evaluation and Results

On-station studies were conducted in 2001 by MCC first in the dry season (February-June) and then in the rainy season (August- November). A current dry season experiment for 2002 is still in progress.

The soils in the Chiang Mai Valley are derived from alluvial deposits and may be classified as old, semi-recent and recent alluvials. Old alluvial soils are found on the edges of the valley, while the recent alluvials are scattered along the main rivers. The MCC station is located on old alluvials having sandy loam to sandy clay loam soils (sand:silt:clay = 61.5 : 13.8 : 24.7) with pH 5.0-5.3, organic matter 1.09-1.16%, P= 35-200 ppm, and K = 40 ppm.

The valley receives an average annual rainfall of 1200 mm, of which 95% falls from May to September. The rainfall pattern is bimodal, with a dry spell period of 3-4 weeks from late June to mid-July. Average temperature is about 26° C but there are well defined hot and cool periods. Rice cultivation in the hot-dry period beginning February faces cool night temperatures that retard seedling growth. In the SRI experiment, 17-day-old rice seedlings reached the 3-leaf growth stage with a seedling height about 15 cm.

Dry season (February-June) 2001

Two glutinous rice varieties (San Patong-1, Hom Sakon Nakorn) and three non-glutinous ones (Hom Nin, Hom Suphan and Malidang) with photoperiod-insensitive growth traits were planted under conventional and SRI water management regimes. Young seedlings aged 17 days old were used to compare with the common use of seedlings about 34 days old. Plant spacing of 25x25 cm was used with a single plant per hill.

The average yield of conventional management practice (34-day-old seedlings and flood irrigation throughout) provided 4.81 t/ha, while the SRI plots produced 4.35 t/ha. The overall effect of young seedlings showed a promising result, with average yield of 4.76 t/ha as against 4.39 t/ha with older seedlings. The varieties showed differential response to SRI and the conventional management practice. The non-glutinous rice, Hom Suphan, provided an SRI yield of 5.64 t/ha, an increment of 24 percent yield over use of conventional methods, 4.54 t/ha (Table 1). It was also recorded that the SRI used only 30 percent as much water as was consumed by the conventional method from transplanting to flowering. From flowering to maturity, the water management of both systems was the same.

A farmer-field day was staged on May 10, 2001. The field demonstration was supplemented with information and pictures provided by Professor Norman Uphoff, showing SRI practice from Madagascar. The farmers were intrigued by the vigorous growth of a single young seedling per hill as compared to the conventional practice. One farmer who produced community rice seed later adopted the younger seedling (25 days) and single plant practice in the production of foundation seed in the following rainy season 2001.

Rainy season (July-November) 2001

Both on-station and on-farm studies of SRI were conducted in the rainy season of 2001. The on-station SRI experiment was carried out in conjunction with green manure crop in rice. Two species of green manure crops were used. *Sesbania rostrata* was shown to be more promising in a rice farming system, while *Crotalaria juncea* was more effective for dryland cropping. One glutinous variety (Hom Sakon Nakorn) and two non-glutinous rice varieties were used in the experiment. Rice seedlings 10 days old and a single plant per hill were used for all the treatments. The overall yield of the rainy season crop was lower than that of the dry season. Average yields of the conventional and the SRI methods were 3.04 and 2.19 t/ha, respectively. The green manure crop, *Sesbania rostrata*, provided better rice yield than *Crotalaria juncea*. It seemed that the effects of green manure on rice yield was more pronounced under continued flooding than with a wet-dry watering system (Table 2).

Another varietal trial was designed to compare the effect of SRI and conventional methods. Three glutinous and three non-glutinous were planted with single seedlings 10 days old at 25x25 cm spacing.

The overall yield with conventional methods outperformed SRI, averaging 4.16 and 2.59 t/ha, respectively (Table 3). It was observed that the young seedlings grew faster under continuous flooding than with the wet-dry irrigation method. Weed infestation was more severe in the SRI plot. The wet-dry sequence prior to flowering as recommended in the SRI practice could hardly be maintained in the rainy season planting. So the soil condition was not kept properly "dry" as required. This could cause deviation from the expected SRI result.

On-farm experiments 2001

On-farm observation plots were carried out in two lowland districts (San Sai and Mae Taeng) in Chiang Mai province with 8 farmer-cooperators who had previously participated in the MCC field-day on May 10, 2001. These farmers had adopted *Sesbania rostrata* as a green manure crop in their rice production system, and sought ecologically appropriate practices to reduce their production costs. They were engaged in community seed production, and so they found a single plant per hill suitable for the production of foundation seed. An additional test site under highland conditions was carried out with one Karen farmer.

The lowland observation plots showed that with the photoperiod-sensitive, glutinous rice variety, RD6, and non-glutinous variety, KDML 105, using 10-day-old seedlings would delay flowering and maturity. Tillering of young seedlings was similar to the older seedlings as practiced by farmers. The overall means of the conventional and SRI were 5.36 and 3.23 t/ha. (Table 4).

The Karen farmer on the highland compared single and three plants per hill with 25x25 cm spacing. Young seedlings were used, and the SRI water management system was adopted. The average rice yield of single plant per hill practice was 2.16 t/ha while the three plants per hill yielded 1.45 t/ha. Strong competition between rice plants within the hill resulted in lower yield of local highland rice.

The McKean Rehabilitation Center (MRC) initiative

During the rainy season 2001, MRC initiated an observation plot at the Center and extended on-farm cooperative trials with assistance from the MRC extension personnel. One observation plot in one village showed vigorous seedling growth with over 30 tillers per plant. Yield data have not been reported but the MRC extension team shared available reports on experiences and recommendations from Madagascar and Sri Lanka with other members of the Northern Thai Sustainable Agriculture Network and the Khao Kwan Foundation in Central Thailand. The team drafted a Thai-language manual in order to facilitate local extension of SRI. The manual is based on translations of English papers from CIIFAD and from Sri Lanka. As it became obvious that local farmers were very much concerned about matters such as organic nutrient supply, alternative insect, snail and crab control methods, and weeding tools, other relevant information had to be looked for, translated and integrated in the manual.

In initial talks with staff and farmers, the general concepts were understood sufficiently; however, it became obvious that farmers are particularly concerned with water management and eradication of weeds. MRC received illustrations on hand weeders from Tefy Saina and ECHO and also located two models of IRRI-designed manual weeding tools at the Agricultural Engineering Division, which were loaned to the MRC. However, neither a local workshop nor a tool manufacturer was able to make additional sets in time.

Learning

The SRI practice requires a good understanding of the rice plant, its growing environment and its management. The production process must also be changed considerably in order to achieve the potential rice yields proposed under SRI.

Land preparation

The visual material from Madagascar revealed that land preparation is critical for the success of SRI. The land was puddled and leveled and drained before rice transplanting. This system is not commonly practiced by northern Thai farmers, who puddle the soil and flood the field. Transplanting is carried out under flooded conditions. However, the land preparation for SRI will be similar to rice production systems in the Lower North and the Central Thai regions where rice is broadcast. Such mud conditions will permit better seed-soil contact for broadcasted rice and better seedling stand in the use of SRI.

Drainage

The wet-dry water management practice requires a good drainage system. In the Chiang Mai Valley, the management of irrigation systems at field level is community- or group-based. Allocation and distribution of water at the lateral canal level are group decisions, so this would affect the working schedule if an individual farmer plans to use water differently from the other farmers. However farmers who have access to farm ponds will be able to be more independent, and to use SRI water management methods.

The rainy season with highest precipitation in August and September makes the control of any system of alternating wet-dry irrigation. All the photoperiod-sensitive varieties are at the vegetative stage during this period and when their tillering is at maximum. The commonly grown varieties, RD 6, RD 15 and KDML 105, will flower between October 21 and 26 when rainfall is receding. Therefore, SRI will require very good drainage and water control system. Highland paddy rice on terraces as practiced by the Karen would have better drainage and water control for SRI than the lowland valleys.

Young seedling and single plant per hill

After the field day in May 2001, a few farmers have accepted the principle of single plant per hill, but they are skeptical about using young, 10 to 15-day-old seedlings. The common practice of rice transplanting during the rainy season is a shared labor or exchange system. This would make transplanting single plants per hill more difficult to control. Farmers perceive that transplanting 3-4 plants per hill is easier to handle than single plants when the work is done under flooded conditions.

However, it was observed that a farmer who produces foundation seed has accepted the single-plant practice, though he still uses 25-day-old seedlings. This practice is found to be suitable for seed production, since any off-type plant can be easily rogued out. Moreover, the farmer can practice single-plant selection to obtain pure lines.

Nursery preparation

We have learned that seedling preparation works best either when rice seed was sown in line on a tray or when it was sown in line on raised beds similar to a nursery for preparing vegetable seedlings. This method of dry nursery is found to be more commonly practiced by the Karen farmers on the highland where water is limited, while lowland rice farmers are used to broadcasting seed in a prepared space near paddy fields. A large quantity of seed is used this way.

Our survey in the 2002 season in three provinces of the Upper North (Lamphang, Phayao, and Chiang Rai) showed that the average rice seed used in nurseries to prepare for transplanting 1 ha of land was 64 kg. With a single plant per hill, the amount of seed was just 10 kg, and with machine planting, the seed requirement for 1 ha of land was 44 kg.

Weed control

Weed population in rice fields reflects land use practice and plot history. Rainfed lowland rice with a single rice crop and a six-month fallow is found to have less weed population. Rainfed lowland rice farmers incorporate fallow vegetation into the soil and allow it to decompose before transplanting. In the irrigated lowland where rice-based cropping systems are common, weed infestation after dry-season cropping is more severe.

Without proper land preparation, weeds can be a serious problem in rice fields. A few farmers have used herbicides in their rice fields. However it was found that when *Sesbania* was used as a green manure crop before rice, a dense population of *Sesbania* was able to suppress weed growth. Therefore, the use of *Sesbania rostrata* for weed control and nutrient replenishment, together with proper land preparation, could reduce weed incidence.

Water management

Our results do not show convincing evidence of SRI. The first dry season trial in 2001 provided similar performance between conventional and SRI methods. Perhaps at certain stages of growth, the SRI rice plants were allowed to go through "unnecessary" drought stress. In addition, we planted several rice varieties with different maturities on the same field receiving the same water regime. All these factors could affect the realization of yield potential.

Since our SRI results were not convincing, and varied from season to season, the assessment on water management, nutrient (particularly nitrogen), and light intensity effects on different rice varieties should be carried out under proper land preparation and nursery management. At present, certain components within SRI practice have been adapted by a few farmers, namely, planting of single, younger seedlings. There will need to be better understanding and field practice of SRI, as well as more convincing yield improvements, before SRI could be disseminated.

Sustainability

Given the high productivity of over 10 t/ha reported with SRI practices in many countries, there are large amount of nutrients, particularly nitrogen, exported out of the nutrient pools. This means that the rice production system would require integrated nutrient management in order to maintain high rice yields. Therefore, SRI practice should be developed in conjunction with a nutrient replenishment system. At present it appears that the use of green manure crops in rice farming system could enhance SRI potential.

Prospects

The principles and practices of SRI are not widely spread in Thailand, but it is encouraging to see the growing interest of NGOs on the use of SRI to increase rice yield, for instance, the McKean Rehabilitation Center, the Northern Alternative Agriculture Network, the Khao Kwan Foundation in Suphanburi Province (Central Thailand), and the Catholic Commission of Thailand.

Green manure crops in rice farming systems are now being evaluated among various institutions: the MCC, farmers' organizations, local administration and extension agents, and the Land Development Department. The diffusion process of SRI could make use of the existing network through the technical support from the MCC, MRC and farmer-facilitators.

In Northern Thailand where the average farm size is small, about 0.8 ha, increasing rice yield through SRI techniques would permit farmers to diversify their land use by switching some of their land, labor, and water to non-rice production for income-generation and increasing rural employment.

Rice seed farmers who are now working with the MCC could incorporate SRI methods in their production of foundation seed on smaller plots during the dry season so that certified seed could be produced in the following rainy season.

Perhaps the most significant use of SRI would be for productivity enhancement of paddy rice in the highlands where rice deficits among ethnic communities still persist. In 2002, the MCC and the Karen community have developed pond agriculture as a way to enhance food security. Karen farmers allocate part of land for a farm pond (15 x 8 x 2 m^3). Increasing rice productivity per unit of land is an important objective. A modified SRI practice that works under those conditions would help close the food gap in the Karen community.

A participatory approach is now being accepted by the Department of Agricultural Extension as an alternative diffusion process. Collaboration and coordination among various institutions at the local level are improving. Farmer field schools and a farmer-to-farmer learning process have been promoted. So SRI that works for different niches is important for improving rice productivity of small farmers. The successful cases from various countries not only provide information support but also inspiration for others to try.

The principles and practices of SRI pose great challenges to rice scientists and development workers. There are still a lot of missing links. The alternate wet-dry system of water management from transplanting to flowering creates physical and bio-chemical changes that can enhance the growth and development of rice plants. The period is critical for vigorous growth-maximizing tiller production and subsequent high seed yield. Understanding the processes and changes that occur during this period would help develop practices for sustainable rice production of small farmers.

Table 1. Average rice yields (kg/ha) as affected by planting young (17-day) and old (34-day) seedlings under SRI and conventional management practices, MCC, February-June 2001

	Conventional		SRI	
Varieties	17 days	34 days	17 days	34 days
1. San Patong-1	5.83	4.66	5.05	4.04
2. Hom Sakon Nakorn	4.88	4.53	4.20	4.21
3. Hom Nin	4.54	3.96	2.73	2.19
4. Hom Suphan	4.88	4.54	5.64	5.18
5. Mali Dang	5.73	6.38	4.15	4.21
Average	**5.17**	**4.81**	**4.35**	**3.97**

Table 2. Average rice yields (kg/ha) as affected by green manure crops (GMC) under SRI and conventional water management practice, MCC, August-November 2001

	Conventional [1]		SRI	
Varieties	GMC [2]	Control	GMC	Control
1. Hom Suphan	2.86	2.66	2.25	2.28
2. Hom Nin	3.74	2.73	1.94	1.70
3. Hom Sakon Nakorn	3.61	2.61	2.75	2.21
Average	**3.40**	**2.67**	**2.31**	**2.06**

[1] *Both conventional and SRI methods used young seedlings (10 days) with single plant/hill.*

[2] *The green manure crop used in Hom Suphan was* Crotalaria jancea, *and in Hom Nin and Hom Sakon Nakorn,* Sesbania rostrata

Table 3. Average yields (kg/ha) of glutinous and non-glutinous rice varieties under SRI and conventional water management practices, MCC, August-November 2001

Varieties	Conventional	SRI
Glutinous rice		
RD 6	3.87	2.52
Hom Sakon NaKorn	4.30	2.15
San Patong-1	4.46	2.27
Non-glutinous		
KDML 105	4.44	2.87
Pathum Thani-1	4.03	2.16
Hom Suphan	3.88	3.55
Average	**4.16**	**2.59**

Table 4. Average rice yield (kg/ha) from on-farm SRI trials in two districts, Chiang Mai Province, August-November 2001

Site	Variety	Conventional	SRI
Mae Taeng district			
Wichit	RD 6	5.00	3.20
Thawin	RD 6	4.25	3.60
Chumnong	KDML 105	6.00	3.55
Rien	KDML 105	5.15	2.25
Average		**5.10**	**3.15**
San Sai district			
Uthaiwan	RD 6	4.60	3.65
Subin	RD 6	5.70	2.80
Praphan	KDML 105	5.85	3.80
Uthai	KDML 105	5.70	3.00
Average		**5.36**	**3.31**
Overall mean		**5.23**	**3.23**

NGO Reports

Experiences with the System of Rice Intensification in CAMBODIA

Yang Saing Koma, Cambodian Center for the Study and Development of Agriculture (CEDAC)

CEDAC is a Cambodian NGO founded in August 1997 with initial assistance from GRET, a French NGO. Since its creation, CEDAC has been working with farmers and other organizations in Cambodia to develop and disseminate innovations in ecological agriculture. Our priority has been the improvement of rice-based farming systems in rainfed lowland areas. We have been working on rice intensification since 1998, with a focus on improving soil and nutrient management practices.

It was thus very timely when CEDAC learned about SRI from the ILEIA's newsletter in December 1999 (Rabenandrasana 1999). In early 2000, we received also more information on SRI from CIIFAD (Uphoff 1999 and 2000), and in the wet season that year, we integrated the elements of SRI, namely, its principles for water and plant management, into our sustainable rice intensification program. Here I will summarize the results and experiences of SRI adaptation in Cambodia since 2000, including some thoughts on the future of SRI in my country.

SRI Compared with Traditional/Conventional Rice Cultivation

Rice is the main staple food in Cambodia, and rice farming provides income and employment opportunity for around 65% of its population.[1] Officially, the national average yield of rice is estimated to be between 1.65 and 1.80 tons per hectare in the wet season (MAFF 1995-2000, and FAO/WFP 1999). This is relatively low compared with other countries in the region.

Improvement of rice productivity has to be one of the main objectives of any agriculture and rural development program in Cambodia. During the last three decades, especially in the 1980s and 1990s, a lot of effort went into improving traditional rice farming. This effort focused on developing and diffusing recommendations for fertilizer applications and on introducing improved, high-yielding varieties as well as integrated pest management (IPM).

Although this approach can help farmers to increase their yields, the environmental sustainability and economic advantage of this for small farmers, and for Cambodia, still remains an issue. Rice productivity remains relatively low compared to the growing demand, while farmers' costs of production are increasing, mainly due to the cost of fertilizer and fuel (for pumping water in the dry season). SRI offers opportunities to increase rice production through changes in plant, water, soil and nutrient management rather than through the use of new or purchased inputs. Thus it can will be very attractive if initial results can be sustained.

Results and Evaluation of SRI Experience

SRI under rainfed conditions

Rainfed rice cropping makes up around 80-85% of the total rice area cultivated in Cambodia. In the wet season 2000, 28 farmers experimented with the principles and techniques of SRI in four provinces of Cambodia. Their total area under SRI was 1.57 ha, and their average yield was 5 tons per ha, which is 150% more than with traditional practices. The most significant advances were made by two farmer brothers in Kampong Thom who got more than 7 t/ha (one of them used SRI on 4,000 m²), and by one farmer in Prey Veng who was able to harvest more than 10 tons per ha (11.8 to 13. 7 t/ha from his different plots). Even though the plots of the latter were small (11 and 8 m²), they showed that even a traditional variety can give a very high yield when grown with SRI practices (Koma 2000).

[1] *About 85% of Cambodia's 12 million people live in rural areas, and about two-thirds of this rural population depend mainly on rice farming.*

In 2001, about 500 farmers adapted SRI in Cambodia, mainly supported by CEDAC, GTZ in the province of Kampong Thom, and by the European Commission's Support Programme for the Agricultural Sector in Cambodia (PRASAC) in Prey Veng and Takeo. According to the data collected from 393 farmers in 6 provinces of Cambodia (see Table 1), the yield under SRI varies considerably, depending mainly on how many elements of SRI are adapted by farmers. More than 80% got yields above the national average.

Even in the same village, there is one farmer who got just 2 tons per ha with SRI methods while another farmer got 10 tons per ha. This showss that SRI is not a fixed technology, but rather a set of principles that farmer can adapt to own specific needs, preferences and circumstances. Also the yield obtained from SRI adaptation depends upon strongly farmer skills and knowledge for managing their plants, water, soil and nutrients.

Most of the farmers got 3 tons per ha or more while rice yields under traditional practice vary between 1 and 2 tons per ha. The most interesting result was that 57 farmers got more than 5 tons per ha, and among these, 3 farmers get more than 10 tons per ha. The highest yield for 2001, 14 t/ha, was obtained by a woman-farmer supported by the GTZ rural development program in Kampong Thom province.

At least 70 different rice varieties were used by farmers, most of these being traditional ones. Table 2 shows that with SRI, higher yields are possible for any variety. However, improved local varieties seem to do better than traditional and IR varieties. Improving seed selection with traditional varieties is crucial for increasing their productivity. Since with SRI, farmers require only small amounts of seed, they can more easily undertake their own seed selection and improvement based on a traditional variety.

Table 1. Number of farmers and yield harvested under SRI, wet season 2001

Yield classification	Number of farmers	Percentage (rounded)
Less than 1 t/ha	20	5
1-2 t/ha	71	18
2-3 t/ha	114	29
3-5 t/ha	131	33
5-10 t/ha	54	14
More than 10 t/ha	3	1
Total	393	100

Table 2. Yield variation according to variety with SRI practices

Category of variety	Number of farmers using variety	Average yield
Traditional varieties	247	3.00
IR varieties	112	3.30
Improved local varieties	34	4.27

SRI used under flood recession

In 2001, we worked with 6 farmers in Prek Lovea village, Kandal province, to test SRI under flood recession conditions in the dry season. Such areas make up about 15% of Cambodia's rice area. The average yield achieved under SRI was 6 t/ha, about 50 % higher than with traditional practices. In 2002, around 40 farmers evaluated SRI under these conditions. Preliminary data show that they are able to get yields from 5 to 10 t/ha (Rady et al. 2001).

Most farmers are using IR varieties in these areas.[2] However, this year at least 3 farmers evaluated the use of SRI methods with a local variety. The first result obtained from one farmer showed that with SRI, the traditional variety could produce 7 tons per ha. This will be a big advantage for farmers since when using IR varieties, they cannot keep seed for more than one season cycle.

Other advantage that flood-recession rice farmers observed was lower expenditure on fuel (for pumping water), pesticides and fertilizers. There is also an environmental benefit as the expansion of area for the cultivation of flood- recession rice has been occurring at the expense of flooded forest. If farmers can produce more rice on a smaller area, then economic pressure on these forest areas can be reduced. On the whole, there is also a benefit for local fisheries because there is less chemical pollution of the water and reduced pressure on the flooded forest areas.

Evaluation of SRI within farming systems

SRI opens the way for more intensified and diversified rice-based farming systems in the rainfed lowlands. All Cambodian farmers who have adapted SRI have con-

[2] *IR varieties are the ones most commonly used in flood-recession rice cultivation. In many communities, the traditional varieties have been lost (Rady et al. 2001).*

sidered it as a good solution for their situation because with SRI they can get a higher yield with less expenditure on purchased inputs and lower seed requirement. The enthusiasm for SRI is very strong in all villages where it has been introduced, and it is expected that around 2,000 farmers will adapt SRI in the wet season 2002. (Note that we avoid the conventional term "adopt" because we expect farmers to be making adaptations in the basic SRI system to fit their own conditions.)

Many SRI farmers consider this methodology as an important means for diversifying their rice-based farming systems because once they can get higher rice production from their small plot, they are ready to convert some of their rice fields into growing upland crops and digging a pond and canal for practicing fish culture. In partnership with farmers, CEDAC is developing SRI into a "System of Intensification and Diversification" of production in the rice field, or SID. Already around 180 farmers have started to develop this system.

Also, as farmers realize that there is a high return from investing in rice farming, they are more ready to invest in increasing the supply of biomass to be applied to the soil through increasing efforts to collect organic matter, grow green manure crops in the rice field, and grow trees for producing green leaves to add as mulch or compost.

Also, with SRI when using a local variety, there is abundant rice stubble after the harvest. This stubble, if used for mulching the rice field, opens the way of minimal tillage or zero tillage. For this wet season, around 10 farmers will be testing this practice as part of SRI.

Conclusions and Future Perspectives

The results of SRI evaluations in Cambodia since 2000 have shown consistently that with SRI, small farmers are able to increase their rice production with less inputs of seed, fertilizer and water. Significant yield increases are possible under a range of natural condition in the lowlands of Cambodia, both rainfed lowlands and flood-recession agroecosystems. Yield increase has been achieved with many different varieties, with traditional varieties doing very well with SRI. Their usual yield is rather low, but their market price is high as consumers much prefer them, so being able to double their yields, or more, is much appreciated.

SRI shows that there is a large biological potential in the rice plant that remains to be tapped. This potential can be effectively used if farmers are enabled to acquire better knowledge and skills for practices of plant, water, soil, nutrient and pest management that capture synergies between root and tiller growth which in turn lead to greater grain filling.

Farmers see SRI as not just a way to maximize rice yield, but as opening the way for them to diversify their rice-based farming systems in the rainfed lowlands. This is good for improving nutrition, incomes, and landscape diversity.

CEDAC has become convinced that SRI is a good solution for millions of Cambodian farmers. Thus, we are stepping up our efforts to develop and diffuse SRI and SID in Cambodia. Collaboration with other organizations is needed to ensure that a maximal number of farmers have an opportunity to learn about SRI. We envision, and are making efforts to ensure, that by the year 2010, all rice farmers in the lowlands of Cambodia will have had an opportunity to learn about SRI.

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Farmer Experimentation with the System of Rice Intensification in LAOS

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Agriculture is the principal economic sector in the Lao People's Democratic Republic, accounting for about 52% of total GDP and employing 80% of the labor force. Rice is the single most important crop in the country. In 1999, the rice-growing area was approximately 717,000 ha, representing more than 80% of the cropped land area. The focus of agricultural activities in the Oxfam CAA-Laos program is the promotion of low-input, low-cost production systems not depending on any synthesized chemicals. In 2001, when OCAA learned about SRI principles and techniques through information provided by Prof. Norman Uphoff (CIIFAD) and Koma Yang Saing (CEDAC), it thought that this system might appropriate for Laos to help in finding long-term alternatives for poor farmers.

In the wet season 2001, OCAA launched the first trials of SRI in two project areas, Feuang district in Vientiane province in northern Laos, and Ta Oy district in Saravan province in southern Laos. Three farmers engaged in a first round of experimentation. This trial was based on self-study of available information and the voluntary efforts of farmers.

Following the first on-farm trials with SRI, a fourth farmer experimented with SRI methods for irrigated rice production in the 2001-2002 dry season in Toumlane district, Saravan province. This trial was initiated by one technical staff member from the Toumlane district Agricultural Extension Section and the experimenting farmer, with OCAA technical and financial assistance.

2001 Wet Season On-Farm Trials

1. **Demonstration plots:** The planted area was 100 square meters in the southern experimental area (Padou village, Ta Oy district, Saravan province), and 360 square meters at the northern site (Nawan village, Feuang district, Vientiane province).
2. **Rice varieties:** Both improved and local rice varieties were used in the experiment. The improved varieties used were both glutinous Thai-IRRI crosses, RD8 and TDK1.[1] The local varieties planted with SRI methods were Feuang Lauang (a local glutinous variety) and Khao Chao Khao (a local non-sticky variety). Rice seedlings were produced in a moist, but not saturated seedbed. Young seedlings were watered once a day only on days when no rain had fallen and there was not enough moisture in the seedbed.
3. **Transplanting:** Seedlings with an age of between 12 and 18 days were transplanted at spacings of 25 cm x 25 cm, 30cm x 30 cm, and 50 cm x 50 cm, with only one young seedling per clump. One exception was that one farmer in the northern area planted two seedlings per hill, because he anticipated incidence of foot rot disease. Approximately 30 percent of his transplanted rice plants suffered from this disease.
4. **Soil fertility management:** Prior to transplanting, 20 kg of chicken manure was applied to the 360 m^2 demonstration plot (in the SRI experiment in northern Laos).
5. **Water control:** A two-day wet and three-day dry water regime was applied in the transplanted areas.
6. **Weeding:** There were no obvious problems with weeds due to well-prepared land and good water control. So the first weeding was done nearly two months after transplanting.

Results and discussion

- Remarkable tillering from single transplanted young seedlings was seen in all three demonstration plots.
- At the **northern location**, the average number of tillers per clump was 11 after one month, 20 after

[1] *These are the rice varieties recommended for the wet-season lowland environment of Laos, according to the National Rice Research Program and the Lao/IRRI Project.*

two months, and 25 three months after transplanting, using TDK1. In the southern location, the local rice variety had on average 23 and 31 tillers per plant transplanted at spacing of 30 cm x 30 cm and 50 cm x 50 cm, respectively (Table 1).

Table 1: Effects of seedling age and hill spacing on tillering

Variables	Average number of tillers per hill
Age of seedlings	
9 days old	43
12 days old	28
18 days old	23
Spacing	
25cm x 25cm	23
30cm x 30cm	25
40cm x 40cm *	43
50cm x 50cm	31

** There is a combination effect here between age of seedlings and hill spacing that influenced tillering as only seedlings 9 days old were transplanted at 40cm x 40cm spacing.*

- There was, however, no increase in yield in the northern trial. The yield calculated at 2.9 t/ha did not surpass the national average rice yield (2.93 t/ha in 1999; 3.2 t/ha in 2000). This lower than expected yield from the trial plot was attributed to the outbreak of foot rot disease at the maximum tillering stage. However, the experimenting farmer was satisfied with the outputs of his trial when he considered the ratio of seed used for transplanting compared to the paddy rice he harvested. This ratio was 1 kg of seed to 207 kg harvest from the SRI trial, whereas with usual rice farming practices, this ratio has been usually 1 kg to 43 kg, nearly a five-fold improvement with SRI methods.
- On the **southern plots**, one of the two experimenting farmers achieved 4.55 t/ha with SRI, using a local rice variety. The other one yielded 3.35 t/ha, using an improved rice variety. The latter farmer had expected to achieve 6 t/ha, but he could not do this because of an early halt in the rainfall that season and the related problem of having used a long-duration rice variety (RD8). Therefore, only 50% of the developed ears could bear full grain.
- Overall, the average yield with SRI in the southern trials was 23% higher than the national average rice yield in 2000. Furthermore, the outputs of these trials in the south were relatively high in comparison with the high-cost, high-input rice production strategy promoted by the Lao National Rice Research Station. According to the Lao-IRRI Project, the previous top yield of intensive rice production was 6 t/ha at the on-farm level and 7.5 t/ha in the research station.[2]
- No calculations were made of the productivity of labor in economic terms, an important consideration. Since this was the first time that OCAA was experimenting with SRI methods at the farm level, we were trying to see how SRI principles might work technically. Thus the knowledge we have gained about SRI so far is only technical.
- The Deputy Head of the Saravan Provincial Agriculture and Forestry Department has gotten a good impression of SRI techniques after visiting the demonstration plot and observing the tillering and harvesting possible in southern Laos. He is anticipating to introduce SRI experimentation in three rice-growing areas around his province in the next wet season 2002.

2001-2002 Dry Season On-Farm Trial

1. **Demonstration plot:** The experimental area was 200 square meters.
2. **Rice varieties:** An improved rice variety, TDK 1, was used in the trial. Single young seedlings with an age of 9 days were transplanted at spacing 40cm x 40cm.
3. **Water management:** The SRI trial implemented in the dry season was dependent on irrigation water. The experimenting farmer faced problems with water just after the single young rice seedlings were transplanted, because he could not afford to purchase fuel to run his pump. It took 10-12 days to get water from the irrigation facility. Therefore, it was observed that the tillering was not much as possible due to the drought stress of newly transplanted rice plants. Afterwards, alternate wet and dry water control was applied, with a two-days-wet, five-days-dry watering system.
4. **Soil fertility management:** 20 kg of rice husk ash mixed with 20 kg of animal dung was once applied to the experimental area of 200 square meters.

[2]*According to Karl Goeppert, IRRI Representative in Laos, and Kouang Douangsila, Coordinator of Lao-IRRI Project.*

5. **Weeding:** This was done three times. The first weeding was 20 days after transplanting, the second at 45 days, and the last at 75 days, respectively. Prior to doing weeding, the field was drained to use hoes and spades for hand-weeding, which differs from use of the rotary weeder.
6. **Pest control:** At the maximum tillering stage, the experimenting farmer encountered stem borers, especially yellow and zigzag stem borers. The damage was estimated at less than 20%. SRI helped the farmer to restrict the stem borer damage to a certain extent.

Results and discussion

- Tillering was very good, with an average of 11, 26 and 43 tillers per hill at 38, 49 and 91 days after transplanting, with the maximum of 58 tillers per hill (Table 2).
- By the end of April 2002, the experimenting farmer harvested his field. After drying the rice in the sunshine for three days, the whole harvest was measured and calculated to be 3.3 t/ha. He could not achieve the expected yield of 5-6 t/ha because of rice bug damage, which was estimated at 40% after winnowing the harvest.
- Despite this loss, the trial output was 65% higher than the average dry season yield of 2 t/ha in Toumlane district of Saravan province using external inputs (100-150 kg/ha of chemical fertilizers). The yield was 120% higher than the usual wet season rice farming practice in the area (1.5 t/ha).

Table 2: Results at different stages of tillering

Days after transplanting	Tillers per hill	Average plant height
38	Hill 1: 5 (minimum) Hill 2: 13 (medium) Hill 3: 14 (maximum)	10 cm
49	Hill 1: 9 (minimum) Hill 2: 30 (medium) Hill 3: 40 (maximum)	30 cm
91	Hill 1: 28 (minimum) Hill 2: 44 (medium) Hill 3: 58 (maximum)	58.6 cm

Lessons learned and follow-up

On May 15, 2002, OCAA and the Toumlane District Agriculture and Forestry Office (DAFO) organized a meeting to evaluate SRI experience. Twelve farmers from 8 target villages working with OCAA, the experimenting farmer, two deputy heads of Toumlane DAFO, one technical staff member of the Agricultural Extension Service, one deputy director of the Provincial Agriculture and Forestry Department, one deputy head of the provincial Agriculture Section, and two OCAA agricultural extensionists attended.

Farmers expressed the following views:

- Rice production with SRI methods can be increased by higher number of tillers and panicles and by the even growth of grains from all panicles in the same hill.
- Spacing of 25x25 cm or 30x30 cm is appropriate. Most farmers felt the spacing of 40x40 cm was too wide.
- Paying attention to gentle handling of very young seedlings (9 days old) during transplanting is important.
- Farmers should put emphasis on doing two or three, even four, weedings throughout the vegetative growth stage despite the higher labor requirement.

There was agreement on spreading the SRI evaluation during the current wet season for rice to more villages with the support of both OCAA and DAFO. The farmer who undertook SRI trials during the wet season 2001 continues his experimentation in the current wet season.

Problems Encountered and Constraints to SRI Application in Laos

- **Lack and/or limitation of technical staff** at the district level to properly conduct, follow up, monitor and evaluate SRI trials at the on-farm level.
- **Non-availability of appropriate and simple manual weeding machines** in the country, if SRI method is to be applied to middle-sized areas like 1/4 or 1/2 hectare farms.
- **Lack of and/or limited access to sources of information on SRI**, which are available in the region and the world as well.
- **Lack of a large number of practical experiences** in applying SRI methods that can convince others who are working on agricultural development and research.

- **Stable water availability** is necessary, especially during panicle initiation until full grain development, even though less water is required overall with SRI practices.
- **Unsystematic design of demonstration plots**, e.g., careful selection and bounding of trial areas is important for well-planned SRI experimentation. This was the case with the experimental location in southern Laos for the dry season, which makes for difficulty in assessing the trials properly.
- **Lack of practical lessons and experience of technical staff** of the local District Agricultural Extension sections and OCAA field staff in Laos.
- **Lack of proper taking of technical field records** on SRI experiments by technical field staff, including observation of agroecological factors like type of soils, secure water availability, climate change during experimenting, etc.

Strategic initiatives for wider application of SRI in Laos

- An **internal network** needs to be established to work on SRI. This could include the national rice research station under Lao-IRRI Project, Laos Extension for Agriculture Project, NGOs, farmers' organizations, etc. This network would have the tasks and functions of organizing national workshops, training sessions, exchange trips and of coordinating and cooperating with regional networks to share information, lessons, and experiences.
- **Scientific research work** that could cover genetic rice research, soil management, development of appropriate, simple and low-cost weeding technology, etc. should be undertaken. SRI relies on exploiting existing genetic potentials of rice plants. Rice plants grown with SRI techniques develop massive roots that can better absorb soil nutrients. If SRI needs to be applied on a middle- to large-scale land areas, intensive labor is required to do weeding at least two to three times, based on SRI principles. Therefore, research as mentioned above is necessary for the application of SRI techniques in order to reach optimal outputs.
- **Information centers** that could be accessed by different institutions, agencies and interested groups or individuals should be set up.
- **Extension approaches** that are appropriate and effective need to be found out. Such approaches could include farmer field schools, farmer-to-farmer networks, etc.
- **Capacity-building** for technical staff as well as farmers would also contribute to more scientific, effective and successful SRI experimentation.

Conclusion

Although rice self-sufficiency can be covered by rice production at the national level (national rice production reached 2.3 million tons in 2000), rice shortages still remain chronic, even occasionally acute in many rural areas of Laos. This is due to various factors. SRI is a promising approach to improving rice production that has boosted rice cultivation in Madagascar and reached production of 10 t/ha paddy or more. The first season trials supported by OCAA showed relatively good results with SRI methods. Therefore, we think that SRI methods may be appropriate to help Laos find alternatives for poor farmers in the long term.

SRI Experience of Association Tefy Saina in MADAGASCAR

Justin Leonard Rabenandrasana, Association Tefy Saina[1]

Association Tefy Saina (ATS) was created in 1990 to carry on the work of Fr. Henri de Laulanié concerning the rural development in Madagascar that he promoted after coming from France to his adopted country in 1961. Many of his students and friends joined ATS, especially to learn about and to disseminate SRI to farmers and NGOs as well as to government departments and others as much as possible. These members belonged to many other organizations, so the efforts of Tefy Saina were broadly diffused, with its members each doing work in other units on SRI and gathering to discuss results at an annual workshop in Antananarivo.

In 1994, a year before Fr. de Laulanié's death in June 1995, ATS began working with CIIFAD in the Ranomafana National Park Project (RNPP). At the end of 1995, ATS cooperated with the government's Department of Agriculture in the Ministry of Agriculture and Rural Development on an evaluation of SRI with support from the French development cooperation agency. The results of this evaluation are reported below. Subsequently, a French NGO, FERT, and the French development agency approached Tefy Saina to participate in some collaborative projects with them. Results from these project activities are also reported here, including some fairly spectacular results achieved in the region of Fianarantsoa by two farmers who got training from ATS regional technicians who have worked with Catholic churches in this region.

The national average rice yield in Madagascar is less than 2 t/ha, and the average amount of seeds used for planting is between 60 and 120 kg/ha. SRI techniques include: the use of less seed (just 5 to 6 kg/ha sown in a nursery only 0.01 ha, i.e., 1 are); transplanting young plants (8 to 15 days old, when they have just 2 leaves), planted one by one and with wide spacing (25 x 25 cm or more); and using less water.

The evaluation of yields by technicians and engineers has been done by measuring the harvest from 4 sample plots each 1 m^2, one from a poor part of the plot, one from a very good part, and two from more typical parts. This is the standard method for estimating yield. Comparisons of the yield estimated by such means with that from fields where it could be calculated from total harvest have been very close. Indeed in the French-supported evaluation in 1996, the yield estimate from sampling was 0.1 t/ha lower than actual whole-field yields.

Results from Ranomafana

Starting in May 1994, ATS provided technicians and supervision to work with farmers in the peripheral zone around Ranomafana National Park as part of a USAID-funded project in collaboration with CIIFAD. Work started slowly because farmers were quite hesitant to adopt practices that are so different from those that they are accustomed to. The first year's results were already very encouraging as shown below. This average yield held up over the following four years that ATS was able to continue working with farmers around Ranomafana.

Number of farmers: 39
Area of SRI rice fields: 5.68 ha
Rice field average/farmer: 14.56 ares
Total seed requirement: 35.34 kg
Production: 46.86
Yield average: 8.25 t/ha

Those farmers who were of Betsileo ethnic origin (28) and who were more used to irrigated rice production were more able to utilize the new system. Also, they had somewhat better water control. On their SRI fields, which totaled 4.56 ha, they had a yield average of 9.18 t/ha. Subsequently the use of SRI began to spread.

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The next year, 1995-96, the results were :

At higher elevations:
- Number of rice farmers: 37
- Rice fields: 10.5 ha
- Total seed requirement: 67.38 kg
- Production: 91,727 kg
- Production average: 8.741 t/ha

At lower elevations:
- Number of rice farmers: 33
- Rice fields: 9.4 ha
- Total seed requirement: 7.75 kg
- Production: 7,657 kg
- Production average: 8.078 t/ha

From 1997 to 2000, the number of cooperating farmers continued to increase around Ranomafana, reaching 275 in 1997-98, after which time, the channels for USAID funding were changed and ATS work in the region was disrupted. Over 800 farmers had signed up to participate with ATS in the 1998-99 season before technical assistance was cut back. Even without as much advice and assistance, over 400 farmers practiced SRI in 1998-99.

Other donor agencies began supporting the process of SRI diffusion, including Foundation Tany Meva, and the Landscape Development Interventions (LDI) project of USAID. ATS was able to evaluate 212 rice farmers practicing SRI in Ranomafana region at the end of 2000. Farmers' respective areas of rice fields under SRI ranged from 1 are to 8 hectares.

The most impressive case was Ralainandrasana Honoré, a farmer who began using SRI in 1994-95, planting just one-quarter hectare (25 ares) with these methods. He now works with SRI on 12 hectares, having extended his rice fields year by year, buying or renting other areas with the profits from his SRI production. Technicians have calculated Honoré's average yield as 8 t/ha, which gives him an income of 8 million Malagasy francs (Fmg) per hectare. By comparison, farmers using the System of Improved Riziculture (SRA) that the government promotes, which requires purchase of high-yielding seeds and chemical fertilizer, have average yields around 3.5 t/ha, with an income of about 3.5 million Fmg/ha.

Honoré's costs of production are somewhat higher per hectare (see FOFIFA report), but his net profits are much higher because of greatly increased yields. With his increased profits, Honoré has built three houses, one in Fianarantsoa and two others in his village, in addition to acquiring more land. We discuss below some of the farmer problems that were identified in our survey.

Results in Madagascar's Highlands

In 1995-96, ATS trained 80 farmers around Antsirabe and 30 around Antananarivo with the support of technical personnel from the government's Agriculture Department, assisted by M. M. Louarn and Eric Bilger of the French aid agency. It is important to know that Antsirabe has volcanic soils so this area is more fertile than Antananarivo or Ranomafana. In Madagascar's highlands, elevations are between 1200 and 1500 m. Technicians supported farmers by making inquiries and filling in technical forms. The results can be summarized in terms of quartiles. Average yields with usual practices in these two areas were 3.9 and 3.2 t/ha, respectively.

Antsirabe
25% of plots produced: 1,425 kg/ha to 5,250 kg/ha
50% of plots produced: 5,250 kg/ha to 9.400 kg/ha
25% of plots produced: 9,400 kg/ha to 18,090 kg/ha

Antananarivo
25% of plots produced: 3,118 kg/ha to 4,900 kg/ha
50% of plots produced: 4,900 kg/ha to 7,600 kg/ha
25% of plots produced: 7,600 kg/ha to 11,810 kg/ha

Yields higher than 10 t/ha were obtained on 21% of plots in the first zone, and on 4% of the plots in the second zone. In Antsirabe, the total area of rice fields under SRI for this evaluation was 6.78 ha with an average of 0.85 ha/farmer, while around Antananarivo, it was 3.56 ha with an average of 0.12 ha/farmer. In Madagascar, it is evident that we are dealing with farming populations that are very land-constrained.

In the highlands, numerous new seed varieties like 1285, 1632 and 2787 have been introduced, but almost all farmers prefer local varieties which generally perform better than the new ones under local conditions. If farmers add any nutrients to their soil, they apply organic fertilizers (usually compost) as few use chemical fertilizers. We have found that some of the new varieties, such as 2067, perform particularly well with SRI management practices. The very highest SRI yields have come with such varieties.

Results on the West Coast

In 1997-1998, with support from the French development agency, ATS worked with the French NGO, FERT, for two rice seasons: a wet season (November 1997-May 1998) and the following dry season (June-October 1998). Each season there were 140 cooperating farmers which produced 280 results dispersed across 7 agroecological zones around Morondava where rice is grown on alluvial soils, and farmers never used chemical fertilizer. After training given by ATS, farmers practiced SRI with the following results:

Wet season

This season is warm (25° to 33°) and also rainy, thus there is much water available. The average area on which farmers experimented with SRI this season was 2.15 ares. Farmers were already using the government's recommended System of Improved Riziculture (SRA), transplanting improved-variety seedlings 30 to 45 days old, using a weeder but little manure. Below we give a comparison of farmers' SRI yields with those from the 'improved' system:

Zone	SRI (t/ha)	SRA (t/ha)
1st	4.77	2.19
2nd	4.00	2.91
3rd	3.79	3.26
4th	5.58	2.53
5th	4.75	2.41
6th	4.35	2.04
7th	3.43	1.85
Average	4.38	2.45

SRI results were consistently superior to those with SRA methods, averaging 80% higher, though they were not as high as seen elsewhere in Madagascar. This is partly because of the poorer soils in the region, but more important, there was too much water in the fields this wet season. SRI methods work best with a minimum of water.

Dry season

Here are the average yields from a season in which there was no rain, and rice cultivation depended entirely upon irrigation, so water supply could be controlled.

Zone	SRI (t/ha)	SRA (t/ha)
1st	7.15	3.05
2nd	9.11	3.32
3rd	5.14	3.54
4th	6.62	3.47
5th	6.71	3.41
6th	7.70	4.30
7th	6.03	3.37
Average	6.92	3.49

About a half of farmers doubled their yield or more, with some getting three times more for the season. Average yield with SRI was practically doubled (97% more) compared to SRA.

25% of plots produced: -55% to 52% of SRA average (average = 24 %)

25% of plots produced: 52% to 91% of SRA average (average = 72 %)

25% of plots produced: 91% to 133% of SRA average (average = 108%)

25% of plots produced: 133% to 366% of SRA average (average = 200%)

Some Remarkable Results

A few farmers have been able to make this production system work extremely well, even better than Honoré in Ranomafana, who has been the most successful in economic terms.

- Our collaborators in Fianarantsoa have identified some spectacular results in the small village of Andriamalaza-Tsaranoro, 50 km south of Ambalavao, which lies south of Fianarantsoa. Ramampionona Pierre has practiced SRI on 30 ares (0.30 ha) having planted *Sesbania mancrata* on his rice field before his rice cropping. He cuts this leguminous shrub after harvest and spreads it on the area. The amount of rice that he harvested in 1996 from 4 m^2 has 9.37 kg, about 24 t/ha. The rice was a japonica variety 1632.
- Another farmer in the Fianarantsoa region, in the village of Soatanana, in Isorana district, who has gotten remarkable results is Ralalason, who uses compost very effectively. Here are his data from the 1997-98 rice season. He planted all of his very small holding, one-eighth of a hectare (13 ares), with SRI methods. These results are from his sixth year of using these methods, having gotten about 10 t/ha the first year he tried them. He has gained skill and confidence in SRI year by year, and the quality of his soil has improved as he puts about 5 tons of very well-made compost on his fields for the inter-season crop that precedes his rice.

  Surface area: 13 ares
  Hills per m^2: 4
  Fertile tillers per m^2: 280
  Yield: 21 t /ha
  Distance of planting: 50 x 50 cm
  Tillers per hill: 80
  Grain number per panicle: 260

Labor Requirements

As part of the evaluation project on the west coast (Morondava) with FERT, Frederic Bonlieu, a French agricultural researcher, analyzed SRI labor requirements. He calculated that the amount of additional time required for SRI practices was around 500 hours/ha. As the wage for agricultural labor is about 1,000 Fmg per hour, the additional labor costs with SRI for the 70 farmers studied was about 500,000 Fmg. One kg of paddy sells for about 1,000 Fmg at harvest time — and twice that much some months later, when the price rises from its harvest-time depressed low. Thus the additional labor for SRI can be repaid with increased production of 500 kg/ha (or even half that much if the farmer can afford to delay selling his harvest). Bonlieu found that for the average increase in yield with SRI practices was 1,930 kg/ha in the wet season and 3,430 kg in the dry season, many times more than the increased labor costs for using SRI methods.

Problems

Training farmers about SRI is easy, but they can have many difficulties in practicing it because they cannot leave suddenly their traditional customs for many reasons. In our Ranomafana survey to assess difficulties of adoption, farmers answered our questions this way:

- SRI is so new for us; we don't like to practice it because it needs much attention and it is too complex.
- During the rice-growing period, we don't have money to pay for the extra SRI work.
- We don't have enough money to acquire a rotary pushweeder.
- Most of the men must migrate out of the village to get a paying job, so there is a shortage of labor for practicing SRI.

Indeed wherever farmers have rotary weeders they are deciding to go ahead with SRI if they are assured of having reliable technical advice.

Henri de Laulanié said that "Those having an agricultural vocation should go ahead [with SRI], persevering, and other farmers will follow them little by little." There can be adoption at first, and then disadoption, and finally readoption after several hesitancies. The Malagasy territory is still large and in total not densely populated (25 inhabitants/km^2). Malagasy farmers are still mostly in a situation of subsistence economy, not yet fully integrated into an economy of exchange. SRI has expanded greatly since Tefy Saina began its efforts in 1990, but we still have a long way to go.

CRS Experiences with SRI in MADAGASCAR

Niaina Andriamanarivo and Patrick Rajaomilison, Catholic Relief Services[1]

Catholic Relief Services (CRS) has been actively extending the SRI technical package for about three years. During 2001, the organization was provided with the first complete results of adoption and yield among program participants. Overall, SRI practices, adopting 3 of the 5 techniques, resulted in a doubling of yield over traditional practices. More complete adoption gave even better results. There is some divergence between agro-ecological regions of yield and adoption of components of the SRI package, as reported in this paper.

CRS has been working in Madagascar for the last 40 years. Since 1998, it has operated a "food security program" financed by USAID which targets vulnerable households in rural areas with an integrated package of maternal and child health assistance and agriculture improvement. The agriculture program seeks to increase food availability through sustainable increases in rice yield in target areas and sustainable crop diversification. SRI is the principal rice improvement technical package being promoted by the extension program. CRS operates its program through partner organizations in seven Catholic dioceses: Tamatave, Antananarivo, Manakara, Mananjary, Antsirabe, Tsiroanomandidy and Mahajanga. As of October 2001, there were 2,445 individuals in 210 farmer groups participating in the program.

The SRI technical package is based on the principles discovered by Père de Laulanié and extended by various organizations in Madagascar. The technical package being promoted consists of the following elements:

- Early transplanting: 8-day seedlings or somewhat older seedlings still with two leaves;
- Single seedlings, carefully transplanted and put into the soil at shallow depth (1-2 cm);
- Wide spacing: 30 x 30 cm in the main season; 25 x 25 cm in the off season;
- Early, multiple weeding: 3-4 times with a mechanical weeder, starting 10 days after transplanting; and
- Water control: applying a minimum of water, and alternating irrigation and drying fields until flowering.

Extension Approach

Training

CRS/Madagascar follows a "farmer-to-farmer" extension approach, identifying volunteer promoters at the village level. These persons are provided technical and organizational training and in turn, they provide training to farmer group members. Training sessions are practical in nature and are undertaken at the village level. Project technicians provide technical backstopping to the promoters.

Demonstrations

Each promoter installs at least one SRI demonstration plot within the village's fields with the objective of training group members and demonstrating the value of the practices to other villagers.

Information, education and communication

In collaboration with other organizations involved in SRI extension in Madagascar (Association Tefy Saina, LDI, ADRA, and the Ministry of Agriculture), CRS has developed a series of counseling cards and a farmer booklet to enhance SRI training. The series consists of 28 cards organized along 8 principal themes: soil preparation, nursery preparation, pre-germination of seeds, transplanting, weeding, irrigation management, animation, and a comparison of SRI and traditional yields.

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[1]*Respectively, head of the Agricultural Unit, and Project Advisor for the Catholic Relief Services program in Madagascar. E-mail addresses are niaina@crs.mg and patrick@crs.mg*

The farmer booklet is designed to reinforce promoters' SRI lessons. It is an easy-to-understand illustrated manual of SRI steps, accessible to non-literate audiences. The booklet provides convenient on-hand references to farmers undertaking the technical package.

Program monitoring and evaluation

The monitoring and evaluation system began collecting farm-level rice surface and yield data on a regular basis during 2001. Results from 2000 are based on a sample relying on farmer recall. Since 2000, results are collected quarterly using a standard form.

SRI Results

Table 1 presents rice yields, number of participating farmers, and the area for which different SRI techniques are utilized by program participants.[2] SRI results are reported according to three levels of utilization: Level 1 consists of one or two techniques of SRI; Level 2 is three or four techniques, and Level 3 is all 5 techniques.

Discussion of results

During the first year of the project, participants were able to increase their rice production:

Table 1. Results throughout CRS zones of intervention

	Traditional techni-ques	SRI techniques		
		Level 1	Level 2	Level 3
2000*				
Average area (ha)	0.59	0.27	0.23	n.d.
Yield				
average (t/ha)	1.2	1.4	2.2	n.d.
maximum (t/ha)	2.5	3.0	4.1	n.d.
2001				
Adoption				
(no. of farmers)	1545	420	493	139
Average area (ha)	0.53	0.33	0.23	0.23
Yield				
average (t/ha)	1.53	2.4	3.7	4.2
maximum(t/ha)	3.0	3.2	7.5	15.0

** Based on a sampling of 10-25% of participating farmers, to have a baseline for comparison in subsequent years.*

- Using only two of the five techniques, yields increased 16% over traditional methods.
- Using 3 or more techniques led to an 83% increase in yield.

During the second year of the project, yield increases were even more dramatic:

- Applying different levels of SRI resulted in yield increases of 56% for Level 1; 141% for Level 2; and 274% for Level 3, respectively
- Yield increases were virtually geometric as more techniques were added.

Between 2000 and 2001, even within SRI levels, increases were dramatic— 71% and 68 % for Levels 1 and 2, respectively. This can be attributed to farmers increasing their mastery of the different techniques.

Adoption of SRI techniques

The following levels of practice adoption were observed among SRI participants:

- 79% adopted the seedling spacing recommendations.
- 64% adopted the early transplanting recommendations.
- 65% adopted the one-seedling transplanting and weeding recommendations.
- 55% adopted the water management recommendations.

These adoption rates have regional variations. CRS works in three regions: the high plateau with high precipitation; the middle plateau with lesser precipitation; and the tropical/humid lowlands with extremely high precipitation.

- In the highlands, there is higher adoption of water management changes, whereas in the tropical lowlands, rice is often cultivated in marshes with insufficient drainage.
- Farmers in the highlands also more often practice wider seedling spacing.
- On the other hand, in the tropical lowlands farmers practice more weeding and transplanting at the correct age and number of seedlings. Farmers in the hot/wet lowlands are obliged to weed more frequently in order to combat the rapidly growing weeds. In the cool highlands, weed competition is less of a problem.
- Yields are also higher in the highlands with more of a tradition of fertilizing fields using cattle manure prior to cultivating. (Also, rice yields are generally higher in more temperate climatic zones compared to more tropical areas.)

[2] *Data for the Diocese of Mahajanga are not available and thus as not included.*

Lessons Learned

- SRI is a complex technical package, as opposed to the spread of a single technique, and thus it requires more time and intensive extension efforts prior to complete adoption.
- Farmers tend to try first one or two of the techniques prior to adopting the entire package.
- Farmers have a tendency to adopt those techniques that are less labor-intensive, e.g., spacing, or techniques that are already being practiced in their area, e.g. weeding in the tropical lowlands.
- The development of good information, education and communication (IEC) tools significantly aids extension agents in their work.
- The agro-ecological diversity in the different zones of intervention demands that extension messages and IEC materials be adapted to each region.
- There is no consensus yet among decision-makers in the country regarding the appropriateness of focusing on SRI as a means to increasing rice production.
- According to program participants, SRI allows them to economize on seeds and increases their productivity while it requires increased labor, particularly for weeding.
- Implementing water management recommendations depends on not only appropriate infrastructure but also on a change of mentality among rice farmers, who believe that rice always needs to be kept flooded.
- There is little communication between organizations undertaking SRI extension and those involved in SRI research. As such, extension services do not have the latest research results, and research organizations are not aware of the demands from the field.
- Related to the preceding point, there is little knowledge about the contribution/interaction of the different techniques in SRI and their respective and collective impact on yield.
- There is little practice of fertility management in relation to soil type.

Prospects

Given the above challenges, CRS/Madagascar recommends the following:

- Emphasize fertility management within SRI.
- Adapt SRI messages to take regional variations into account.
- Reinforce extension messages through IEC materials.
- Transmit more SRI research results to farmers.
- Get better communication between research and extension services.
- Do more systematic research on SRI in different agro-ecological regions.

Annex 1. Characteristics of CRS/Madagascar Zones of Intervention

	Zone I	Zone II	Zone III
Diocese	Antananarivo Antsirabe	Toamasina Mananjary Manakara	Tsiroanomandidy
Region	Central, oriented toward east	East	Central, oriented toward west
Altitude	> 1,000 m	Near sea level	> 1,000 m
Climate	Humid: 1,200-1,500 mm annual rainfall	Semi-humid: 1,500-3,000+ mm annual rainfall	Sub-humid: 600-1,200 mm annual rainfall
Temperature	Average : 22 ° C Maximum : 29° C Minimum : 04 ° C	Average : 27 ° C Maximum : 32 ° C Minimum :10 ° C	Average : 28 ° C Maximum : 33 ° C Minimum : 10 ° C
Soils	Mineral soils, coarse and little weathered Sesquioxyde and ferrallitic soils	Soils very marshy, rich in organic matter, often saturated with excess of water	Mineral soils, coarse and little weathered Ferruginous tropical soils

Source: J. Hervieu, Géographie des sols malgaches.

Annex 2. Adoption of techniques according to Zones of Intervention and agro-ecological zones

	Zone I	Zone II	Zone III	Total
Diocese	Antananarivo Antsirabe	Mananjary Manakara Toamasina	Tsiroano-mandidy	Total
Number of SRI participants	469	138	251	858
Single seedlings	264 56%	98 71%	138 55%	500 58%
Age of seedlings	302 64%	110 79%	144 57%	556 65%
Spacing	402 86%	80 58%	200 80%	682 79%
Water management	232 49%	47 34%	193 77%	472 55%
Frequent weeding	250 53%	119 86%	135 54%	504 59%
Technique most adopted	Spacing	Frequent weeding	Spacing	Spacing
Technique least adopted	Water management	Water management	Frequent weeding	Water management

Annex 3. Analysis of results with SRI according to agro-ecological zones

			SRI		
2001	Unit	Traditional Techniques	Level 1	Level 2	Level 3
Zone I: Antsirabe and Antananarivo (Cultivators: 598)					
Adoption	farmers	347	232	243	73
Average area	ha	0.36	0.25	0.22	0.22
Yield					
average	t/ha	2.3	3.2	4.7	4.5
maximum	t/ha	–	–	–	15.0
Zone II: Toamasina, Manajary and Manakara (Cultivators: 834)					
Adoption	farmers	739	29	109	22
Average area	ha	0.45	0.2	0.07	0.08
Yield					
average	t/ha	1.22	1.30	2.44	4.0
maximum	t/ha	–	–	–	9.0
Zone III: Tsiroanomandidy (Cultivators: 522)					
Adoption	farmers	369	159	141	45
Average area	ha	0.67	0.4	0.37	0.23
Yield					
average	t/ha	1.74	2.1	2.6	3.0
maximum	t/ha	–	–	–	18.0

Annex 4. Discussion of differences according to agro-ecological zones

Zone I (Antsirabe and Antananarivo)

- The adoption of SRI permits improvement in rice yields by 39 to 200%, with a maximum measured yield of 15 tons per hectare.
- The average level of yield with SRI Level 3 is not much different from SRI Level 2 probably because of poor management of water.
- In this zone, the adoption of techniques is, in this descending order:
- Spacing,
- Age of seedlings,
- Single seedling and frequent weeding, and
- Management of water

Spacing is easily adopted by participants in this zone where there has been intense promotion of line planting.

Agriculturalists in this zone are generally very receptive to innovations as there have been many projects and much research here. The level of participants' education is also higher in this zone compared to others.

Zone II (Toamasina, Mananjary and Manakara)

- The results obtained with SRI Level 1 are not enough to reach the objectives of the program, which is to augment rice yield by at least 10% as only an 8% increase was achieved.
- Rice culture in this zone is not very well developed, and thus there is less spread and adoption of SRI.
- In this zone, the techniques adopted are, in this decending order:
- Frequent weeding and age of seedlings,
- Single seedlings,
- Spacing, and
- Management of water.

Management of water is more difficult in this semi-humid zone. Also, with higher average temperatures, there is rapid proliferation of vegetation and particularly of weeds, for example, *Cyperacees*, so it is very necessary to weed frequently. These conditions are very favorable for the rapid development of young seedlings (good tillering, vigorous growth) so it is easier to plant 8-day seedlings with just two leaves here. Transplanting single seedlings is also very practical in this zone. Much of this zone is confronted with the problem of permanent soil saturation of its rice paddies, however.

Zone III (Tsiroanomandidy)

- One sees in this zone that average yield does not increase so much. SRI Level 1 yields are only about 20% above those from traditional practice. Level 3 adoption gives almost 50% more yield than does Level 1.
- In this zone, techniques are adopted in this descending order:
- Spacing,
- Management of water,
- Age of seedlings and single seedings, and
- Frequent weeding.

In contrast to the other two zones, Zone III offers a situation where water management is more favorable. The climate is propitious for good rice culture. Given the constraint of rainfall, farmers have more incentive to manage their water resources.

The Practice of the System of Rice Intensification in Northern MYANMAR

Humayun Kabir, Metta Development Foundation[1]

SRI experience began in Myanmar through the efforts of Metta Development Foundation, a pioneering national NGO in this country. Metta has been facilitating an ecological approach to improve crop production through the introduction of Farmer Field Schools (FFSs) in collaboration with local organizations and church groups in different parts of Kachin State and Shan State in the northern part of the country.

In 2000, Metta organized its first season-long, training-of-trainers (TOT) course for 32 staff and volunteers of three local organizations, who have been implementing FFS in the communities. With technical assistance from the International Institute for Rural Reconstruction (IIRR) based in the Philippines, the TOT was coordinated and managed by former IIRR staff member, myself. While working at IIRR as a rice specialist, I had learned about SRI from Norman Uphoff (CIIFAD) and initiated trials with SRI methods in the northern parts of the Philippines, and in Sway Rieng province of Cambodia under IIRR's collaborative projects with partners of those places.

Although these trials were not managed carefully and the practices were not all used correctly, I was impressed by the number of tillers that each rice plant produced in those trials. During the TOT in Myanmar, I introduced the idea of SRI to the training participants. The participating Metta staff found the concept of synergy embodied in SRI very congenial with their agroecological thinking and they began trials.

Evaluations

For the vast majority of farmers in the Kachin and Shan States, rice is the major source of livelihood. However, low yields of rice, associated with many soil and water problems, have kept their communities below the poverty line. An important aim of the FFSs is to provide farmers there with the knowledge and skills to increase the productivity of their rice fields.

Our primary focus has been on improving soil fertility by enhancing the biological activity of soil, and by efficient use of water since water is very scarce and valuable in the area. Improving productivity of both these resources is, coincidentally, important in SRI. Finding this great similarity of objectives with SRI, Metta started implementing SRI trials in its own training center and in farmer's fields in the year 2000.

2000 trials

The first trials were carried out in farmers' fields during Metta's first season-long-training, July-November, at Alam, Myitkyina, the capital of Kachin State. The wet season there usually has monthly rainfall of 12 to 18 inches between June and October. The trials were established in two separate plots, 800 and 1,000 square meters, respectively, each managed by a small group of participants.

Each plot was planted with three different spacings: 25x25, 30x30, and 35x35 cm, and with 10-day-old seedlings. The seedlings were planted one by one (a single seedling per hill) immediately after they were uprooted from the seedbed. The variety was an improved local variety. However, the planting was done one month later than is optimal for that season.

As an alternative to compost in each plot, 300 kg per hectare of oilcake was used. Weeding was done every ten days using a rotary weeder. The soil was maintained moist through well-drained by removing the excess water. Water was given whenever field moisture was limiting. After panicle initiation, the field was maintained with 5 inches of standing water. Water was removed 15 days before harvesting the rice.

[1] *Agricultural advisor. E-mail: metta@mptmail.net.mm or hkabir@progetelbd.net*

Unfortunately, because the crop was planted late, the resulting yields were disappointing, 1.97 to 2.73 t/ha. The tillering was, however, vigorous and impressive. The late planting date meant that only about half of the potential tillering, and subsequent grain filling, was achieved in these trials

2001 results at Metta Center

In this year Metta organized a season-long TOT course again for another batch of staff, held at its newly developed Center for Action Research and Demonstration (CARD) at Alam, Myitkyina. Along with other crop trials, a number of SRI plots were planted, but this time in a more systematic way and at the proper time, again in the wet season.

The trials were established in two separate plots of the field, each around 1,000 square meters. However, it should be mentioned that the soils of this field were terribly poor. Farmers who cultivated the land previously had abandoned it about ten years ago because of its poor quality. It was thus quite challenging to grow rice there, and farmers were keenly waiting to see whether we could grow any decent rice on this land.

A significant amount of compost and animal manure was applied to the field, but not more than 4 tons per hectare, and no chemical fertilizer was used. All other management practices in the trial plots were maintained as in the previous year's trials. Two varieties were used, both improved local varieties. All relevant field data were recorded on a weekly basis.

During the tillering stage, the growth of SRI plants was very impressive. The average number of tillers per plant was 19, with 42 the highest number in wider spacing. Tillering in SRI was 30% higher than in our FFS/IPM trials. Average yields of harvested rice in SRI plots measured 5.5 tons per hectare, 175% higher than from farmers' usual practice, and 37.5% higher than FFS/IPM practices with local variety, and 15% higher than FFS/IPM practices with improved varieties. The major differences between the FFS/IPM practices and SRI practices used in these comparisons were only seedling age and number of seedlings per hill because farmers had already begun to adapt the spacing, weeding and water management practices from SRI to their other plots.

2001 results in farmers' fields

Along with the trials in the CARD training field, the graduated alumni facilitators from our first TOT course implemented SRI trials at 30 Farmer Field Schools that they established and supervised in 2001. On average, each FFS had 10-15 farmer participants. The FFSs were spread over the entire Kachin State. The FFS trials were conducted during the wet season—the only period when farmers grow rice.

The trials in each FFS were from 1,000-3,000 square meters. Farmers' traditional practices for growing rice in the area involve: use of very tall and old seedlings (45-60 days), transplanted densely and in a random way. They never use manure or chemical fertilizer. Seedlings are usually transplanted in a hill with 5-6 plants together and are grown in 2-3 inches of standing water.

Therefore, it was very difficult for FFS farmers to adopt all the practices of SRI. They, however, simplified the practices based on their local conditions. As a result, the practices that were used in the name of SRI differed among FFSs. The major SRI practices that farmers used in the FFS trials included: (a) use of 12 to 20-day-old seedlings; (b) a single seedling per hill, with a few FFSs planting 2 seedlings per hill; (c) wider spacing 20x20, 20x25 and 25x25 cm; (d) transplanting in lines, not (yet) in squares; and (e) application of some animal manure. Due to high rainfall in the wet season, most of the time the soil was saturated. All the trials in the FFS were monitored and supervised by the FFS facilitators.

The average rice yields in all of these 'SRI' plots were found to be higher than the yields of any other fields in the FFSs. Farmers in the FFSs even got higher yields with SRI methods than did our technicians at CARD, with some reaching 6.5 tons per hectare. This is, perhaps, because the soil quality in the FFS areas is better than that in the CARD training field. For purposes of comparison, the average yields of farmers in the FFS area range between 2 and 2.5 tons per hectare.

2002 evaluations

As all the previous trials were done in wet season, farmers found that keeping soil dry during this season was a big problem. This year, trials were started in the dry season. In February 2002, Metta began another three-month training course designed for farmers. Sixty farmer leaders have been attending this 'Farmer-led Extension' course, and they have planted half an acre of summer rice in the training field using SRI practices.

In addition, in the Mung Baw area of Shan State, Metta has been conducting action research. Due to the prolonged winter there, farmers grow only a single rice crop each year. However, they are interested to see if summer rice could be introduced by adjusting the planting period. In 21 villages, more than 12,000 farmers have been carefully observing SRI. This year in their rice cultivation, water has been managed more carefully, keeping the soil alternately dry and wet, and rotary weeders have been used to cultivate the soil.

Overall Results

For Metta, the first year was a learning year for the introduction of SRI. Although the yields were disappointing in 2000, the staff achieved confidence that the system can work. Subsequent results have been impressive. All 2001 data from the training field and from farmer's fields in FFSs demonstrated that the production with SRI methods can be 2-3 times higher than from farmers' usual practices in Kachin State.

Through the FFSs, Metta has been promoting IPM as an ecological approach to improve the production and productivity of farmers' rice fields. Field trials provide them and the staff with an opportunity to learn and to improve rice production systems. This means that many production methods are evaluated along with SRI. In all the trials, SRI yields have been substantially higher, 15-37%, more than with the best previous FFS practices.

Moreover, the uniform color and vigorous growth of SRI rice plants have attracted thousands of Kachin farmers, from both upland and lowland, to observe this new methodology. For upland farmers, the water-saving aspects of SRI are particularly attractive as farmers do not have enough water supply for their crops.

CARD serves as a demonstration center for the whole region. Thousands of farmers across Kachin State and Shan State now visit the center on a regular basis, some formally and others informally. For them, the major attraction has been the SRI field. In addition, each FFS has organized its own field day, and SRI was the center of attraction. Visiting farmers were given seeds from the SRI field which they could see were of good quality and pure. In the coming years ahead, many of these farmers are expected to practice SRI.

Learning

The major difficulties that have been faced are to maintain the planting depth of seedlings, and to level the field well. These practices are very essential for planting tiny seedlings. Planting seedlings deeper than 1-2 cm into the soil adversely affects their tillering; on the other hand, seedlings get washed away by water when they are planted too shallow. In both cases, seedling mortality is a problem. Therefore, gap filling must be done on a regular basis, which farmers feel is added work.

The requirement of labor with SRI is, of course, higher than with traditional practice. But this does not seem to be a problem when farmers have seen the tremendous increase in yields that is possible, unless there is some crisis of labor shortage in the area. In both Kachin and Shan States, rice is grown only in the wet season, so sometimes excess water can be a problem for planting small seedlings in the fields.

Despite these problems, the approach of SRI is already bringing significant improvements into the overall system of rice production in our area. Since SRI requires a relatively small number of seedlings and thus only a small amount of seeds, farmer are taking more care in selecting good quality seeds for planting. They are thus producing better quality seedlings, which are a great improvement over traditional seedlings, which are taller, weaker and grown from seeds of uneven quality as no effort is made to select good seed.

In addition, the practice of using manure and compost in SRI has given another boost to our project, as it focused efforts on the improvement of soil fertility by using biological inputs. Farmers, usually, are reluctant to apply any manure or compost to their fields. However, when they practice SRI they feel obliged to use manure or compost, and get good results from their effort.

Prospects

Based on these results, project staff as well as farmers have become highly impressed with SRI, and therefore SRI has become an important part of Metta's FFS program. As of 2001, Metta had already trained 56 staff (FFS facilitators), and 60 farmer leaders are currently receiving training on SRI. Each of these facilitators and farmer leaders will provide training to 10–20 farmers each year based on the size of the FFS.

Integration of SRI into Metta's program will provide an extra opportunity to improve the yields of rice in the region where the program is working. We have found that SRI practices are supplementary to and improve upon the existing practices that Metta was promoting to improve the productivity of rice fields. SRI is not like introducing a new technology. The program, therefore, will continue to work on SRI and adapt the practices based on their suitability for farmers.

A Deputy General Manager of Myanmar's Ministry of Agriculture and Irrigation, after learning about SRI during a visit to Sri Lanka on an FAO mission in January 2002, has taken an interest in getting SRI evaluated more widely in his country. In June 2002, Norman Uphoff visited Myanmar, hosted by the Ministry and Metta Development Foundation, to meet with both Ministry officials and with farmers to disseminate an understanding of SRI opportunities.

My reporting at these sessions on our experience in northern Myanmar made the results reported from other countries more credible for those hearing about SRI for the first time. One Divisional Manager for the

Ministry has previously experimented with transplanting single young seedlings, widely spaced, getting good results, so there is already some active interest within the government in taking up SRI practices in other parts of the country.

The Practice of the System of Rice Intensification in SIERRA LEONE

Abu Yamah, World Vision/Sierra Leone[1]

Environmental degradation caused by the traditional practice of shifting cultivation in Sierra Leone has increasingly necessitated utilization of the lowlands, particularly the inland valley swamps, for rice production. Rice is the preferred staple food in Sierra Leone, but its production is inadequate as the current average lowland rice yield is just 1.5 t/ha. Most households do not have access to as much rice as they would like, so root crops are a major source of calories. Because of many years of domestic conflict, infrastructure and supply systems have been badly disrupted, and poverty and hunger are pervasive. A methodology for growing rice that can give increased production with no requirement for purchased inputs would thus be particularly beneficial to our food-insecure population.

SRI was introduced in 2001 to selected groups of farmers in eight communities in southern Sierra Leone as a production system that can give better utilization of land and water resources. This process was initiated by the late Hilton Lahai, a senior research coordinator for World Vision/Sierra Leone (WV/SL), who made a study tour to Madagascar in November 2000 to learn about SRI. There he was hosted by Association Tefy Saina (ATS), an NGO actively involved in the promotion of SRI.

Process of Introduction

On-farm demonstrations of SRI practice

Eight farming groups, each consisting of 20 members, were established for participation in on-farm demonstrations of the SRI methodology in southeastern Sierra Leone. Each of 8 groups worked alongside WV/SL field-based extension agents in establishing two inland valley rice plots. One plot was planted to SRI, with 10-day old seedlings, a single seedling per hill, and spaced 25 cm, while the other plot was planted using farmers' practices, with 30-day old seedlings, multiple seedlings per hill, and irregular spacing. Both local and improved varieties were used.

Both SRI and farmers' seedbeds were prepared with two passes of a field cultivator with an attached harrow. Both seedbeds were kept moist but not flooded throughout the vegetative period. After flowering, the fields were kept in saturated condition, but were again not flooded. The fields were gradually drained between the ripening and harvesting period. Weeds that emerged after transplanting were uprooted by hand and buried into the soil at 4 weeks after transplanting and at 7 weeks. No fertilizers were used. Rice yields were determined by harvesting sample areas of 5 x 5 m^2. Harvested grains were dried, cleaned, and weighed. Panicle counts from the culms with fertile panicles were taken from the harvested area.

Factorial trials

Treatment combinations varying the factors of seedling number per hill, seedling age, and plant population were also evaluated during 2001. Plots were planted in a randomized complete block design in multiple locations. The variety used was Suakoko 8, an iron toxicity-tolerant, medium-duration variety. Control treatments were the same as above.

Agronomic conditions for both the on-farm and factorial trials were representative of the often difficult conditions for growing rice in Sierra Leone. The major rice soils in southern Sierra Leone are:

- Sandy-loamy —valley bottom soils, with low water retention and common P deficiency .
- Loamy clay — valley bottom soils, relatively more fertile, with good production potential, and high water retention.

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- Peaty soil— high in organic matter, with iron toxicity and drainage problems.
- Organic silty clays — found on river flood plains, with high percolation rates, subject to annual flooding, characterized by high silt and humus deposition.

The main feature of the climate is the heavy rainfall, with total precipitation averaging 2,500 to 3,500 mm per annum. The rainy season is monomodal, lasting from April to November. Southern Sierra Leone is characterized by high temperatures throughout the year with a mean of about 27^0 c.

Results

The results of the on-farm demonstration of SRI practice are shown in Table 1. The average tiller number was 77% higher with SRI practices compared to tiller numbers with farmers' methods. Plant vigor was also noticeably higher with SRI than with farmers' practice. On some of the fields, up to 69 tillers were produced per hill with SRI. No significant difference was observed with SRI management in vegetative performance between the improved rice selection used (ROK 10) and local rice varieties (Wusui, Patae or Peipei).

With SRI, the average number of panicles produced per hill was three-fold, irrespective of the variety used. Grain yields were doubled with SRI compared with farmers' techniques even though no external inputs were used.

The results of the factorial trials at 11 locations are presented in Table 2. The full SRI plots had a comparatively higher tiller count per hill due to the combined factors of seedling age, number, and spacing.

Compare these results with the current average lowland rice yield obtained by farmers of 1.5 t/ha. With full SRI methods or a combination of single, young seedlings and wide spacing the yield was about 6.72 t/ha, a four-fold increase over farmers' traditional practices. With even partial SRI, there was almost a two-fold increase in grain yield over the national average.

The average yield obtained with multiple, older seedlings at wide spacing — but grown in soil kept weed-free and moist but not flooded throughout the vegetative phase — was higher than usual yields in Sierra Leone where there is less effort made to control weeds and no efforts to have aerated soil. Thus simply adopting the soil and water management practices of SRI could give a definite improvement in yield. The plant management practices add even more. For evidence of the synergistic effects of SRI practices used together, see Table 3.

Learning

With SRI there was about a 25% reduction is the quantity of seeds used to plant a given area. Farmers can thus make substantial savings in seed needed, and seed wastage can be minimized. However, more man-hours are required for handling and transplanting tiny, fragile SRI seedlings. As one farmer observed "planting only one seedling and [having] several tillers emerge from that seedling is magic. I would love to see how much rice would be obtained from this plot."

Table 1. Yield and yield components of rice grown with SRI and farmers' practice, Sierra Leone, 2001

	SRI techniques (N=8)[1]		Farmers' techniques (N=8)	
	Mean	Range	Mean	Range
No of hills/m^2	16	10–25	52	42–64
No of tillers/ hill	38.1	20–69	8.6	8–9
Panicles/hill	28	20–45	6.5	6–7
Spikes/panicle	122	118–149	95	83–120
Yields (t/ha)	5.3	4.9–7.4	2.5	1.9–3.2

[1]These data are from the reports from eight groups, each having 20 members.

Table 2. Rice yields (t/ha) in response to production techniques, Sierra Leone, 2001

Combinations of production techniques	Average grain yield (t/ha)
Single seedling, 10 days old, 25 cm spacing	6.72
Single seedling, 10 days old, farmers' spacing	4.56
Single seedling, 21 days old, 25 cm spacing	4.42
Single seedling, 21 days old, farmers' spacing	4.09
Multiple seedlings, 10 days old, 25 cm spacing	4.35
Multiple seedlings, 10 days old, farmers' spacing	4.37
Multiple seedlings, 21 days old, 25 cm spacing	4.39
Multiple seedlings, 21 days old, farmers' spacing	3.97

Table 3. Increments achieved with combinations of SRI practices
(SRI practices in **boldface**; yield and comparisons in t/ha)

	Practices			Yield	Comparison
Traditional practice	MS	21	FS	3.97	0.00
One SRI practice	**SS**	21	FS	4.09	+0.12
	MS	**10**	FS	4.37	+0.40
	MS	21	**25**	4.39	+0.42
Average				4.28	+0.31
Two SRI practices	MS	**10**	**25**	4.35	+0.38
	SS	21	**25**	4.42	+0.45
	SS	**10**	FS	4.56	+0.59
Average				4.44	+0.47
All SRI practices	SS	**10**	**25**	6.72	+2.75

Key: MS=Multiple seedlings/hill; SS= Single seedling/hill; 21=21-day-old seedling; 10=10-day-old seedlings; FS=Farmer spacing; 25=25x25 cm spacing.

Note: Water control was maintained as best as possible for all plots; Weeding also was not a variable in these conditions.

The performance of the seedlings in the SRI plots was very good when tiller production and other yield attributes are considered. Lower tiller production on the farmers' practice plots was probably because the older seedlings may have spent part of their tiller production phase in the nursery.

Maintaining water in the rice plots at less than saturation level enhances tiller production and ensures plant nutrient uptake and utilization.

Weed re-growth was higher in the SRI plots compared to those farmers' practice. Weed infestation was minimal in the farmers' plots because they remained submerged under flooded water. Two or more weeding regimes were required in the SRI plots.

Most farmers in Sierra Leone plant late, weed late, or sometimes do not weed at all. Farmers experience labor bottlenecks during critical periods of farm operations like transplanting and weeding. The use of a rotary weeder could help to ease labor shortage during weeding.

Prospects

There is now some, albeit limited, understanding of SRI practice in Sierra Leone. Some of the farmers who participated in the demonstrations have shown interest in this innovation, but are worried about weed infestation in the SRI plots. There is need therefore to understand the timeliness and frequency of weeding with a view to identifying the critical weeding times for SRI. There is need to also promote the local fabrication and use of mechanical hand weeders.

The farmers observed that many hands were needed to perform critical operations like transplanting and weeding. Better training to help farmers perform these operations more quickly and easily will be important for SRI's spread. There is need further to investigate the economics of rice production with SRI so that farmers can know just how much benefit can be obtained from these practices.

The higher yields reported from the SRI plots were under the native fertility of the soil. A next step will be to work on improving soil fertility by adding nutrients from organic and/or inorganic sources. Farmers are eager to know whether or not there is a difference with SRI results when fertilizer is added and when it is not. If yes, they would like to know what is the economic rate of application? Improved understanding is needed of the effects of organic and inorganic fertilizers on SRI yield.

Research Reports

The System of Rice Intensification and Its Use with Hybrid Rice Varieties in CHINA

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There are significant differences between the System of Rice Intensification (SRI) and Chinese methods of traditional rice cultivation (TRC) as summarized in Table 1.

The Demands of Super-High-Yielding Hybrid Varieties for SRI

SRI supplies very favorable conditions for vigorous growing and fully brings out the latent yield potentials of rice. However, external causes must achieve their effects though internal processes. That is to say, super-high-yielding cultural conditions are needed to enable hybrid varieties to accomplish super-high-yields.

In 2001 we have made field comparison experiments with two-line medium-duration hybrid rice varieties using SRI methods in Yunshun County, Hunan Province. The results showed that the yield potentials of different hybrids are generally enhanced by SRI practices compared to TRC (Table 2).

According to these experimental results and the characteristics of SRI methods, it appears that hybrid varieties, to have the highest yield potential when used with SRI methods, should have the following characteristics:

Strong tillering capacity

Under a transplanting density of 25x25 cm to 50x50 cm and with just 1 seedling/hill, the tillering potential of rice can be more fully achieved. If a variety's tillering capacity is weak, the subsequent number of effective panicles, which are the main factor influencing yield, will not be numerous enough to achieve the expected target yield, and the goal of increasing grain production by large margins cannot be reached.

Lodging resistance

Generally speaking, hybrid varieties with lodging resistance have the following characteristics. Their stems are strong and elastic; the lead sheath firmly surrounds the stem; there is higher degree of silicon in the stem; the root system is flourishing and powerfully absorbs nutrients; there is quick growth of spikelets and high degree of grain filling.

Table 1. The main differences in cultural measures between SRI and TRC

Practice	SRI	TRC
Seedling age (days)	8 - 12	25 - 35
Seedlings/hill (no.)	1	5 - 6
Plant spacing (cm)	25 x 25 – 50 x 50	16.7 x 20 – 20 x 26.7
Weedings (no.)	4	3
Method of weeding	Rotating hoe, called "wolf's fang" hoe in Chinese	By hands or by feet
Types of fertilizer	Organic sources: compost and/or barnyard manure	Organic and chemical fertilizers
Irrigation pattern	Discontinuous irrigation combining damp soil with drier soil	Discontinuous irrigation and continuous irrigation

Table 2. Grain yield and its components with two-line hybrid, medium-duration rice varieties using SRI methods

Variety	Effective panicles (10^4/ha)	Spikelets/ panicle	Grain setting (%)	1000-grain weight (g)	Theoretical yield (t/ha)	Actual yield (t/ha)	Yield compared to TRC (%)
Pei'ai 64S/171	261.0	205.2	81.9	26.4	11.58	11.97	+2.57
Pei'ai 64S/004	246.0	209.8	80.0	26.5	10.94	10.98	-5.91
38S/9311	256.5	194.9	84.6	26.2	11.08	11.48	-1.63
Zhun S/572	202.5	218.5	92.0	29.8	12.13	12.23	+4.80
Yaza 1	240.0	233.0	84.9	27.5	13.07	12.79	+9.60
Yaza 2	226.5	229.0	83.2	27.5	11.87	10.61	-9.08
Pei'ai 64S/9311 (TRC methods)	203.2	238.3	92.2	26.8	11.97	11.67	—

Greater stress resistance

First, there should be strong ability to resist losses due to diseases and insects such as rice blast, bacterial blight, stem borer, and rice plant hopper. Second, there should be ability to endure adverse environmental conditions, such as resistance to cold in the early stage of medium-duration rice and the late stage of long-duration rice, and also tolerance of heat in the late stage of medium-duration rice and early stage of long-duration rice.

Enormous yield potential

The results of many studies have showed that hybrid varieties with enormous yield potential present the following main characteristics: very strong photosynthesis capacity, particularly from heading stage to maturing stage; ideal plant and leaf type; optimum canopy disposition from the 5th reverse leaf to the 1st reverse leaf at heading stage; a long, straight, narrow and thick flag leaf; long and large panicles; large grains; high percentage of grain-setting; and a full extent of grain ripening.

For example, the Taizhong 16 line which achieved a yield of 21 t/ha in Madagascar with excellent use of SRI methods had 280 effective panicles per square meter (4 plants/m^2 x 70 panicles/plant), with 260 grains per panicle, according to data from Association Tefy Saina.[1] This represents a 1000-grain weight of 28.3 g and a weight per panicle of 7.54 g. The Yaza 1 hybrid with a maximum yield of 12.79 t/ha as seen in Table 2 has 240 effective panicles per square meter, and 198 grains per panicle, with a 1000-grain weight of 27.5 g and grain weight per panicle of 5.33 g. These and other such improved varieties possess enormous yield potential.

Wide ecological adaptability

Whether a hybrid variety of rice can give super-high-yields under various environmental conditions depends to a great extent upon its ecological adaptability. The growth duration of variety Taizhong 16 line with SRI methods at Madagascar was about 120 days, so daily grain yield achieved 121 kg/ha. This is above the usual achievement of TRC. The achievement of such maximum yield comes not only from the cultivator's mastery of the SRI techniques and from the enormous yield potential of the variety, but also from the suitability of the variety to the particular soil and climatic environment it is growing in.

Some Discussion of the Application of SRI Methods in China

Control of ineffective tillering

From the evidence on enhanced rice yields by using SRI methods, we conclude that accelerating tiller development and grain-filling are the key factors for increasing yield. For best use of SRI in China, it will be necessary to regulate the number of infertile tillers with these methods. We suggest the following:

- First, one should select hybrid varieties that have strong tillering ability, high biological potential, and high economic coefficients. Such varieties have the potential for raising area productivity by enlarging individual plants.

[1] *Yuan Longping (2001). The system of rice intensification (SRI).* Hybrid Rice*, 16:4, pages 1-3.*

- Second, cultivation practices should focus on creating high-yield populations through exploiting these individual plant potentials. This will be done by adoption of SRI and by coordination of SRI methods with irrigation and fertilizer management.

Selection of optimum planting density

Young, single seedlings planted sparsely and in a square pattern (25x25 to 50x50 cm) is an essential part of SRI. But how sparsely the seedlings should be planted needs to be determined empirically.

- First, there are varietal differences to consider. If the variety has characteristics of longer growth duration, higher plant height, stronger tolerance to fertilizer, and stronger tillering ability, then sparse planting (25x25 cm or more) may be productive; with other varieties, narrower planting will be better.
- Second, planting density should be decided according to the soil fertility and irrigation conditions. This will usually need to be determined empirically.

As stated above, SRI is a possible path to achieve higher-yielding rice cultivation in China, but the extension of SRI should be adapted according to the local situations and optimum hybrid variety. Setting up experiments and demonstrations will be necessary to support SRI extension efforts.

Assessment of Using SRI with the Super Hybrid Rice Variety Liangyoupei 9

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The two-line super hybrid rice variety Liangyoupei 9 was studied with the cultivation methods of the System of Rice Intensification (SRI) in 2001. Its grain yield reached to 12.15 t/ha, a yield increase of 21.3% compared with use of conventional methods. This paper discusses methods used for analysis and the benefits of using SRI methods hybrid variety Liangyoupei 9.

SRI methods offer advantages of seeds-saving, nursery-saving, less water requirement, lower-cost, high yields and greater resource efficiency. They can also obviously decrease the amounts of chemical fertilizer and herbicides applied, improving the eco-environment of the soil and being good for developing organic agriculture. SRI methods, which were first put forward and used in Madagascar, have gotten the result of doubled grain yield.

In recent years, researchers in Indonesia, Philippines, China and other countries have been testing these methods. Professor Yuan Longping, Chinese academician, has actively promoted and introduced the new methods and has organized experiments in different ecological regions throughout country. The results reported here are from one of these experiments along the Yangtze River. The study evaluated the yield potentials and main technical points of SRI methods.

Materials and Methods

This experiment was carried out in Anqing Research Institute of Agricultural Sciences (ARIAS), which is located at 30 32' N latitude and 117 03' E longitude, in a northern subtropical climatic zone along the Yangtze River. The soil is an alluvium type with organic matter of 35.4g/kg. The total amount of N is 0.11%, P_2O_5 is 11.5mg/kg, and K_2O is 73 mg/kg. Thus the content of available effective P and K in this soil is low.

Genetic material

The two-line super hybrid rice variety Liangyoupei 9 was used as the experimental material for all the trials.

Experimental design

Two SRI plant densities were evaluated along with traditional cultivation (TRC) techniques:

- Treatment I: SRI spacing 33.3 x 33.3 cm (6,000 plants/667 m)
- Treatment II: SRI spacing 40 x 40 cm (4,168 plants/667 m)
- TRC conventional spacing: 16.7 x 26.7 cm (15,000 plants/667m).

The experimental area was 0.3 ha, with 0.1 ha for each treatment.

Field preparation

Thirty tons of compost (including 8 t chicken excrement) and 750 kg of rapeseed cake fertilizer were applied to the fallow paddy field before plowing. Field preparation was done according to normal cultivation methods. Each ridge (raised bed) was 350 m in length and 4m in width, with the width and depth of ridge furrow 20 cm and 25 cm, respectively.

The test materials were seeded in plastic trays on May 3, 2001. There were 19 x 30 holes in each tray which was 60 cm in length and 43 cm in width. Rice seedlings with 2.6 leaves at the age of 8-12 days were transplanted singly for the SRI trials. After the seedlings had recovered, the field was manually weeded four times.

The compost and rapeseed cake fertilizer used as base fertilizer contained, on a per hectare basis, 742.5 kg N, 46.5 kg P_2O_5 and 30 kg K_2O, and 150 kg of KH_2PO_4 per hectare was applied as dressing at the first weeding. The methods of disease and insect control used were the same as neighboring rice fields. Shallow irrigation was done in the panicle formation stage, with dry and wet conditions alternated for growth during the late stage.

Trait measurements and methods

Three representative locations, each with 20 rice plants, were selected to evaluate each treatment. Leaf age and dynamic formation of tillers were observed for the selected plants, and agronomic traits—spikelets, filled grains, seed-setting rate, and 1000-grain weight—were evaluated. Paddy grains were harvested and weighed for each treatment.

Results and Analysis

Yield increase

A yield of 12.15 t/ha was obtained in treatment I, which was 21.3% higher than TRC (10.02 t/ha), and 11.25 t/ha in treatment II, 12.3% more than TRC. The results showed that the SRI methods had a significant effect on increasing yield (Table I). The theoretical yield for the two treatments reached 15.85-17.56 t/ha, indicating that there still was more yield potential under SRI methods.

Contributions to yield increase

Increase of effective panicles formed the basis for higher yield. In the experiment with SRI methods using Liangyoupei 9, even though only 60,000-90,000 plants per hectare were transplanted, 60-70 tillers and 45-50 effective panicles were formed from each plant (Table 1). Effective panicles with treatments I and II reached to 4.050 and 3.075 million per hectare, respectively, an increase of 26.6-66.7% compared with TRC having 2.430 million effective panicles per hectare. Therefore, the increase of effective panicles established the solid foundation for higher yield.

Larger panicles with more grains were the key to higher yield. In Table 2, we see that SRI methods produced more low-order tillers and therefore formed more effective panicles. The tiller from the main stem (TMS) and tillers from the primary tillers (TPT) in treatment I accounted for 71.1% of total tillers, and the total number of grains and filled grains per panicle were respectively over 220 grains and about 200 grains. TMS and TPT tillers in treatment II accounted for 72.8% of total tillers, and spikelets and filled grains per panicle were similar to treatment I, although the number of spikelets and filled grains per panicle from TPT tillers increased greatly compared with treatment I, which were, respectively, 196.2 grains, 176.2 grains, and 176.1 grains. There were a lot of tillers produced in treatments under SRI methods, and most of the tillers grew earlier and were located at low nodes. Moreover, there were enough sunlight, air and water with SRI methods so that large panicles with more grains were formed compared with TRC and the rate of seed setting was higher than with TRC. Thus, it can be seen that large panicles and more panicles developed coordinately.

The high rate of seed-setting and 1000-grain weight also contributed to high-yield. The rates of seed-setting in two treatments were, respectively, 85.0% and 01.1%, which were 0.5%-5.6% higher than with TRC (84.5%); 1000-grain weights were, respectively, 25.5 g and 26.1 g, i.e., 0.3g-0.9 g more compared with that of TRC. The rate of seed-setting and 1000-grain weight in the two treatments did not increase markedly, but they contributed to higher yield in combination with more effective panicles.

Table 1. Comparison of agronomic and yield of Liangyoupei 9 with SRI methods

Treatment	I (33.3 x 33.3 cm)	II (40 x 40 cm)	TRC (16.7 x 26.7 cm)
Maximum number of tillers/hill	62.1	68.2	13.0
Effective panicles/hill	45.2	49.3	10.8
Rate of effective panicles (%)	72.8	72.3	83.1
Total grains/panicle	200.2	221.6	218.1
Filled grains/panicle	170.1	197.4	184.0
Rate of seed setting (%)	85.0	90.1	84.5
1000-grain weight (g)	25.5	26.1	25.2
Actual yield (t/ha)	12.15	11.25	10.02
Theoretical yield (t/ha)	17.56	15.85	11.31
Yield increase over TRC (%)	21.3	12.3	—

Table 2. Regulation of tillering, formation of effective panicles, and yield structure

SRI treat-ment	Order of tillering	Number of tillers	Number of effective panicles	Rate of effective panicles (%)	Contribution of each order to total number of tillers (%)	Grains per panicle	Filled grains per panicle	Rate of seed setting (%)
I	TMS	11.0	10.0	90.9	22.2	222.7	201.4	90.0
	TPT	29.0	22.0	76.0	48.9	222.8	194.1	84.8
	TST	20.0	13.0	65.0	28.9	157.3	132.0	83.1
	TTT	2	0	0	0	0	0	0
	Total	62.0	45.0	72.6	–	–	–	–
II	TMS	10.0	9.0	90.0	20.0	225.1	205.61	91.4
	TPT	32.0	26.0	81.2	52.8	223.4	202.3	90.5
	TST	24.0	14.2	63.3	27.2	196.2	176.1	89.8
	TTT	2	0	0	0	0	0	0
	Total	68.0	49.2	72.4	–	–	–	–

**TMS = tillers from main stem; TPT = tillers from primary tiller; TST = tillers from secondary tiller; TTT = tillers from third tiller.*

Growth Characteristics of Liangyoupei 9 with SRI Methods

Early tillering and vigorous tiller potential

We found that there is dynamic curvilinearity of tillering development of Liangyoupei 9 under treatments I, II and TRC. But, the curvilinearities of treatments I and II both ascended more steeply. This indicates that Liangyoupei 9 with SRI method had a more vigorous tillering potential and good regulation of leaf and tiller growth.

The periods of vegetative growth of the first two treatments in the field were 20 days longer with treatments I and II than with TRC. Yet the time of maximum tillering in these treatments was the same as with TRC. So under SRI methods, there were much longer period of effective tiller formation and thus more tillers in treatments I and II so that more effective panicles formed from early low-order tillers.

High resistance to diseases and lodging

According to our investigation in the field, the incidence of rice sheath blight in treatments I and II ranged from 58.4% to 54.6%, lower than that with TRC (70%). Also the indexes of disease grade were lower than for TRC, as was incidence of rice false smut. With SRI methods, there were still one or two green functional leaves in the treatments at maturing stage because of the strong root system, while the functional leaf of TRC trials became yellowish, and some rice plants lodged.

Key Techniques of SRI Methods for Super Hybrid Rice Variety

Application of more organic fertilizer and quality compost

Super hybrid rice varieties need more fertilizer, especially the proportion of balanced application of N, P and K. Therefore, a large amount of organic fertilizer application and balanced application of N, P and K are important for high yield. The amount of organic fertilizer should not be less than 30 t/ha. Other organic fertilizer such as rapeseed cake fertilizer and green fertilizer instead of compost are considered effective.

Ridge cultivation

Field preparation was done according to the normal cultivation methods used with hybrid varieties. Each ridge (raised bed) was 250 m in length and 4 m in width, and the width and depth of the ridge furrows was 20 cm and 25 cm, respectively. All these preparations were to control better the wetness of the field during irrigation. They assured that there was no water laying on the field during the vegetative growth phase of the crop.

Dry nursery in plastic trays

The number of seedlings when transplanting super hybrid rice with SRI methods was fewer than with conventional cultivation. It was simple and convenient to use plastic trays for raising seedlings, and dry cultivation of the nursery was also beneficial to boost the vigorous root system for early and quickly growing of tillers after transplanted. The plastic tray with big holes was good for root development. With SRI, the seedlings should be transplanted in a timely way. Seedlings with 2.6 leaves at an age of 8-12 days are suitable for being transplanted.

Field management

Weeds grew very rapidly due to having fewer rice plants in the field and no water layer according to SRI methods. Weeds should be removed not only earlier but also more times, which makes the plow layer looser and for more air permeability in the soil. After transplanting, the prevention from rice thrips damage is very important. In the first phase of rice growth, water was kept in the furrows at all times to maintain moisture in the field. Shallow water was applied through irrigation in the panicle-formulation stage. Irrigation was applied alternatively for wetting and drying of the field. Water supply did not stop earlier in later stage.

Prospects of Economic Benefit

Saving of seed and nursery costs

The amount of hybrid seed of Liangyoupei 9 needed was only 3.0-4.5 kg/ha with the SRI methods, giving in general a seed saving of 8.3-10.5 kg and a nursery saving of 90% which could save a cost of about 215 Yuan/ha.

Saving of fertilizer cost

Mainly compost and stall fertilizer were applied to Liangyoupei 9 with SRI methods, while with conventional methods, 10.0-12.0 t/ha of fertilizer would be applied, about 450-600 kg of urea and 275-450 kg of compound chemical fertilizer, with a cost of chemical fertilizer amounting to about 1,200 Yuan/ha. Although SRI methods might increase the cost of labor for making compost and weeding in the field, they reduced the use of chemical fertilizer and herbicides and are also beneficial to the eco-environment system, lowering costs and decreasing paddy pollution.

Saving water resources

SRI methods are well-adapted to water-saving irrigation with no water layer maintained on the field. The amount of field evaporation was only 1/4-1/6 of that with conventional irrigation methods. So SRI saved about 3,000 tons of water, equal to about 150 Yuan/ha.

The total saving with SRI methods thus amounted to about 1,555 Yuan/ha. In addition, the rice grain yield was raised by 15%, which amounted to an increase of 1.5 tons of rice per hectare, which is worth about 1,500 Yuan. So the total additional profit with these methods was more than 3,000 Yuan/ha.

SRI methods with Liangyoupei 9 can fully develop the hybrid variety's tillering potential, with larger panicles having more grains, higher resistance to pests and diseases, and good rice quality. It had an obvious effect for increasing production and has a large potential in increasing yield. If the SRI cultural practices level can be further enhanced, an expected yield of 15 t/ha can be acquired in single-cropping rice along the Yangtze River valley.

SRI methods not only have the advantages of seed-saving, nursery-saving, high yield and efficiency, but also decrease the application of chemical fertilizers and herbicides through the increased use of organic nutrients. SRI practices energetically improve soil structure and the eco-environment. Also, they are beneficial to the development of organic agriculture.

Under the conditions of diminishing water resources available within the single-cropping rice region north of the Yangtze River, SRI can be beneficial to the development of water-saving agriculture. Thus, it can be concluded that SRI represents an important innovation in rice cultivation technique and will have a wide developing prospect.

Physiological Characteristics and High-Yield Techniques with SRI Rice

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Physiological characteristics and high-yield cultivation techniques under SRI (system of rice intensification) condition were studied with the cultivars of Wuyuegeng 9, 9916 and Liangyoupeijiu. The results showed that the SRI significantly enhanced the following: root viability; contents of soluble sugar; non-protein nitrogen; proline and malondialdehyde (MDA) in leaf; dry matter in vegetative organs; partitioning percentage of stored carbohydrate and nitrogen; percentage of effective leaf area; spikelet number per unit leaf area; single stem and sheath weight; and percentage of productive tillers.

Under SRI cultivation, rice population growth and harvest yield differed with variety. On Indica rice, population tiller number at effective tillering stage, spike number and yield under SRI were 5% lower than those under conventional cultivation. However, on Japonica rice, no difference in population spike number between SRI and conventional cultivation was observed, while under SRI cultivation, population quality and biomass partitioning efficiency increased distinctively, and grain yield was 11750 kg/ha, higher than that under conventional cultivation (11497 kg/ha).

With Indica rice, if one seedling per hill was changed to two seedlings per hill, population tiller number at effective tillering stage and spike number increased obviously, yield difference between two cultivation systems decreased, and with suitable nitrogen fertilization, grain yield under two seedlings per hill of SRI was higher than that under conventional cultivation. In Wuyuegeng 9, with 150 kg/ha nitrogen fertilization, the yield with two seedlings per hill of SRI cultivation (9253 kg/ha) was 200 kg/ha higher than under conventional cultivation. However, dry matter production and translocation from vegetative organs after heading decreased and population size and spike number were enhanced with increasing nitrogen fertilizer. Therefore, yield increase under SRI cultivation should not rely on the excess nitrogen fertilization.

Rice has been well adapted to inundation and half-hydrophytic environment. However, part of water requirement in rice is only to meet the ecological demand of improving nutrient uptake, soil processes, and thus is of certain plasticity. Studies inside and outside China have provided some effective water-saving irrigation methods such as thin and shallow moist irrigation, intermittent irrigation, SRI cultivation and so on.

The common characteristic of above-mentioned irrigation methods is that no water layer is maintained on paddy field or soil water content is lower than saturated water content in a period of time during rice growth. Especially, the SRI cultivation technique has been extended and applied in Southeast Asia, and produced significant social, economic and ecological benefits.

To elucidate the basis of high yield with SRI, the present study was conducted to determine the differences in plant physiology, population development, yield formation between SRI and conventional rice cultivations as well as impact of management techniques on the SRI performance.

Materials and methods

Experiment design

Four experiments were conducted from 1999 to 2001.

Experiment 1

The experiment consisted of two cultivation methods: SRI and traditional rice cultivation (TRC). Under SRI treatment, 12 to 13-day-old rice seedlings with two leaves were transplanted, one seedling per hill. From transplanting to 7 days after transplanting, a water layer of 1 to 3 cm deep was maintained on the paddy field. From 7 days after transplanting to maturity, there was no water layer on the field, and soil water was main-

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tained in moist condition by quick irrigation as desired. In addition, the lowest water contents of the paddy field were maintained at 85% field capacity from 7 days after transplanting to effective tillering stage, 70% field capacity from effective tillering stage to emergence of the second leaf from the top, 85% field capacity from emergence of the second leaf from the top to ten days after heading, and 75% field capacity from 10days after heading to maturity. When soil water was lower than the lowest water content, no water layer was added in the afternoon.

Under TRC treatment, 28 to 30-day-old rice seedlings with five leaves were transplanted, with two seedlings per hill. A water layer of 1-5 cm deep was maintained on the rice field during the entire growth period except at the ineffective tillering stage, which was under moderate drought.

Experiment 1 was conducted in concrete boxes and designed as a randomized block with three replications. The concrete box was 1 m long, 1 m wide and 0.8 m high, with bottom coverage and rainproof at 2.5 m high. Uniformly mixed soil was loaded 30 days before transplanting, with total soil nitrogen and fast available nitrogen at 0.09% and 54.7 mg/kg, respectively; field capacity of top 10 cm soil layer was 25.89 g water per 100 g dry soil.

The experimental variety was Wuyuegeng 9 (local Indica cultivar), transplanting spacing was 25×15 cm; nitrogen rate was 300kg/ ha, and manual irrigation was provided and measured with tap water.

Experiment 2

This experiment was carried out in Jiangyin city, Jiangsu Province. Contents of soil total nitrogen, fast available nitrogen were 0.15% and 108.7 mg/kg respectively. The experiment consisted of three planting densities as 30×20 cm (D1), 25×25 cm (D2), 30×30 cm (D3) under SRI cultivation; plus the control with 30×12 cm planting density under conventional cultivation (TRC2). Detailed management practices were the same as in experiment 1, except that variety 9516 (a common Indica cultivar) was used. The experiment was designed in randomized block with three replications.

Experiment 3

This experiment was conducted in Jiangsu Academy of Agricultural Sciences. Contents of soil total nitrogen and fast available nitrogen were 0.12% and 85.1 mg/kg, respectively. The experiment consisted of six treatments as non nitrogen fertilization × one seedling per hill (S1), non nitrogen fertilization × two seedlings per hill (S2), 150 kg/ha nitrogen × one seedling per hill (S3), 150 kg/ha nitrogen × two seedlings per hill (S4), 300 kg/ha nitrogen × one seedling per hill (S5), 300 kg/ha nitrogen × two seedlings per hill (S6). The treatments were imposed under SRI cultivation, with 25×25 cm planting density; the same irrigation criteria and transplanted seedling age as in experiment 1. The control was 30×12 cm planting density under conventional cultivation (TRC2) with variety Wuxianggeng 9; other cultivation practices were the same as in experiment 1. The experiment was designed in randomized block with three replications.

Experiment 4

This experiment was carried out on Jiangpu farm of Nanjing Agricultural University. Contents of soil total nitrogen, fast available nitrogen were 0.14% and 99.6 mg/kg, respectively. Demonstration of SRI cultivation with normal Indica and hybrid rice was conducted in 3000 m^2 field, which was equally divided into four blocks.

The experiment consisted of four treatments: normal Indica rice × SRI (CSRI) with 25×25 cm planting density, one seedling per hill; normal Indica rice × conventional cultivation (CTRC), 25×15 cm planting density, two seedlings per hill; hybrid rice × SRI (HSRI), h 30×30 cm planting density, one seedling per hill; and hybrid rice × conventional cultivation (HTRC), 30×15 cm planting density, two seedlings per hill. Varieties used were Wuyuegeng 9 (Indica rice) and Liangyoupeijiu (hybrid rice). The other cultivation practices were the same as in experiment 1.

The seedlings in all experiments were raised in a dry-land nursery. Basal application of phosphorus and potassium fertilizers was done at rates of 135 kg P_2O_5/ha and 210 kg K_2O/ha. Nitrogen was applied as follows: 50% as basal fertilizer, 10% as tillering fertilizer; 20% as early flowering fertilizer, and 20% as late flowering fertilizer.

Measurements and Observations

A plastic ruler was inserted into a fixed position of each plot to measure water layer height. When no water layer in field was observed, soil water content down to 10 cm was measured with dry weight method after an interval of three days. Plant dry matter was measured at the stages of transplanting, effective tillering (N-n), jointing (n-2), heading, and maturity. 100 seedlings were sampled at transplanting stage; and at other stages, two to five hills of plants were sampled according to average tiller number in each plot to measure dry weights of leaves, stems, sheathes and spikes.

Total nitrogen, protein nitrogen and non-protein nitrogen were measured with Kjeldahl's method, soluble sugar and starch contents by Anthrone Colorimetric method, malondi-aldehyde (MDA) content with TBA method, Proline content with Acidic Ninhydrin method, and root oxygenation ability of ∝-NA was measured by consulting Zhangxianzheng method.

Results and Analysis

Physiological differences between SRI and conventional rices

Root activity

Figure 1 showed that during each development stage, root activity in SRI rice was significantly higher than in conventional rice (TRC). Root oxygenation ability of ∝-NA under SRI treatment was 1.9 times more than under TRC treatment at N-n stage, 2.3 times more at n-2 stage, 2 times more at heading stage and 2.9 times more at maturity. The enhanced root activity during the entire growth period, especially during late growth stage, was an important physiological characteristic in SRI rice plants.

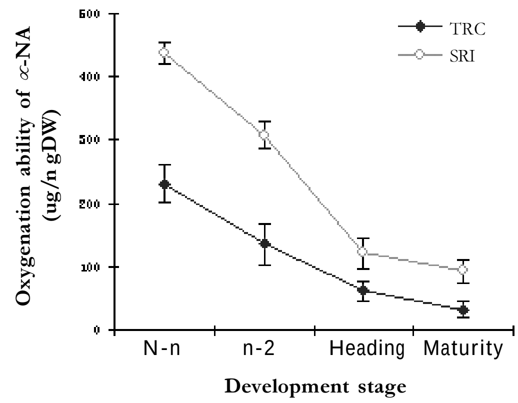
Carbohydrate and nitrogen content and physiological activity in leaf

Contents of soluble sugar, non-protein nitrogen, MDA and proline in leaves of SRI rice were obviously higher than those in conventional rice. Soluble sugar, non-protein nitrogen, MDA and proline contents in leaves of SRI rice were 54.5%, 24.6%, 32.7% and 11.7% higher at jointing stage, and were 61.5%, 23.4%, 103.8% and 26.5% higher at heading stage than those of conventional rice, respectively (Table 1). As main osmotic regulators in rice plant, accumulation of soluble sugars and non-protein nitrogen would enhance rice ability for drought tolerance, which was another important physiological characteristic of SRI rice. The higher content of MDA under SRI treatment implied that drought damage in SRI rice could be more serious than in TRC rice.

Assimilate translocation after heading

Accumulation of carbohydrates, nitrogen and dry matter in vegetative organs of rice reached the maximum at full heading stage; then the stored assimilates partitioned to spikes gradually. Table 2 shows that with SRI treatment, the absolute partitioning rate of stored matter from vegetative organs was remarkably higher than with TRC treatment. The rates of dry matter and stored carbohydrate from leaves were more than three times, and from stems and sheathes were about 1.4 to 1.7 times of those with TRC treatment. The total translocation of nitrogen from leaves, stems and sheathes was 66.9% higher, and apparent translocation percentage from leaves, stems and sheathes were distinctively higher than with TRC treatment. Higher translocation and conversion rates of stored matter from vegetative organs was of significant importance for enhanced grain filling and spike weight in SRI rice.

Figure 1. Root activity in SRI and conventional rices (Wuxianggeng 9)



Differences in population development between SRI and conventional rices

Population tiller number and dry matter accumulation

Under typical SRI cultivation of one seedling per hill and slight drought stress in the paddy field, population tiller numbers including final spike number at all growth stages were obviously lower than those in conventional rice. Figure 2 shows that with SRI treatment, spike number was 5.4% lower than that with TRC treatment. Harvest yield with SRI treatment was 7846.2 kg/ ha at maturity, 5.5% lower than that with TRC treatment (significant difference). The reduction in spike number was proportional to yield reduction, indicating that a lack in spike number largely limited the harvest yield of SRI rice.

At the jointing stage, dry matter accumulations under SRI and TRC treatments were 3916 kg/ha and 4096 kg/ha, respectively. At heading and maturity stages, dry matter accumulation under SRI treatment were 10,479 and 19,139 kg/ha, slightly higher than 10,136 and 18,910 kg/ha under TRC treatment with the differences insignificant.

Table 1. Contents of soluble sugar, non-protein nitrogen, malondialdehyde (MDA), and prolinein leaves of SRI and conventional rices (Wuxianggeng 9)

Treatment	Development stage	Content of soluble sugar (umol/gFW)	Content of non-protein nitrogen (g/kg DW)	Content of malondialdehyde (nmol/gFW)	Content of proline (ug/gFW)
TRC	Jointing	30.32±2.17	5.7±0.4	7.37±0.31	13.54±0.65
	Heading	198.51±17.81	7.7±0.7	10.25±0.66	14.53±1.54
SRI	Jointing	46.84±3.11	7.1±0.7	9.78±1.01	15.13±0.20
	Heading	320.63±20.38	9.5±0.1	20.89±1.42	18.38±1.61

Table 2. Translocation of assimilate in SRI and conventional rices (Wuxianggeng 9)

			Translocation of assimilate from organs (kg/ha)			Apparent translocation percentage (%)			Apparent conversion percentage (%)		
Treat-ment	Item	Net accumulation in spike (kg/ha)	Leaf	Stem & sheath	Leaf, stem& sheath	Leaf	Stem & sheath	Leaf, stem & sheath	Leaf	Stem & sheath	Leaf, stem & sheath
TRC	Dry matter	9403.2	110.1	518.9	629.1	3.5	10.6	7.8	1.2	5.5	6.7
	Carbohydrate	7376.6	76.9	343.1	419.9	26.0	47.6	41.3	1.0	4.7	5.7
	Nitrogen	90.9	12.4	18.1	30.5	18.4	30.7	24.1	13.6	19.9	33.5
SRI	Dry matter	9889.3	341.1	887.7	1228.8	9.9	18.3	14.8	3.5	9.0	12.5
	Carbohydrate	8414.9	242.4	488.2	730.6	55.7	60.7	59.0	2.9	5.8	8.7
	Nitrogen	95.3	21.8	29.2	50.9	31.5	45.5	38.3	22.9	30.6	53.5

*Note: Apparent translocation percentage (%) = [dry matter or carbohydrate or nitrogen at full heading stage - dry matter or carbohydrate or nitrogen at maturity] / dry matter or carbohydrate or nitrogen at full heading stage * 100*

*Apparent conversion percentage (%) = [dry matter or carbohydrate or nitrogen of organs at full heading stage - dry matter or carbohydrate or nitrogen of organs at maturity] / net accumulation of dry matter or carbohydrate or nitrogen in spikes * 100*

Differences between SRI and TRC treatments were highly significant (P<0.01)

Table 3. Population quality indices of SRI and conventional rices (Wuxianggeng 9)

	Heading stage						
Treatment	LAI	Effective LAI	Effective leaf area percentage (%)	Total spikelet number (million/ha)	Spikelet number per unit leaf area (number/cm2)	Dry weight of stems and sheathes (g/Tiller)	Percentage of productive tillers (%)
TRC	7.85	7.14	90.93	365.44	0.465	1.79	67.29
SRI	7.13**	6.99	97.97**	370.09	0.519**	1.87	77.17**

*** Difference between SRI and TRC treatments highly significant (P<0.01).*

Population quality

SRI cultivation had an improving effect on population quality (Table 3). Percentage of productive tillers under SRI treatment was distinctively higher than that under TRC treatment. Total population spikelet number, single stem and sheath weight, and spikelet number per unit leaf area at heading stage of SRI exhibited an increasing trend, and thus sink demand for source assimilate was enhanced, which might be the fundamental reason for higher assimilate translocation percentage in SRI rice.

Figure 2. Tiller dynamic of SRI and conventional cultivation rice (Wuxianggeng 9)

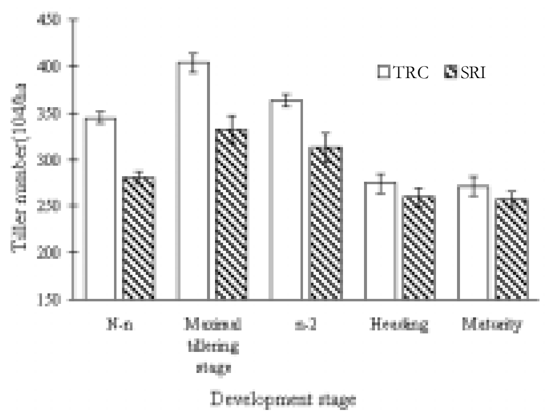
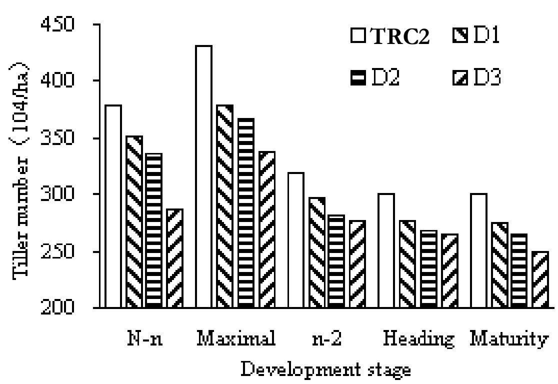


Figure 3. Population tiller number in SRI rice with different planting standards



Impact of cultivation factors on growth and yield of SRI rice

Regulation of transplanting standard on tiller number and yield

With the increase in planting density from 30×30 cm to 30×20 cm — 111.100 to 166.700 ten thousand/ha — the population tiller number of SRI rice during main growth stages was enhanced to a certain degree, with the largest increase at N-n stage. Planting density under D1 treatment was higher than that under D2 and D3 treatments, yet tiller number at N-n stage under D1 treatment was slightly lower than that under conventional cultivation (Figure 3). The number of matured spikes with the three planting densities under SRI cultivation was 8.2%, 11.5% and 16.8% lower than under conventional cultivation, and yields decreased 4.1%, 7.8% and 5.9% respectively (Table 4). These data indicate that increasing planting density could only partly compensate for the limited capacity in tiller production with the SRI.

Impact of combining density and N on population quality, photosynthetic ability, and yield

Increasing seedling number per hill and nitrogen fertilization can promote the population development in SRI (Figure 4). Population tiller number at effective tillering stage with two seedlings per hill was remarkably enhanced as compared to one seedling per hill. The effect of nitrogen fertilization on tiller number was greater with treatment of two seedlings per hill than with one seedling per hill. When the rate of nitrogen fertilization was over 150 kg/ha N, the population tiller number at effective tillering stage under the two

Table 4. Yield and yield components of SRI rice with different planting standards

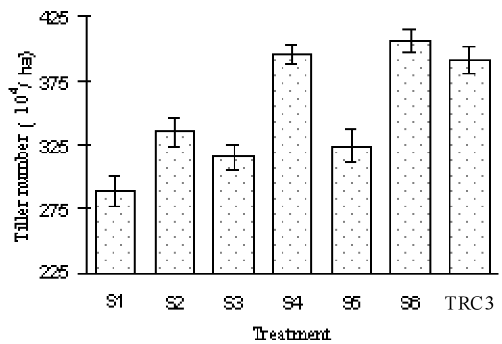
Planting standard	Spike number (10^4/ha)	Grain number per spike	Percent ripened grains (%)	Thousand grain weight (g)	Yield (kg/ha)
D1 (30 x 30 cm)	274.80	128.45	94.10	26.53	8535.0
D2 (25 x 25 cm)	265.05	126.45	93.55	26.72	8205.0
D3 (30 x 30 cm)	249.15	152.23	87.01	26.96	8370.0
TRC2 (30 x 12 cm)	299.55	130.35	89.51	26.17	8896.5

seedlings per hill (S4 and S6 treatments) was higher than under conventional cultivation. These results indicated that a combination of two seedlings per hill and suitable nitrogen rate could promote population tiller number in SRI rice up to that in conventional rice.

Dry matter accumulation at heading stage enhanced with the increasing nitrogen rate, and the effect was 1000 kg/ha greater under two seedlings per hill than under one seedling per hill, and was over 2000 kg/ha higher at 300 kg/ha N than at 150 kg/ha N (Table 5). Enhancement of seedling number per hill appeared to increase dry matter production after heading, although the difference was insignificant, whereas excess nitrogen tended to decrease dry matter production after heading. For example, dry matter production after heading under S6 treatment was 6.7% lower than that under S4 treatment.

Table 6 shows that effective and high effective leaf area percentages were higher with two seedlings per hill than with one seedling per hill, but lowered at highest N rate. With increased N, the chlorophyll content (SPAD), the maximum fluorescence efficiency (Fv/Fm) and photosynthetic rate of the last four leaves at heading stage was enhanced, but the extinction coefficient increased remarkably, and thus light penetration ability into the canopy decreased. The results indicated that the treatment of two seedlings per hill could increase effective and high effective leaf area percentages, but decrease photosynthesis ability of single leaf, whereas enhanced nitrogen rate could increase population LAI and photosynthesis ability of single leaf, but decreased effective and high effective leaf area percentage and light penetration ability.

Figure 4. Population tiller number at N-n stage with the treatments combining density and fertilizer (Wuxianggeng 9)



Yield and yield components remarkably differed under the treatments combining different densities and N rates. Harvested spike number with two seedlings per hill was higher than that with one seedling per hill, and was reduced with decreasing N rates. Grain number per spike was enhanced significantly with the increasing nitrogen rate. The percentage of ripened grains and thousand-grain weight with one seedling per hill tended to be higher than with two seedlings per hill. Percentage of ripened grains at different nitrogen levels was in the following order: low nitrogen > no nitrogen > high nitrogen. Thousand-grain weight appeared to

Table 5. Main population quality indices with the treatments combining density and fertilization (Wuxianggeng 9)

	Heading stage						
Treatment	LAI	Spikelet number (million/ha)	Spikelet number per unit leaf area (number/cm2)	Weight of stem and sheathe (g/Tiller)	Dry matter accumulation (kg/ha)	Dry matter accumulation after heading (kg/ha)	Percentage productive tillers (%)
S1	4.53 fD	253.7 eD	0.56 eD	1.63 dE	6863.7 fF	6662.9 a	73.65 eD
S2	5.14 eD	359.8 dC	0.70 bAB	1.91 bB	8136.5 eE	7697.1 a	84.66 bB
S3	5.83 dC	408.1 cdC	0.70 bAB	1.80 bcBCD	9500.6 dD	7144.5 a	79.29 cC
S4	6.96 cB	515.0 aA	0.74 aA	2.14 aA	10617.1 cC	7833.1 a	88.35 aA
S5	7.28 bcB	458.6 bB	0.63 cdC	1.74 cdCDE	11714.1 bB	6852.0 a	77.14 dC
S6	8.24 aA	535.6 aA	0.65 cBC	1.85 bcBC	12853.3 aA	7306.1 a	85.81 bAB
TRC3	7.52 bB	451.9 cBC	0.60 dCD	1.67 dDE	11746.7 bB	6442.7 a	84.87 bB

Table 6. Photosynthetic ability at heading under the treatments combining density and fertilization (Wuxianggeng 9)

Treatment	Effective leaf area (%)	High effective leaf area (%)	Average value of the last four leaves			Population extinction coefficient
			SPAD	Fv/Fm	Photosynthetic rate	
S1	88.62	79.90	40.42	0.698	13.5	0.160
S2	94.81	84.65	39.24	0.696	12.8	0.178
S3	93.19	81.65	43.62	0.705	16.3	0.183
S4	97.69	85.72	42.28	0.701	15.1	0.194
S5	90.35	79.02	46.52	0.766	17.9	0.208
S6	93.43	82.88	45.47	0.752	17.8	0.224
TRC3	84.78	75.48	46.59	0.712	19.6	0.249

Table 7. Yield and yield components with the treatments combining density and fertilization (Wuxianggeng 9)

Treat-ment	Spike number (10^4/ha)	Percent of grain number per spike	Percentage of ripened grains (%)	Thousand-grain weight (g)	Yield (kg/ha)	Harvest Index (HI)
S1	222.04 fD	108.43 cC	91.39 bcB	27.73 aA	6236.4 eD	0.461 bcAb
S2	300.76 deC	109.43 cC	81.76 eD	24.37 cB	6397.7 dC	0.404 dB
S3	289.51 eC	116.47 bB	95.76 aA	26.30 abAB	8432.0 cB	0.507 aA
S4	363.99 bA	120.84 aA	86.70 dC	24.53 bcB	9253.2 aA	0.502 abA
S5	313.38 dBC	120.09 aA	90.11 cB	26.18 abAB	8694.2 bB	0.492 abA
S6	385.22 aA	108.96 cC	82.07 eD	25.26 bcAB	8479.9 bcB	0.421 cdB
TRC3	334.11 cB	115.64 bB	91.60 bB	25.86 bcAb	9050.8 bB	0.498 abA

decrease with enhanced nitrogen. The S4 treatment produced the maximum yield with 9253.2 kg/ha, as compared to the yield of TRC3 at 9050.8 kg/ha (Table 7). Data also indicated that two seedlings per hill accelerated assimilate distribution into grains under SRI cultivation, but high nitrogen inhibited translocation of stored assimilate from vegetative organs to grains. Thus, the combination of moderate nitrogen and two seedlings per hill was in favor of yield increase with SRI rice.

Responses of normal Indica rice and hybrid rice to SRI cultivation

Experiments with normal Indica rice and hybrid rice showed that responses to SRI cultivation differed with genotypes. Since hybrid rice had strong tillering ability and vegetative growth advantage, tiller number at effective tillering stage and spike number were similar between SRI and conventional cultivation. In contrast, significant differences were observed with Indica rice (Figure.5). Under SRI cultivation, dry matter accumulation at effective tillering stage and from heading to maturity with Indica rice decreased, whereas with hybrid rice, dry matter accumulation decreased only during ineffective tillering stage, but did not decrease during effective tillering stage and from heading to maturity (Figure 6). Yield under CS treatment was distinctively lower than that under CC treatment, but yield under HS treatment was close to that under HC treatment (Table 8).

Table 8. Yield and yield components for normal Indica and hybrid rices

Treatment		Spike number (10^4/ha)	Grain number per spike (grain/spike)	Percentage of ripened grains (%)	Thousand grain weight (g)	Yield (kg/ha)
Variety	Method					
Conv.	SRI (CS)	326.7	124.8	93.8	26.2	9837.0
Conv.	Conv. (CC)	363.5	122.2	91.3	26.7	10581.0
Hybrid	SRI (HS)	312.2	196.0	91.6	21.2	11749.5
Hybrid	Conv. (HC)	314.1	194.8	92.3	20.6	11497.5

Discussion

Physiological demand of water by the rice plant is indispensable for normal metabolic activities, but ecological water demand has certain flexibility. With the root zone kept moist under SRI cultivation, supplemental gas and heat were continuously provided into the soil on the basis of meeting physiological water demand, thus making the soil environment more suitable for rice root growth. This could be a major reason for enhanced root activity in rice plant of SRI. The reduced ecological water supply under SRI created a slight drought stress, as seen with the increased contents of soluble sugar, proline and malondialdehyde (MDA) in leaves. This water stress had little impact on hybrid rice with strong root and vegetative growth advantage, but did obvious impact on Indica rice with weak root and tillering ability, resulting in yield decrease in Indica rice. Thus, with Indica rice, improved cultivation techniques are needed under the SRI, such as enlarging population by two seedlings per hill.

Translocation rate and percentage of assimilate from leaves, stems and sheathes, conversion percentage of stored assimilate before heading, and harvest index with SRI rice were all higher than with conventional rice. It seems that slight drought stress improved population quality, especially grain number per unit leaf area at heading stage increased remarkably; thus the sink became larger and the source became smaller, and single plants became stronger. On the other hand, the leaf age at transplanting was young with the SRI, thus tillers occurred earlier and at lower tillering nodes on the stem. Commonly, SRI rice was transplanted with just two leaves, three leaves less than with conventional rice, and tillering began at five leaves. Maximum tiller number usually occurs before effective tillering stage when rice if grown under conventional (flooded) conditions. Tiller number was smaller with

Figure 5. Difference of tiller number between normal Indica rice and hybrid rice

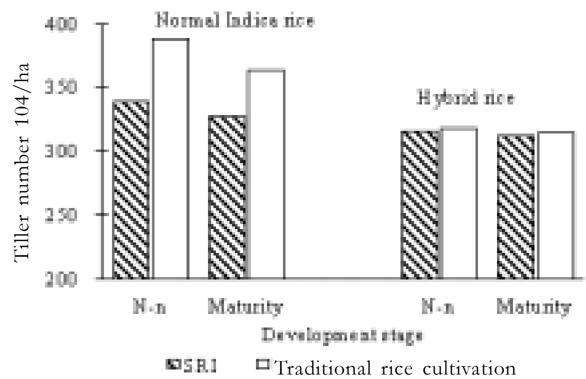
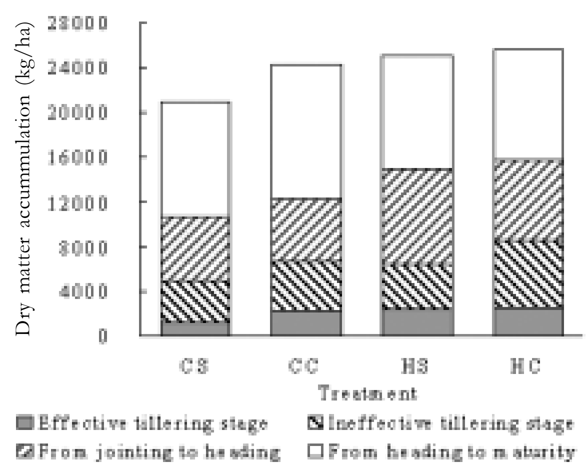


Figure 6. Difference of dry matter accumulation between normal Indica rice and hybrid rice



SRI, but tillers were larger and stronger, and single stem and sheath weight at heading was remarkably higher than with conventional rice.

In experiment 1, rice irrigation application was strictly measured. Without impact of rainfall and leakage, average irrigation provided during the whole rice growth period under SRI was 5,500 t/ha, about half of the 10,220 t/ha provided under conventional cultivation. Thus, water-saving efficiency under SRI was remarkable, with a 75% increase in irrigation water-to-grain ratio. However, irrigation applications during vigorous growth period were frequent, averaging one time every five to seven days; thus the labor cost of irrigation was fairly expensive. Further studies are needed to develop more effective irrigation techniques for SRI cultivation.

Tillering Patterns and the Contribution of Tillers to Grain Yield with Hybrid Rice and Wide Spacing

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The reported success of SRI is based on the synergetic development of both the tillers and roots. With more vigorous root growth, plants can become both fuller and taller and get better access to the nutrients and water they need to produce more tillers and more yield. The practices of SRI include: early transplanting, wide spacing and planting one plant per hill, with application of compost, frequent weeding, and less use irrigation water in order to capture the full potential for tillering and root growth (Uphoff, 2001).

In recent years, planting practices in China have been shifting from close spacing to wider spacing in high-yielding cultivation, especially for hybrid rice varieties. This improves the canopy's photosynthesis, increases the percentage of productive tillers, and the spikelet number per panicle. At same time, in combination with less irrigation water, pests may be better controlled and lodging prevented (Zhu, 2002).

However, there is little knowledge available about the contributions of tillering to yield and what are reasonable numbers of productive tillers per plant to aim for with wider spacing so as to get the best rice production. In this paper, the results of several studies on the pattern of tillering and the contributions of greater tillering to yield with wide spacing are reported.

Materials and Methods

Experiment 1

Spikelet numbers per panicle according to tillers from different orders (sequences) was studied in 2000 using hybrid rice varieties 65002 and Shanyou 63 in pot experiments. The pot size was 20 cm in diameter and 30 cm in height. Single plants with tillering in the fourth phyllochron were transplanted into pots containing clay soil, with 20 plants of each variety planted in this way.

The emergence of primary, secondary and tertiary tillers was recorded separately, and each tiller was marked with a plastic label every second day. Twenty replications per variety were harvested at 5 days after heading. Panicles from different tiller orders were separated carefully, and the spikelet numbers for each panicle in different tiller orders were determined.

Experiment 2

The effects of having a different numbers of productive tillers per plant on spikelet numbers per panicle were studied also in 2000. The same hybrid rice varieties, 65002 and Shanyou 63, were used in pots sized 20 cm in diameter and 30 cm in height. Single seedlings with tillering in the fifth phyllochron were transplanted in each pot. By removing late small tillers every 3 days, tillers per plant were controlled to be 3, 6, 9, 12 and 15. The experiment had ten replications. At harvest, the ten replications were harvested, and spikelet number per panicle was counted.

Experiment 3

An experiment was done under field conditions in 2001 with different spacings and three replications. Two hybrid rice varieties, Xieyou 9308 and Youming 8, were used. Plant density was 7, 9, 11 and 13 hills per m^2. One 21-day seedling per hill was transplanted. (Note that this is older than the recommended seedling age with SRI practices — 8-12 days old, with a maximum of 15 days.) The results of this experiment would not necessarily reveal much about tillering dynamics with SRI methodology, but it is interesting in any case to know more about tillering patterns. The plot size was 3 by 4 m.

Tiller numbers in each plot were counted every 4 days from 12 sampled plants between transplanting and heading. Only tillers that had at least one green leaf were counted. The percentage of productive tillers was calculated as panicle number divided by the maximum tiller number per plant. At maturity, a sample of 5m^2 was harvested from each plot. The panicles were threshed, dried and weighed, and grain yield was adjusted to 14% moisture content.

Results and Discussion

Components of different types of tillers and spikelet number

The numbers of tillers that emerged from the main tiller and subsequent tillers according to respective tiller orders (main, primary, secondary, tertiary) reflecting their sequence of emergence are indicated in Figure 1. The number of total tillers and tertiary tillers increased exponentially as the number of *phyllochrons* (often referred to as leaf number) advanced.[1] It was the growth in number of tertiary tillers that drove the total number up so sharply.

The number of primary and secondary tillers increased more linearly with the advance of phyllochrons (the number of periods of tiller emergence). The first primary tiller emerges from the main tiller in the fourth phyllochron, with additional primary tillers up to six in the next five phyllochron periods. The first secondary tiller comes out later, from the base of the first primary tiller, in the seventh phyllochron, while the first tertiary tiller emerges from the base of the first secondary tiller in the tenth phyllochron.[2]

[1] *Phyllochrons are a regular interval or period of plant growth observable for all gramineae species. These 'growth cycles' can be as short as 5 days (under ideal growth conditions) or up to 10 days (with less favorable conditions). During each phyllochron beyond the third, one or more phytomers (a unit of tiller, leaf and root) are produced from the plant's apical meristematic tissue. They are particularly important for rice, which is a potentially high-tillering plant provided that its root system is intact and the root system and canopy are not constrained by crowding. Between 6 and 12 phyllochrons may be completed before panicle initiation, when vegetative growth stops and the plant goes into its reproductive phase. The most detailed discussion of phyllochrons in rice in English language is by Nemoto et al. (1995), though they were first identified and analyzed by a Japanese researcher, T. Katayama, about 75 years ago. In 1995, a special issue of the journal Crop Science (Vol. 35, No.1) was devoted to phyllochrons, though mostly with respect to wheat. For more on phyllochrons, see Moreau (1976) and Matsuo et al. (1997: 223-226). [Editors.]*

[2] *The detailed work on phyllochrons by Fr. de Laulanié (1993), who developed SRI, found somewhat different numbers. He agrees that the first primary tiller emerges in the 4th phyllochron, but according to his observations, the first secondary tiller emerges in the 6th phyllochron, and the first tertiary tiller in the 8th phyllochron. A total of 84 tillers should be possible by the end of the 12th phyllochron according to Laulanié's calculations (a) if that many could be completed before panicle initiation, (b) if the plant has not lost much of its root system due to hypoxia and (c) if its root and tiller growth is not constrained by close planting. [Editors.]*

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The distribution of different types of tillers at the various phyllochron stages is indicated in Figure 2. The percentage of primary tillers among total tillers decreased with the increase of phyllochron. The peak percentage of secondary tillers occurs in the tenth phyllochron; after that, the percentage decreases slowly.

Figure 1. Theoretical numbers of different types of tillers produced in successive phyllochrons

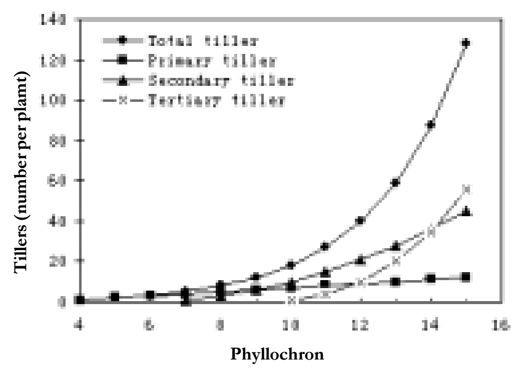
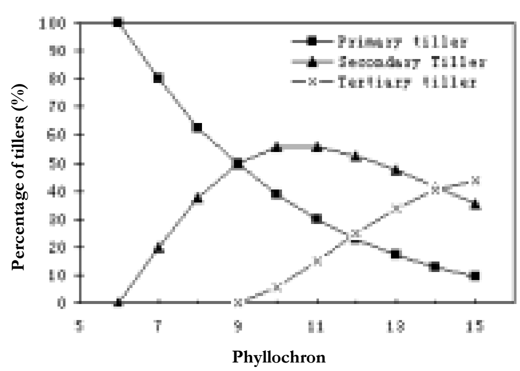


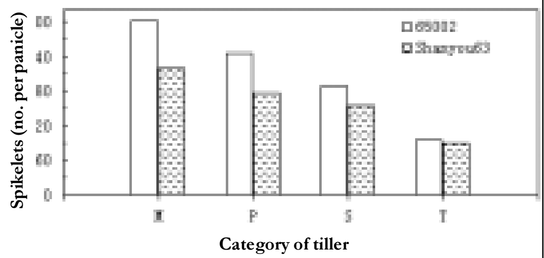
Figure 2. Components of different types of tillers calculated theoretically according to increasing number of phyllochrons



The percentage of teritary tillers increases from the ninth phyllochron by about 5% in the increase of each phyllochron. Therefore, after the ninth phyllochron, the percentage of tertiary and secondary tillers among total tillers increases. Theoretically, with the advance of phyllochrons, especially after the ninth period, small and late emergent tillers will occupy a large portion of the total number of tillers in the rice plant. Reasonable tiller number should be a consideration in assessing the components of panicle performance for high-yielding cultivation of rice.

Observation of spikelet numbers for different types of tillers indicated that the spikelet number per panicle decreased linearly with the advance of tiller order (Figure 3). Spikelet number per panicle on tertiary tillers is only one-third of the spikelet number per panicle found on the main tiller. Kim (1991) found the same results in tropical rice varieties with different tillering capacity. It was seen that the percentage of productive tillers among tertiary tiller is much lower than for primary tillers. Tertiary tillers and late primary and secondary tillers make little contribution to grain yield. In high-yielding cultivation, therefore, getting more early and bigger primary and secondary tillers should be explored, while late small primary, secondary and tertiary tillers may be controlled because they are less fertile.[3]

Figure 3. Spikelet number per panicle on different types of tillers



Rice varieties 65002 and Shanyou 63
M = main, P = primary, S = secondary, T = tertiary

Productive tillers per hill and their distribution with sparse planting

In farmers' rice fields with hybrid rice, about 20 hill per m^2 with one plant per hill are commonly planted. In that case, the average of number of panicles per hill is 14, with panicle number per hill largely distributed between 10 to 18 with hybrid varieties (Figure 4).

However, with wider spacing of only 9 or 11 hills per m^2, planting one plant per hill of Youming 86, the average number of panicles per hill was 23.7 and 19.7, respectively. Panicle number per hill was largely distributed between 22 and 28 at 9 hills per m^2, and between 16 and 22 at 11 hills per m^2 (see Figure 5).

For variety Xieyou 9308, with the wide spacing of 9 and 11 hills per m^2 and one plant per hill, the average numbers of panicles per hill were 26.5 and 19.7, respectively. Panicle numbers per hill were largely distributed between 26 and 30 at 9 hills per m^2, and between 18 and 22 at 11 hills per m^2 (see Figure 6). Clearly, with a decrease in density, the panicle number per hill increases, though it is panicle number per square meter that is most important for yield.

Effects of number of panicles per plant on spikelet numbers per panicle

The spikelet number per panicle and its variation seen with controlled numbers of productive tillers are shown in Figure 7. For both Shanyou 63 and Xieyou 9308, with an increase in panicle number per hill, the spikelets per panicle decrease linearly while their variation increases. Panicle number per hill increased from 3 to 15, but the spikelet number per panicle decreased by 41% in Shanyou 63 and 51 % in Xieyou 9308. The decrease in spikelet number per panicle in Shanyou 63 which has high tillering capacity is more than that in Xieyou 9308 which has lower tillering capacity. The more the number of panicles per hill is, the fewer spikelets per panicle.[4]

Relation of the percentage of productive tillers to tillering pattern

When transplanting small seedlings, the tiller number per hill increased linearly up to maximum tillering stage in both Xieyou 9308 and Youming 86 (Figures 8 and 9). The maximum number of tillers per hill reached 45 and 40 with densities of 9 and 11 hill per m^2 in Youming 86, respectively, and 50 and 43 at densities of 9 and 11 hill per m^2 in Xieyou 9308. The percentage of productive tillers was between 43 % and 67 % for Youming 86 (Figure 8) and 44% and 74% for Xieyou 9308 (Figure 9). With an increase in the maximum tiller number, the

[3] *This conclusion may, however, be conditioned by soil and water management practices. With SRI practices, which support a large and healthy root system throughout the crop cycle, the performance of secondary and tertiary is reported to be greater in terms of spikelets and filled grains, so one may not want to limit them.*

[4] *This is the general pattern reported in the literature. However, with SRI practices, one often observes a positive rather than inverse relationship between number of panicles and grains per panicle. This is what accounts for the increase in per area yield.*

Figure 4. Distribution of panicles of Xieyou 63 and Xieyou 9308 at 20 hills/m²

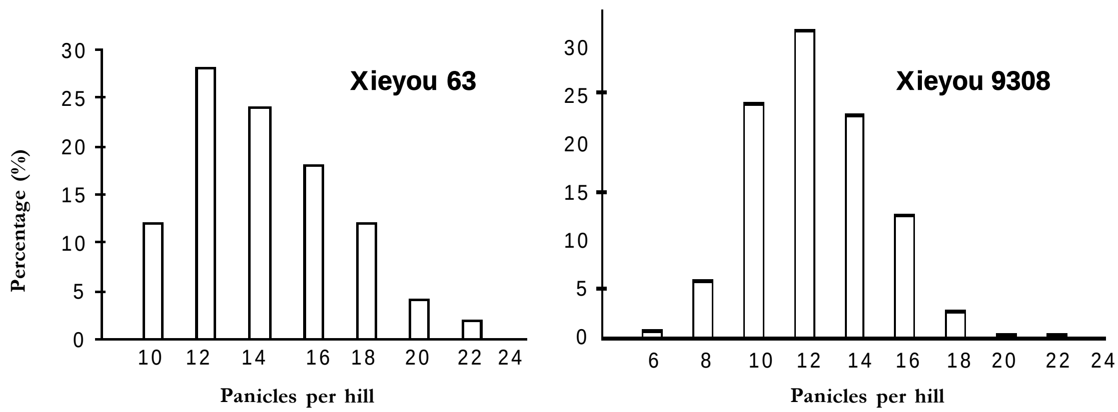


Figure 5. Distribution of panicles of Youming 86 at different densities

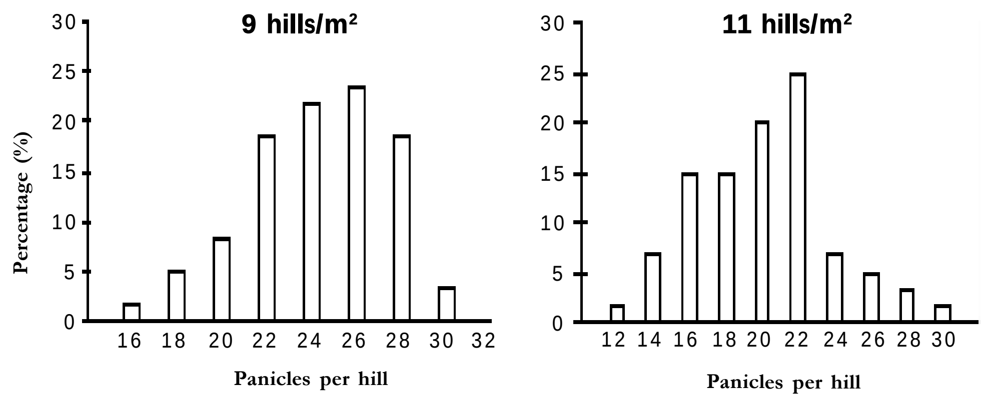
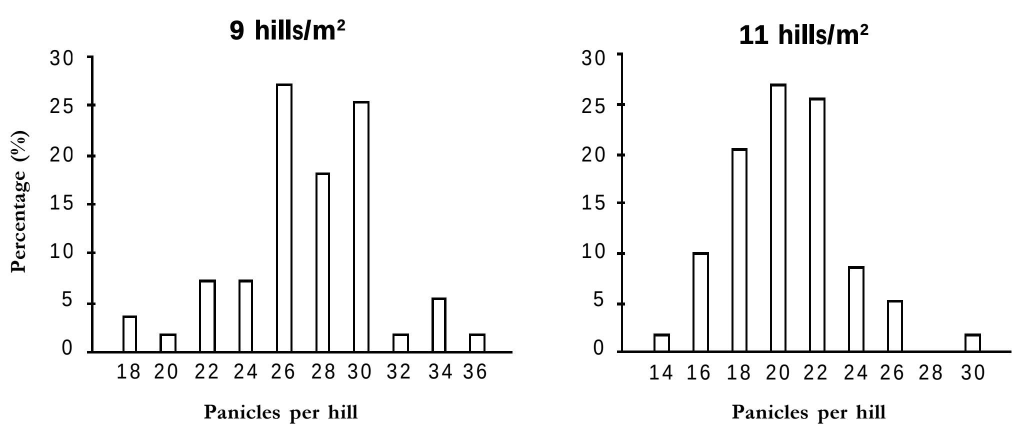


Figure 6. Distribution of panicles of Xieyou 9308 at different densities



percentage of productive tillers decreased, however. The higher the peak of the maximum tiller number, the lower was the percentage of effective tillers.

Comparison of root distribution with different plant spacing

Compared to the closer spacing of 17 hill per m^2 with Xieyou 9308, total roots per plant are higher with the wider spacing of 11 hill per m^2. However, with the wider spacing, most roots are distributed in the top layer, and roots become shallower (Figure 10). Also, roots per stem with the wider spacing decreased in different soil layers, with roots below 5 cm from the soil surface decreasing significantly (Figure 10). It seems that plant roots become shallower with the wider spacing. This may, however, reflect water management practices and the extent and depth of soil aeration.

Yield and its components with different plant spacing

Yield and its components with different spacings using Xieyou 9308 and Youming 86 are listed in Table 1. Yield was higher with closer spacing than with wider spacing. The difference in yield in different spacing was 0.7 t/ha with Xieyou 9308 and 0.5 t/ha with Youming 86. The yield with close spacing was mainly due to an increase in panicle number per unit of land and total spikelet number. The spikelets per panicle with wider spacing were higher than those with closer spacing.

Figure 7. Spikelet number and standard deviation (CV) of Shanyou 63 and Xieyou 9308 in different panicle number per hill

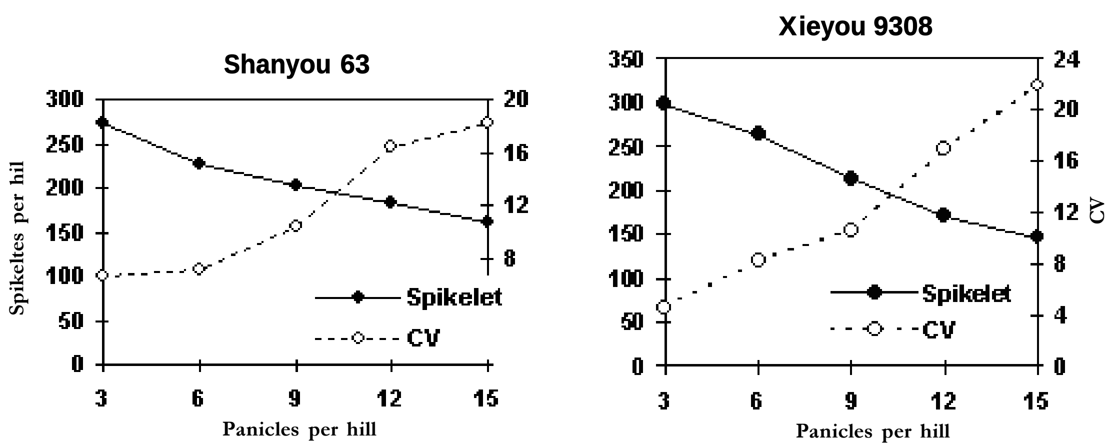


Figure 8. Tillering pattern of Youming 86 at different plant spacings with different percentages of productive tillers

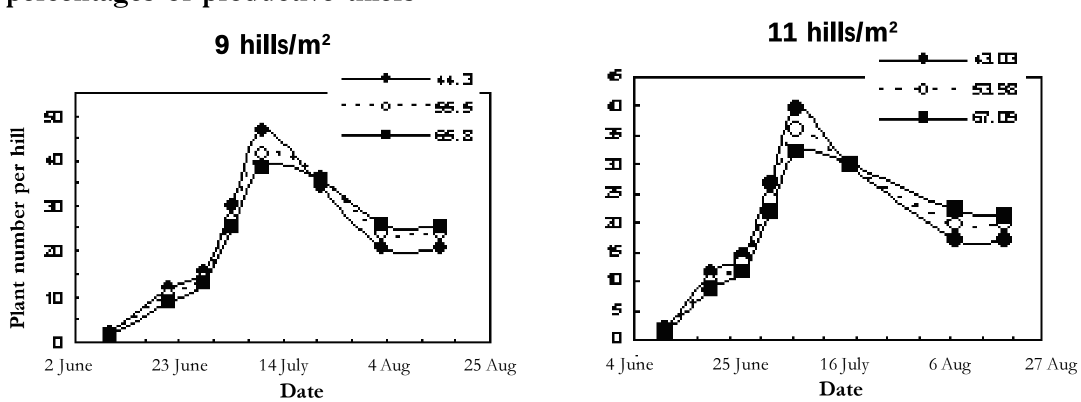


Figure 9. Tillering pattern of Xieyou 9308 at different plant spacings with different percentages of productive tillers

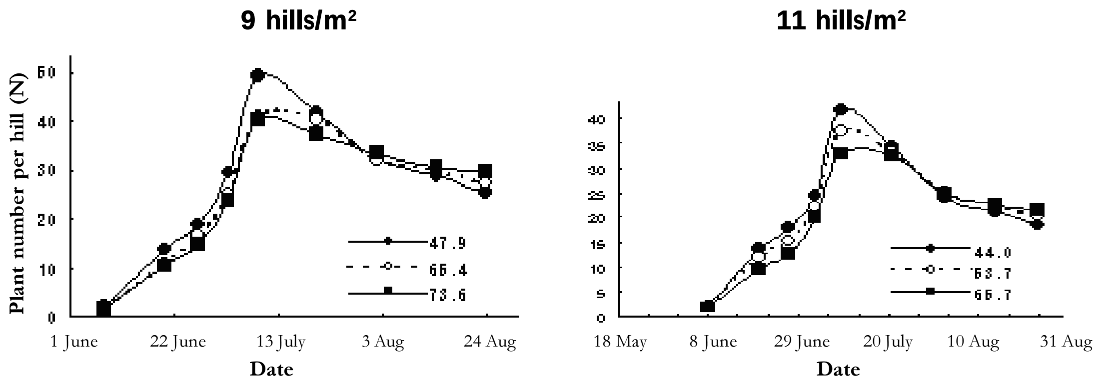


Figure 10. Distribution of root dry weight at different plant spacings in Xieyou 9308

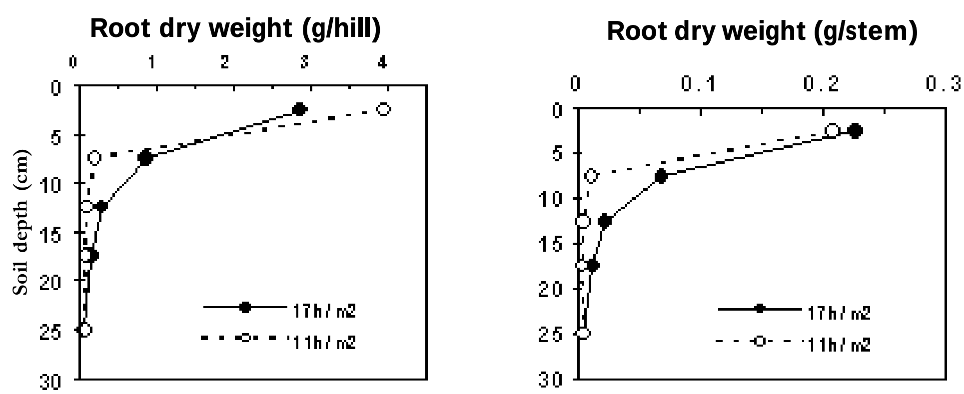


Table 1. Yield and its components with Shanyou 63 and Youming 86 at wider spacing

Hybrid variety	Density (hills/m²)	Panicles (No./m²)	Spikelets (No./panicle)	Spikelets (No./m²)	Total Fertility (%)	Grain weight (g/1000)	Yield (t/ha)
Xieyou 9308	7	185.1	161.9	29967.7	80.6	26.4	6.4
	9	203.0	159.3	32337.9	81.7	26.0	6.9
	11	201.1	157.9	31753.7	82.6	26.6	7.0
	13	219.0	153.7	33660.3	80.6	26.3	7.1
Youming 86	7	177.6	187.6	33317.8	84.8	26.7	7.5
	9	196.9	172.3	33925.9	84.3	27.0	7.7
	11	199.5	173.2	34553.4	83.9	27.3	7.9
	13	207.5	170.4	35358.0	82.2	27.4	8.0

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Physiological Effects of SRI Methods on the Rice Plant

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The physiological effects of different rice crop management systems were studied by comparing the results associated with traditional methods of flooded rice irrigation (TRC) to non-flooded rice farming with young seedlings and wider spacing (SRI). SRI, we observe, forms high biomass by large individual plants, and dry matter accumulation after heading accounted for 40% of the total dry matter. More than 45% of the material from stem and sheath was contributed to grain yield in SRI. At the same time, SRI facilitates a heavier and deeper root system.

However, several disadvantages were also observed with SRI: (1) There were less amount of root exudates with lower zeatin content and a lower respiration rate. (2) The flag leaf photosynthesis rate from filling stage to ripening stage decreased with SRI, and stomatal resistance was increased compared to traditional flooded irrigation. Some possible ways for increasing photosynthesis rate by improved physiological activity of the plant during the grain-filling stage were also examined.

Material and methods

Two hybrid rice varieties, Liangyou-peijiu (a two-line hybrid rice) and Xieyou 9308 (a three-line hybrid rice), were selected as testing material. The age of seedlings for the SRI trials was 15 days, with single seedlings planted at a density of 60,000 hill/ha. Water supply was limited and controlled, and 7.5 t/ha of organic fertilizer were applied as a basic treatment, with P and K supplied during panicle initiation. The TRC method was the traditional flooded irrigation system, with seedling age of 30 days, single seedlings, and transplanting density of 180,000 hill/ha. The factors observed were:

- Plant dry weight apportioning
- Light intensity in the canopy
- Distribution of root dry matter
- Weight-bearing ability on the base inter-node
- Output efficiency of the photo-nutrients
- Photosynthesis rate and stomatal resistance
- Root exudates, and
- Root respiration rate and cytokinin content.

Main results

Plant type with SRI

Larger individual plants were formed with SRI, facilitating better light distribution, as portrayed in the following figures.

Figure 1. Plant type and light intensity of SRI at heading stage

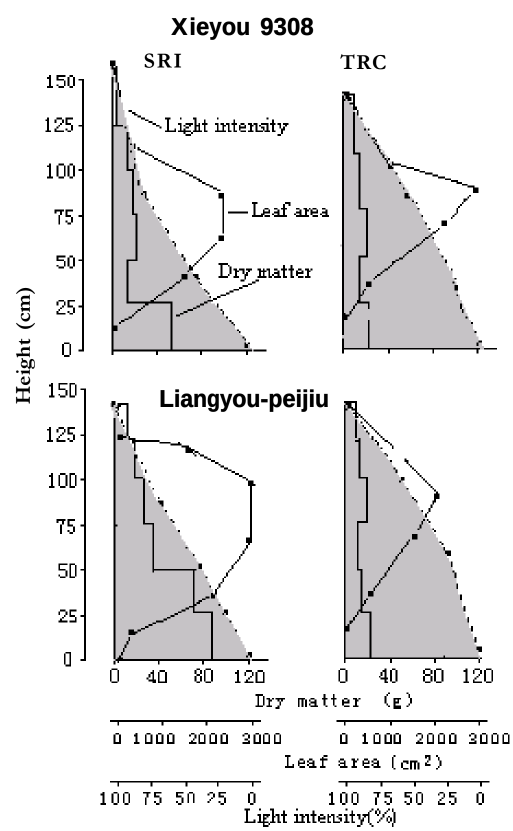


Figure 1 shows that (1) Plant height of Xieyou 9308 with SRI methods was higher than with TRC, although there was no significant difference in height for Liangyou-peijiu; (2) There was an evident difference in plant type between SRI and TRC for both hybrid varieties as the base inter-node weight-bearing ability (dry weight of the plant between 0~25 cm divided by the dry weight of the rest part of the plant) for Xieyou 9308 was 74.5% and 39.7% for SRI and TRC, respectively, and for Liangyou-peijiu, it was 63.4% and 33.3%; (3) The total leaf area with SRI was larger than with TRC for both hybrid varieties. Plant leaf area was mainly distributed at a height between 50 and 100 cm with SRI, and at 75 to 100 cm with TRC; (4) The plant type of SRI methods was improved with a better light distribution. With SRI, the light intensity of Xieyou 9308 at 75% of its height was 85% of the maximum, compared to 75% with TRC.

Root growth with SRI

Root growth was markedly greater in SRI plants. Figure 2 shows the root systems were distributed mainly from 0-20 cm depth in the soil. (1) Root dry weight per plant of Xieyou 9308 was 13.2 g and 8.2 g, respectively, with SRI and with TRC methods, and for Liangyou-peijiu, it was 9.8 g to 7.6 g; (2) Roots extended 10-15 cm deeper with SRI than with TRC.

Figure 2. Dry matter distribution of roots in SRI and TRC plants at heading stage

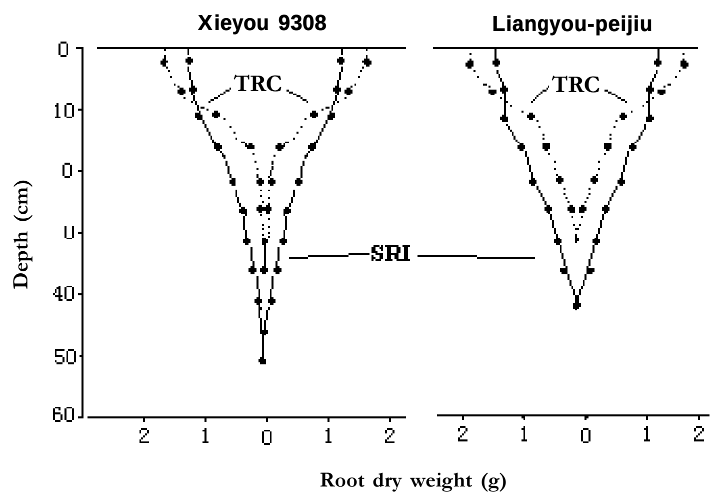


Table. 1 Dry matter production of rice plant on SRI (kg/ha)

Hybrid variety	Cultivation system	Initial tiller	During productive tillering	At panicle initiation	At heading	At yellow ripening
Xieyou 9308						
	SRI g/hill	1.31	25.8	49.1	168.3	276.0
	Kg/ha	78.6	1548	2946	10098	16560
	TRC g/hill	0.44	13.3	26.6	82.5	135.6
	Kg/ha	52.8	1596	3198	9903.5	16372
Liangyou-peijiu						
	SRI g/hill	0.86	28.6	56.4	207.4	340.0
	Kg/ha	51.6	1716	3384	12444	20400
	TRC g/hill	0.29	14.8	27.9	182.9	168.2
	Kg/ha	34.8	1776	3340	12352	20184

Dry matter production and distribution

From Table 1 we see that: (1) Dry matter accumulation for Liangyou-peijiu was higher than for Xieyou 9308 with both SRI and TRC methods; (2) Total plant dry weight with SRI was higher than with TRC, this difference becoming significant during the reproductive stage; (3) Biomass accumulation at full heading was about 40% of that for the total duration.

Figure 3 shows the photo-nutrient distribution during filling stage: (1) The output efficiency before the heading stage for Liangyou-peijiu was 47.3% and 38.0% for SRI and TRC, respectively, and for Xieyou 9308, it was 47.9% and 34.7%, respectively. The output efficiency was 10% greater with SRI than with TRC for both varieties; (2) The leaf sheath got yellow at the full heading stage for Xieyou 9308 with TRC, and at milk stage with SRI. The yellow leaf sheath appeared at the initial heading stage for Liangyou-peijiu, so Liangyou-peijiu appears more susceptible to senescence than Xieyou 9308; (3) The yellow leaf sheath in the base stem appeared later with SRI than with TRC.

Flag leaf photosynthesis rate and stomatal resistance

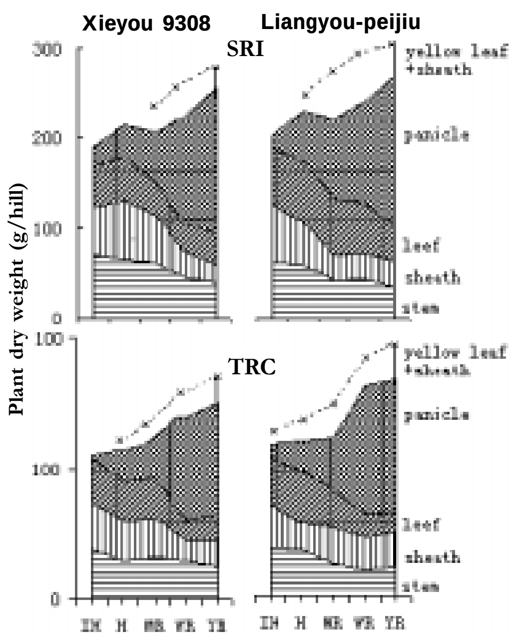
Figure 4 below shows that: (1) The flag leaf photosynthesis rate for both varieties was lower with SRI than with TRC; (2) Liangyou-peijiu suffered more than Xieyou 9308 as far as the photosynthesis rate was concerned; (3) The stomatal resistance rate increased after flowering for both varieties with SRI methods.

Root physiological activity of SRI

The amount of material exuded from the root when cut can be regarded as an index of root physiological activity and also as a signal of stem growth status. Note that this is not the same thing as "root exudates" which are the photosynthate that is exuded by the root system into the rhizosphere and utilized by soil biota.

It can be seen from Figure 5 that: (1) The material exuded by the root was, somewhat surprisingly, less with SRI than with TRC in both of the hybrid varieties used in this experiment; (2) This exudation increased as the stem and root system increased, and reached a maximum value at panicle initial stage, then sharply decreasing after heading stage. There was no significant

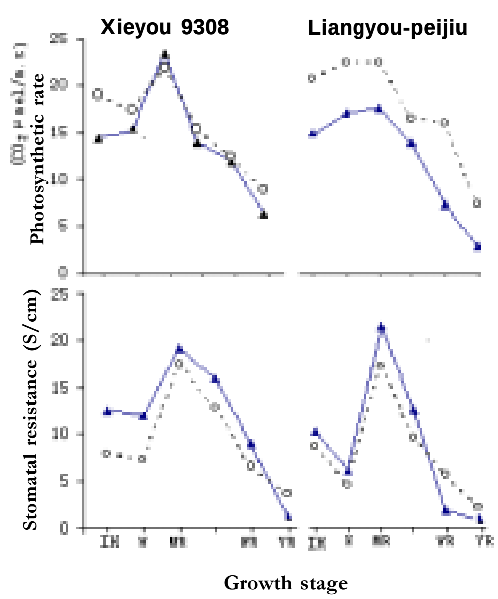
Figure 3. Dry matter distribution of rice plants during ripening stage



IH = Initial heading stage
H = Heading stage
MR = Milky ripening stage
WR = Wax ripening stage
YR = Yellow ripening stage

+—+ SRI o—o TRC

Figure 4. Photosynthetic and stomatal resistance rate of flag leaf during grain filling stage



IH = Initial heading stage
H = Heading stage
MR = Milky ripening stage
WR = Wax ripening stage
YR = Yellow ripening stage

•—• SRI o—o TRC

Figure 5. Root exudates with SRI

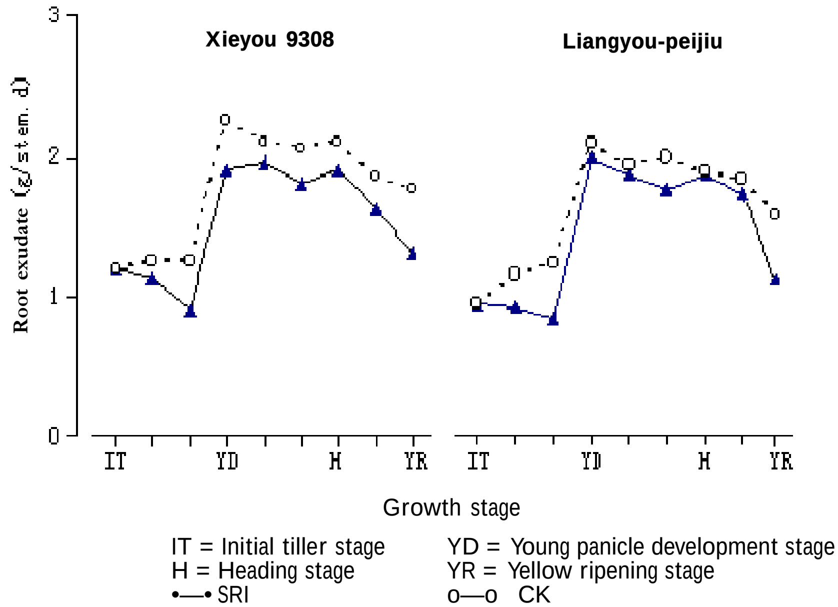
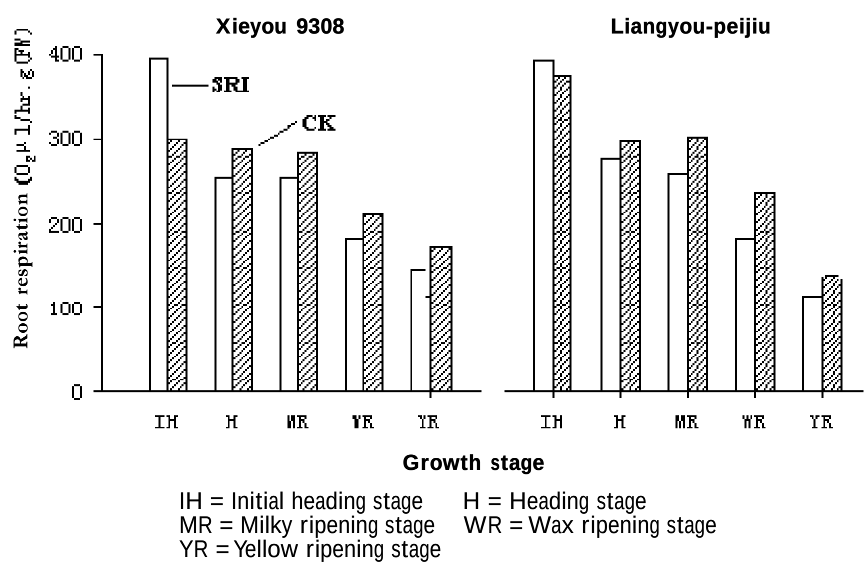


Figure 6. Root respiration rate on SRI and TRC



difference between SRI and TRC in this regard as far as exudation dynamics were concerned; (3) The range of exudation decreased in SRI plants during the grain-filling stage was larger than in TRC plants.

Some plant hormones were measured in this experiment, as shown in Table 2. (1) The amount of cytokinins in root exudates was higher in Xieyou 9308 than in Liangyou-pei-jiu; (2) The amount of diHZR, a non-active zeatin form, was increased, while active zeatin plus iPA decreased as the rice stem got older; (3) The total amount of CTKs decreased in SRI compared with TRC. What a decrease in the zeatin value caused by SRI

Table 2. Cytokinin content in root exudation of hybrid varieties by planting method and growth stage (pM)

	Hybrid Variety											
	Xeiyou 9308						Liangyou-peiju					
	SRI			TRC			SRI			TRC		
	IH	H	YR	IH	H	YR	IH	H	YR	IH	H	YR
Zeatin	26.0	30.1	1.2	29.5	25.6	7.6	19.0	24.0	ND	24.1	31.0	4.6
iPA	0.9	1.6	1.5	1.2	2.4	1.5	0.7	1.9	1.2	1.2	4.3	2.1
diHZR	1.7	2.9	35.4	1.2	7.3	27.5	13.3	13.8	30.4	13.2	7.6	28.4
CTKs	28.6	34.6	38.1	31.9	35.3	36.5	33.0	39.7	31.6	38.5	42.9	34.5

IH = Initial heading stage
H = Heading stage
MR = Milky ripening stage
WR = Wax ripening stage
YR = Yellow ripening stage
CTKs = Cytokinins
Z = Zeatin
iPA N^6 = isopentenyla adenosines
diHV = Dihydrozeatin riboside

methods means for plant performance is not clear but is worth further investigation. Overall plant growth was greater with SRI, so one might have expected these hormone values to be higher. We are obviously just beginning to gain an understanding of the physiological processes that are affected or induced by the plant, soil, water and nutrient management activities combined in SRI. There remains much interesting research to be done.

Experiments with a Modified System of Rice Intensification in INDIA

T. M. Thiyagarajan, Tamil Nadu Agricultural University[1]

Rice is the staple food for 65% of the population in India. The crop accounts for about 22% (42 million ha) of the total cropped area, 34% of the area under food crops, and 42% of the area under cereals. India is the second largest rice-producing country in the world. The rice output of 82 million tons in 1994-95 amounted to approximately 46% of the country's cereal production and 42% of its total food grains. India needs to increase production by at least 2.5 million tons of milled rice every year to sustain the present level of self-sufficiency.

Tamil Nadu is the most southern state in India with a geographical area of 13 million ha and a cultivable area of 5.8 million ha. Rice is grown in about 2 million ha, mostly under irrigated conditions. The average productivity of rice in the state is the highest in the country, with an average yield of 5 t/ha.

The concepts of SRI came to be known at Tamil Nadu Agricultural University during 2000 through a communication from Dr. H. F. M. Ten Berge of Plant Research International in the Netherlands. The soil aeration aspect of SRI stimulated the conduct of an observation trial during 2000-2001. A detailed study involving SRI concepts was taken up during this past year through the water-saving rice production project funded by the Dutch government through the Plant Research International at Wageningen. At present, SRI is under evaluation only and has not reached any popularization stage.

Evaluations

Initial evaluation

The first observation trial was conducted with rice cultivar CO43. The treatments included two methods of crop establishment (wet seeding of sprouted seeds, and transplanting of 10-day-old seedlings) and five plant densities (4, 8, 16, 32 and 64 plants/m^2). The plots were irrigated in the evening and drained in the following morning. Though there were no spectacular yield differences, the study confirmed that flooding was not necessary to maintain yield.

Detailed study

This experiment was conducted during August 2001 to January 2002. Some of the components of SRI cultivation practices were compared with conventional practices for transplanted rice. Four factors were evaluated, with treatment combinations replicated four times.

For the *modified SRI practice:* (1) seedlings were raised in the 'dapog' manner,[2] and 14-day-old seedlings were placed on the surface of a puddled field; (2) up to the flowering stage, irrigation was given to a depth of 2.5 cm after surface cracks developed in the soil; after flowering, irrigation was similar to conventional practice; (3) all weeds were incorporated into the soil during weeding with a conoweeder, and prior to transplanting, green manure at 6.25 t/ha was incorporated into the soil.

For *conventional practice:* (1) 23-day-old seedlings were planted; (2) irrigation was given to a depth of 5 cm one day after the disappearance of surface water; and (3) weeds were manually removed.

In *both practices,* a plant density of 25/m^2 was used compared to a conventional plant density of 50/m^2 in order to permit use of the conoweeder. Also single seedlings were planted per hill with both practices. Since these are both essentially SRI practices, the evaluation

[2] *'Dapog' is a method developed in the Philippines, where seedlings are raised on a surface, like a banana leaf, so they can be easily transported to the field and transplanted at a young age.*

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was really of “modified” SRI, assessing the effects of only three of the six basic SRI practices. The “control” fertilization treatment was a conventional N, P, K plus Zn application, with the experimental treatment being this plus incorporation of green manure and an additional N application, which is not really an SRI practice.

Location: Wetland Farm, Tamil Nadu Agricultural University
Design : Strip plot
No. of replications: 4
Plot size: 6 x 4.4 m
Variety : CORH2 (hybrid)
Planting density: 20 x 20 cm (25/m^2)

Treatments

Planting P1: Conventional: standard nursery, 24 d old seedlings, 2-3 seedlings/hill

P2: Modified SRI: dapog nursery, 14 d old seedlings, single seedling/hill

Irrigation I1: Conventional: irrigating to 5 cm depth after disappearance of ponded water

I2: Modified SRI: irrigating to 2 cm depth after surface cracks develop up to flowering and thereafter as in I1

Weeding W1: Conventional: hand weeding at 18, 34 and 38 DAT

W2: Modified SRI: incorporating weeds and aerating soil with conoweeder at 15, 26, 36, 47 and 57 DAT

Nitrogen N1: Recommended applications of N, P, K and Zn

N2: Recommended N, P, K and Zn applications + *dhaincha* green manure (6.25 t/ha) prior to planting + 25 kg N/ha at tillering

Soil Characteristics

Clay: 470 g/kg	Organic carbon: 8.2 g/kg
Silt: 90 g/kg	$KmnO_4$: 232 kg/ha
Sand: 440 g/kg	Olsen-P: 32 kg/ha
Bulk density: 1.18 g/cc	NH_4Oac-K: 740 kg/ha
pH: 8.3	Elec. conductivity: 0.54 dS/m

Climate

The experiment was conducted during the northeast monsoon season. Weather conditions prevailing during the crop growth period are summarized in Table 1 below.

Results

Grain yields for the sixteen treatments varied from 5059 kg/ha to 7612 kg/ha. The results showed that by adopting the modified SRI irrigation practice, there was a water saving of 56% under conventional planting and 49.8% under modified SRI planting without any significant effect on grain yield when compared with conventional practice.

The maximum yield (7612 kg/ha) was obtained for the modified SRI practice with younger seedlings, restricted irrigation, addition of green manure, and incorporation of weeds with soil aeration.

With green manure application and conventional weeding, water-saving irrigation practices reduced yield compared with conventional irrigation practices, but not significantly. *In situ* incorporation of weeds of the modified SRI practice significantly increased the yield (6737 kg/ha) when compared to conventional weeding (6076 kg/ha).

Table 1. Weather conditions prevailing during the crop growth period

	Max. temperature (°C)		Min. temperature (°C)		Rainfall (mm)		Solar radiation (MJ/m)	
Crop growth period	P1	P2	P1	P2	P1	P2	P1	P2
TP-AT	31.9	31.6	22.6	22.5	98.6	203.1	14.9	14.4
AT-PI	30.9	30.4	22.0	22.0	284.7	178.9	13.8	14.6
PI-FL	29.8	28.9	21.9	21.1	129.1	91.4	14.9	15.1
FL-HT	28.3	28.5	19.0	19.0	23.6	14.8	16.2	16.3

Learning

- Irrigating fields up to the flowering stage to a depth of 2 cm after surface cracks developed, and thereafter irrigating conventionally, was found to give a similar yield compared to conventional irrigation, with a 50 to 56% saving of water.
- Incorporation of weeds is more beneficial for increasing the grain yield than removing them from the field, though part of this effect might be attributed to the soil aeration achieved with the cono-weeder.
- Younger single seedlings per hill and 25 hills/m^2 produced yield similar to 3-week-old seedlings, 2-3 per hill, and 50 hills/m^2. This new practice could reduce farmers' seed cost, especially for hybrid seeds.

Prospects

Modified SRI methods offer scope for considerable reduction in the water requirement and in seed requirements, with an increase in yield attributable in large part to the incorporation of weeds in the soil and to soil aeration along with different plant management practices.

Evaluations of the System of Rice Intensification in Fianarantsoa Province of MADAGASCAR

Bruno Andrianaivo, FOFIFA, Fianarantsoa

The province of Fianarantsoa is situated in the south-central highlands of the country, with elevations between 1200-1500 m above sea level, at longitudes 47°-45° and south latitudes of 21°-22°. SRI was introduced into the Fianarantsoa province in the 1990s by Père Henri de Laulanié with the NGO, Association Tefy Saina (ATS). Dissemination of SRI in the Fianarantsoa region has been done by several institutions and projects: ATS with CIIFAD in the Ranomafana Park peripheral zone, and with the African Highland Initiative (AHI) of the CGIAR system; a Catholic Relief Services (CRS) project with the Fianarantsoa diocese; the Landscape Development Interventions (LDI) project funded by USAID; and FOFIFA in cooperation with CIIFAD, as reported below.

Evaluations

One of the first evaluations was done in 1998 by CIRAGRI, the governmental extension agency. Five types of trials have been done since 2001 under FOFIFA auspices with support from a Rockefeller Foundation grant through CIIFAD:

1. **Density of transplanting** with trials involving different spacing patterns (from 20 x 20 to 50 x 50 cm) and number of seedlings (1 to 3) per hill.
2. **Water control** in combination with different types and frequencies of **weeding**:
   - Water application periodically and shallow vs. continuous deep water.
   - Use of herbicides vs. rotary weeding under intermittent irrigation conditions.
3. Study of **soil management and fertility** comparing **organic and inorganic fertilizer**:
   - Use of **compost** vs NPK.
   - Long-term fertility trial evaluating the residual effects and cumulative effects of **organic matter** on the rice-based cropping system.
   - Evaluation of a **rotational cropping system** alternating an unirrigated, inter-season crop with irrigated rice production, where compost is applied to the former but not the latter.
4. Study of the relationship between **root development of seedlings** and physical soil properties in the nursery.
5. Evaluation of **blast infestation** on two most promising varieties for SRI (2067 and x265) under conditions of high soil fertility.

Experimentation with SRI has been going on for two years, 2001 and 2002. Participatory research started in the first year with experiments on SRI conducted with 10 farmers on their own fields. The next year, those farmer-experimentors became rural animators, and we found that SRI adoption has spread to over 13 hectares located in five valleys. The number of participants has increased to 23 families.

The verification technology trial was carried out at CAPR Tsionjohezaka, a center for professional development in agriculture, where 50 young farmers are trained in SRI methods. All of those activities are located within four valley areas around Fianarantsoa town, are supervised by myself and are undertaken with the collaboration of CIIFAD.

At the beginning in 2001, one local variety (*Vary vato*) and five improved varieties of irrigated rice were tested with SRI methods, both japonica (Yumehika, Omachikane, and 2067) and indica (X265 and Soameva).

Soil types

Major lowland irrigated rice fields in Fianarantsoa region are divided in three types of soil:

- Loamy-clay — with good water management capabilities
- Loamy-sand — usually cultivated as rainfed lowland.
- Peat soil — high organic matter content, with deep water in flood-prone areas.

Climate

The highlands of Madagascar are characterized by a subtropical climate. Annual rainfall average is recorded as about 1375 mm with a maximum at 368 mm. The rainy season occurs during the hot months in the year. The average temperature is over 20°C within that period. It decreases to 14°C in July and reaches 21°C in January. Fianarantsoa region is often affected by cyclonic perturbations during the rainy season.

Results

Average yield in the Fianarantsoa region is 2 t/ha with traditional practices, i.e., transplanting mature seedlings more than 45 days old into flooded paddy soil without any fertilizer application, and weeding just once. Irrigation is continuous with depths of more than 10-20 cm. Typically, the field is left fallow after the irrigated rice crop. Even partial SRI, i.e., using young seedlings with the traditional land preparation and other practices, can give a higher yield, as much as 6 t/ha.

SRI in Fianarantsoa is increasingly linked with the use of compost in rotational cropping where potatoes, beans or other vegetable crops are planted in the off-season *(contre-saison)*. We have attained rice yields of more than 8 t/ha the first year using limited, i.e., intermittent, water application along with other SRI practices. The residual and cumulative effects of the soil organic matter coming from compost applied to the off-season crop occur in the second and succeeding years, when rice yield can increase up to 16 t/ha.

One should not expect that the maximum attainable yield will be achieved with SRI practices in the first or the second year. However, by the sixth year we have measured yields as high as 20 t/ha around Fianarantsoa, on farmers' fields in Tsaramandroso, Talatamaty and Soatanana.

As seen from data in Table 1 on page 142, SRI raises the productivity of labor quite substantially. With a yield of 8 t/ha from SRI practices, a net return calculation shows this to be 5 million Fmg for SRI (about US$770), figuring transplanting as requiring 40 man-days/ha of labor, compared to a return of around 250,000 Fmg, less than US$40, with traditional methods.

Many changes are now occurring with the use of SRI:

- More and more farmers are fertilizing their soil with **farmyard manure or compost**, which promotes positive soil biological processes. Increasingly, compost is being incorporated into the soil for the unirrigated off-season crop that precedes irrigated rice.
- An important and specific result from farmer experience with SRI around Fianarantsoa is a **rotational cropping system** that plants crops, usually vegetables, even twice rather than just once, during the dry season between wet seasons when rice is grown. Increasingly, farmers grow potatoes in their rice fields followed by beans or other vegetables before completing the cycle with an irrigated rice crop.
- Many farmers now utilize **rotary weeders** as well as doing intermittent (alternating wet-dry) irrigation. Also, random transplanting is being replaced by planting in rows or a square pattern.

Learning

Some difficulties have been encountered when farmers using SRI are constrained in their use of compost by not having enough biomass or manure for a large planted area. There is often not enough plant biomass or manure production in the Fianarantsoa region. So farmers need to **develop integrated agro-livestock systems** for maximum production. Or they should take steps to increase the growth of biomass on land around them that is otherwise unused. Leguminous species such as tephrosia and crotalaria grow well in Madagascar even on poor soil.

We found a positive impact on farmer incomes from **diversified cropping with SRI** through development of *rotational cropping systems*. Money from potato and bean production is used to pay for wage labor during land preparation, transplanting and weeding in rice cultivation. Also, the off-season crop contributes to better soil fertility for the following SRI crop.

Prospects

We have been found the utilization of diverse sources of information and experience is important for good technical support. Particularly we should take advantage of the **indigenous technical knowledge** (ITK) of certain Malagasy farmers who are very knowledgeable and good observers. We have found that a participatory research approach involving the effective involvement of farmers and researchers working together is an important strategy for evaluation and dissemination.

The main impediments to be overcome: We need a better understanding of **how to enhance the advantages to be gained from accelerating biological processes in the paddy field.** The fertility of soil is found to be the main factor required for successful intensification of the rice crop, and this depends on a combination of different plant, soil, water and nutrient management practices.

We have found that with certain intensification practices, there can be a problem of **high rate of grain sterility** and sometimes **lodging** of rice plants. This needs to be evaluated further to minimize such problems with SRI methods.

Table 1. Economic analysis of rice production in Fianarantsoa calculated in terms of costs and returns per hectare (monetary values are given in Francs Malgache [Fmg] with US$1.00 = 6,500 Fmg)

		Traditional practices[a]			SRI methodology[b]		
Activities	Units	*Qty*	*Unit Cost*	*Cost*	*Qty*	*Unit Cost*	*Cost*
Nursery operations							
Land preparation	Man/days	6.5	4,000	26,000	3.5	4,000	14,000
Sowing and related activities	M/d	3	4,000	12,000	1.5	4,000	6,000
Removal of seedlings	M/d	10	4,000	40,000	2.5	4,000	10,000
Transport of seedlings	M/d	10	4,000	40,000	2.5	4,000	10,000
Manure cost	Cartload	2	5,000	10,000	1.5	5,000	7,5000
Transport/broadcast manure	M/d	2	4,000	8,000	1.5	4,000	6,000
Rice seeds	Kg	80	1,000	80,000	6	2,000	12,000
Sub-total	Fmg			**216,000**			**65,500**
Field operations							
Plowing	M/d	36	4,000	144,000	43	4,000	172,000
Harrowing	Plower	5	15,000	75,000	5	15,000	75,000
Puddling	Harrower	6	15,000	90,000	6	15,000	90,000
Transplanting	M/d	36	4,000	132,000	40	4,000	160,000
Irrigation	M/d	60	4,000	240,000	25	4,000	100,000
Weeding	Weeder	0	0	0	24	5,00	120,000
Manure cost	Cartload	5	20,000	100,000	5	20,000	100,000
Transport of fertilizer	Cartload	5	4,000	100,000	5	20,000	100,000
Incorporation of fertilizer	M/d	5	2,000	20,000	5	4,000	20,000
Basket cost	Number	10		20,000	10	2,000	20,000
Sub-total	Fmg			**921,000**			**957,000**
Harvest							
Cutting and transport	M/d	53	4,000	212,000	77	4,000	308,000
Threshing and drying	M/d	15	4,000	60,000	89	4,000	356,000
Cleaning and storing	M/d	10	4,000	40,000	26	4,000	104,000
Sub-total	Fmg	**78**	**4,000**	**312,000**	**132**	**4,000**	**768,000**
Revenue from production	Ton	2	850F/kg	1,700,000	8	850F/kg	6,800,000
Total costs of production	M/d	243		1,449,000	251.8		1,790,500
Net return per hectare	Fmg			**251,000**			**5,009,500**

Sources: [a] DIRA, Fianarantsoa, 1998; [b] Data gathered by author, 2002.

Evaluation of Nutrient Uptake and Nutrient-Use Efficiency of SRI and Conventional Rice Cultivation Methods in MADAGASCAR

Joeli Barison, Cornell University [1]

Despite evidence from several countries that rice yields can be at least doubled with the System of Rice Intensification (SRI) in comparison to conventional practices, there is still some skepticism about it among rice scientists. With the guidance of my thesis advisor, Prof. Erick Fernandes, I have sought to gain a better understanding of the physiological factors that underlie this higher performance with SRI practices.

For this purpose, I undertook an evaluation of the nutrient uptake and nutrient-use efficiency of SRI-grown rice compared with conventionally-grown rice in four areas of Madagascar, including an evaluation of plants grown on the fields of 108 farmers. The objectives of the research were: (1) to determine the nutrient uptake and the nutrient-use efficiency (NUE) of SRI methods compared to conventional systems of cultivation; and (2) to estimate the N, P and K requirements of rice plant cultivated with either SRI or conventional practice.

Evaluations

On-station study of nutrient uptake and NUE comparing SRI and conventional systems

This evaluation was undertaken at the Beforona research center in the eastern part of Madagascar during the 2001 main growing season (October 2000 through May 2001.) The trials were done on clay-sandy soil with 43.8 g organic matter/kg, 27 g organic C/kg, 1.88 g total N/kg, and 17.8 g available P/kg (Olsen method extraction). Exchangeable K was 0.15 cmol(+)/kg exchangeable K, and cation exchange capacity was 2.6 cmol(+)/kg.

Experimental design

Five treatments were arranged in a randomized block design with a three-time block replication. Plot size was equal to $20m^2$. Treatments were the following, with SRA being the system of "improved" rice cultivation *(systèm de riziculture ameliorée)*, which the government promotes, with row planting, use of new varieties, and agrochemical inputs.

- T1: SRI cultivation method with compost application
- T2: SRI method without compost
- T3: SRA method with chemical fertilizer (NPK 11-22-16)
- T4: SRA method without fertilizer
- T5: Conventional system used by farmers

Rice grain yields after measurement were adjusted to 14% moisture content. Plant samples were collected at three different stages (panicle initiation, anthesis, and maturity) and were analyzed for their macro-nutrient content (N, P and K.)

On-farm evaluations of nutrient uptake, NUE and nutrient requirements comparing SRI and conventional systems

For more extensive and realistic comparisons between SRI and conventional systems, the on-station trials were complemented by an on-farm survey with farmers in four rice-growing areas of Madagascar (Ambatondrazaka, Imerimandroso, Antsirabe, and Fianarantsoa). 108 farmers, each practicing both SRI and conventional production methods on their farms, were included in our study although only 98 farmers are included in the agronomic analysis here because we could not get com-

[1] *This research is reported and analyzed in more detail in: Joeli Barison (2002): Nutrient-use efficiency and nutrient uptake in conventional and intensive (SRI) rice cultivation systems in Madagascar, a Master's thesis for the Department of Crop and Soil Sciences, Cornell University, Ithaca, NY. This thesis is available electronically upon request to: ciifad@cornell.edu*

Table 1: Characteristics of SRI, SRA and conventional systems

System of cultivation	SRI	SRA	Conventional
Age at transplanting (days)	8	25	45
No. of seedlings/hill	1	2-3	4-6
Spacing (cm)	25 x 25	20 x 20	14 x 14
Water management	Irrigate at night and drain in the morning is recommended, or alternate wetting-drying	Standing water of 3-5 cm	2-3 cm standing water for 2 weeks after transplanting; then 5 cm for rest of season
Fertilization	Compost	NPK and urea	No fertilization

plete data for 10 in the sample. The plants of these farmers were followed closely throughout the growing season, taking soil and plant samples for analysis of macro-nutrient content.

Results

On-station study

Grain yield comparison

Significant grain yield differences were observed among the three systems (Table 2.) The highest grain yield was obtained from plots where SRI was used and compost applied, with grain yield of 6.26 t/ha. This yield was statistically significantly different from that of the SRA system (4.92 t/ha with NPK and urea fertilized plots, and 4.67 t/ha for non-fertilized plots) and the conventional system (grain yield of 2.63 t/ha) (see Table 2; p=0.001, ANOVA test). Actually, this SRI yield was lower than usually obtained with these methods, probably due to late planting of the SRI plots by one month. Previously at the Beforona station, the SRI yield was 10.2 t/ha,.

The higher grain yield observed with SRI cultivation methods in the 2001 season was the result of a higher number of panicles and grains/m^2 (Table 3). For the SRA treatments, the lack of significant difference between the fertilized and non-fertilized plots were due to a greater attack of blast (*Pyricularia oryzae*) in the fertilized plots during the grain-filling period.

Evaluation of the root growth and distribution by root length density

Root length density (RLD), a standard method for the measurement of the root growth and proliferation, was done at harvest time. From our measurements, we noticed that in all of the treatments, root growth decreased rapidly in relation to the soil depth.

Rice plants grown with conventional and SRA methods had higher root growth in the first 20 cm in comparison to those with SRI (see Table 4). Most root growth was observed to be superficial with plants cultivated with conventional methods. However, the root growth of conventional and SRA rice plants began to be offset by SRI plants at a depth of 20-30 cm. Furthermore, greater root growth was noticed with SRI plants at lower depths, below 30 cm. This greater root growth to lower depths suggested that plants cultivated with SRI methods, which include alternate drying and draining of the soil, were capable of developing greater root penetration in comparison to SRA and conventionally grown plants.

Evaluation of nutrient uptake

The highest nutrient uptake of N, P and K was recorded in the SRI plots while the lowest was seen with conventional cultivation practices.

Table 2: Mean grain yields, by treatment

Treatment	Mean	Group
SRI with compost	6.26	A
SRI without compost	5.04	AB
SRA with NPK and urea	4.92	B
SRA without fertilizer	4.68	B
Conventional system	2.63	C

LSD test at 5% indicated by letters

Table 3: Grain yield components in the on-station experiment

Treatment	Plants/m²	Panicles/m²	Grains/m²	1000-grain weight (g)
SRI with compost	16	242	20,445	29.43
SRI without compost	16	248	18,827	29.22
SRA with NPK and urea	25	212	15,634	29.35
SRA without fertilization	25	152	10,826	29.70
Conventional	53	290	9,237	30.12

On-farm evaluation

Grain yield and Harvest Index comparisons in the on-farm survey

A predominant strategy in recent years for breeding rice with increased grain production has been to reduce the share of non-harvestable biomass so that the edible proportion of biomass is higher. This is described as increasing the Harvest Index, i.e., the ratio of grain yield to total biomass. (Note, however, that this HI is calculated for above-ground biomass only, not taking root biomass into account; this is an omission done mostly for practical rather than theoretical reasons.)

This objective of raising the HI has led researchers to create shorter-stature cultivars that produce fewer barren tillers and a higher number of grains per fertile tiller (Khush, 1993). At the same time, conventional strategies for raising yield have recommended an increase in planting density. According to this reasoning, one would expect that higher tiller numbers and reduced planting density should lower the Harvest Index. As seen below, however, this does not happen with SRI.

Comparisons of yield between SRI and conventional systems in the farmer plots surveyed showed that with SRI, the grain yield was significantly higher, with fewer plants and with plants having greater biomass both above and below ground. Farmers who used the SRI method on their rice plots obtained an average yield of 6.36 t/ha compared to an average grain yield of only 3.36 t/ha with conventional methods.

This 89% increase over conventional grain yield for the farmers surveyed in this sample is actually 218% higher than the national average grain yield of 2 t/ha. That farmers in the sample got higher yields with conventional methods than typical nationally suggests that they were either more skilled and/or motivated, and/or had better soil and other growing conditions.

This grain yield increase was accomplished with rice plants that had significantly higher numbers of tillers than conventionally grown rice plants but a *similar* Harvest Index**.** While the Harvest Index with conventional methods averaged 0.49, with SRI methods this ratio was 0.48. Furthermore, a comparison on the Nutrient Harvest Index indicated very similar relationships. The nutrient harvest index was 0.68g N/g, 0.71g P/g, and 0.27g K/g for SRI, compared to 0.65g N/g, 0.72 g P/g, and 0.25 g P/g in rice grown with the conventional methods. See also differences in Table 5.

These numbers indicate that despite the higher tiller number of SRI plants, which normally results in higher non-harvestable biomass, the HI with SRI methods was practically the same, and in some cases higher than with conventionally grown rice. SRI plants apparently benefit from improved rooting development.

Table 4: Root length density (cm/cm³) for SRI, SRA and conventional systems

	Soil layers (cm)					
Treatment	0-5	5-10	10-20	20-30	30-40	40-50
SRI with compost	3.65	0.75	0.61	0.33	0.30	0.23
SRI without compost	3.33	0.71	0.57	0.32	0.25	0.20
SRA with NPK and urea	3.73	0.99	0.65	0.34	0.18	0.09
SRA without fertilization	3.24	0.85	0.55	0.31	0.15	0.07
Conventional system	4.11	1.28	1.19	0.36	0.13	0.06

Table 5: Total aboveground N, P and K uptake of rice plants (kg/ha)

Treatment	N	P	K
SRI with compost	176.74	35.89	153.33
SRI without compost	159.39	34.84	136.92
SRA with NPK and urea	133.63	30.08	113.37
SRA without fertilization	122.62	29.24	116.17
Conventional	62.95	13.34	55.86

The appearance of more nodal roots for every newly formed tiller led to a more developed root system, since root and tiller growth from the apical meristem is coordinated. This increase was stimulated, we think, by the joint effect of better soil aeration by different water management practices and by the transplantation of young seedlings. The resulting root systems can exploit a greater volume of soil and can potentially access greater amounts as well as more diversity of nutrients.

Nutrient uptake of the rice plant

The total above-ground nutrient accumulation for the SRI system averaged 95.07 kg N/ha, 21.03 kg P/ha, and 108.64 kg K/ha. while for plants grown with conventional practices, the average was 49.99 kg N/ha, 12.69 kg P/ha, and 56.77 kg K/ha (Table 6). These results showed that modification of plant, soil, water and nutrient management practices could enhance plant uptake by 91% for N and K, and by 66% for P.

Interestingly, the relatively high increase of accumulated N and K, on one hand, and the lower increase of accumulated P, on the other, suggests that possibly conventional plants had either a low N and K uptake or a high P uptake. It is also possible that in these soils, P was the limiting macro-nutrient and that growth could have been greater with more available P.

To get a clearer picture of nutrient uptake constraints on yield, one should to compare grain yields with nutrient content and concentration differences between SRI and conventional systems. As we have seen, SRI grain yield for these 108 farmers averaged 6.36 t/ha while that of conventional rice was 3.36 t/ha, an increase of 90% in grain yield, reflected in the increased N and K concentrations and content in the rice plants and grain.

It could be possible that the increase of grain yield with SRI compared to that of conventionally grown rice was due to farmers allocating their best sites to SRI or to application of more compost to SRI plots. Results from our soil analyses, however, showed that SRI and conventional plots had similar soil fertility as commonly evaluated. The average nutrient content were 0.16% N, 8.51 ppm P-Olsen, and 0.08 cmol (+)/kg K in the SRI plots, and 0.17% N, 9.39 ppm P and 0.09 cmol(+).kg^{-1} K in the plots conventionally cultivated.

Moreover, *only about 6 farmers in our sample used any compost on their SRI plots*. Excluding their grain yield hardly changed the comparison: grain yield of 6.35 t/ha with SRI vs. 3.36 t/ha with conventional methods. So SRI nutrient practices were not affecting the results; 90% of the farmers were getting their higher SRI yields just from using the other SRI methods, not making any soil nutrient amendments. See Table 6.

Internal nutrient efficiency

Nitrogen internal efficiency (NIE) with conventional practices was higher compared with SRI, but a t-test indicated that it was not significant at the 5% level of confidence (p=0.197.) A significant difference was noticed in regard to the P use-efficiency; more efficient use of P for grain production with SRI cultivation methods was observed. This is apparently the result of higher N uptake with SRI plants, evident in the N : P : K ratio (ratio of N to P and K to P.) The nutrient ratio for plants grown with SRI methods was higher (5 : 1 : 4.9) than with conventional practices (3.9 : 1 : 4.1). See Table 7.

Table 6: Nutrient uptake of rice plants for SRI and conventional systems (kg/ha)

System of cultivation	N	P	K
SRI	95.07	21.03	108.64
Conventional system	49.99	12.69	56.77

Table 7: Evaluation of NIE with SRI and conventional systems

Para-meter	Unit	Sample size	Mean Conv.	Mean SRI	Two-sample t test p-value
N IE	kg/kg	94	74.9	69.2	0.197
P IE	kg/kg	94	291.1	347.2	0.001
K IE	kg/kg	94	70.4	69.7	0.884

Discussion

Rice plants cultivated with conventional and SRA systems had higher root growth at the top 20 cm than those with SRI methods, but there was better root growth at lower depths evident with SRI plants.

No apparent reduction of the Harvest Index was seen to result from SRI practices. This suggests that even with a higher number of tillers, SRI plants' better root growth and soil penetration enabled them to achieve proportionally higher grain formation.

A 91% increase of N and K uptake, compared with nutrient uptake in conventionally-grown rice plants, in conjunction with a 90% increase in grain yield and a 66% increase of P uptake, reflected a greater capacity of plants cultivated with SRI methods to access and take up P. It is possible that in addition to better nutrient supply, the enhanced root growth with SRI allowed the plants to access sub-soil P that was not available under the conventional system.

What our research did not examine and cannot resolve is whether this effect is more due to changes in plant structure and physiology or to changes in the rhizosphere in response to SRI's practices for plant, soil, water and nutrient management, particularly greater abundance and diversity of beneficial microorganisms or some combination of both. This remains to be explored in future research.

Prospects

The greater nutrient uptake with SRI cultivation methods suggests that rice plants grown with these practices are capable of taking up more nutrients and converting them into directly and indirectly beneficial biomass more grain, and more tillers and leaves that support this grain. We were not able in this research to evaluate the uptake of micronutrients, which could help to account for better production performance and also for reports that SRI plants have greater resistance to pest and disease damage.

Greater nutrient uptake suggests that there might be some increase of available N in the soil due to higher mineralization of organic-N in a soil environment that alternates aerobic and anaerobic conditions. Furthermore, greater activity of N-fixing bacteria such as N_2-fixing endophytes within the root cells and in the root rhizosphere might also be present in the SRI plant-soil environment.

It was not possible to evaluate N-fixation in this research, but we can hypothesize that the greater uptake of N is attributable to the better root growth and root activity in conjunction with greater activity by larger and more diverse soil microbial populations. This hypothesis remains to be experimentally tested through evaluation and assessment of the dynamics of microbial populations associated with SRI plant, soil, water and nutrient management practices. Some initial research on this is reported in the following paper by Prof. Robert Randriamiharisoa.

Reference

Khush, G. S. (1993). Breeding rice for sustainable agricultural systems. In: D. R. Buxton, et al., eds., *International Crop Science* I. Proceedings from International Crop Science Congress, Ames, IA, 14-22 July, 1992, 89-199. Madison, WI: Crop Science Society of America.

Research Results on Biological Nitrogen Fixation with the System of Rice Intensification

Robert Philipposon Randriamiharisoa, University of Antananarivo[1]

In Madagascar, rice production still remains low with an average national yield of about 2 t/ha, despite governmental efforts to promote rice production over the past 50 years. These actions were based mainly on the use of chemical fertilizers and improved varieties, directed to the three or four major rice-producing areas in the country. Peasants represent 80% of the Malagasy population, and half of them own only about 0.25 to 0.30 hectare of rice field upon which they depend for their survival. Hence, increase in the productivity of land area is imperative for achieving food security and reducing poverty.

To bring solutions to small farmers who lack resources, and particularly financial resources, SRI is most promising. High yield attainment, up to 8 to 12, and even 16 tons per hectare, and plants' resistance to diseases observed during on-farm experiments are particular features of this system. It will be really significant if small farmers can produce over 500 kg paddy from 0.05 ha surface area with this system as this can contribute greatly to family food security.

With this system, farmers need only use farmyard manure and/or compost to get best results. This is a form of biological agriculture that benefits from the maximum action of soil microorganisms. We have seen that there is biological nitrogen fixation (BNF) associated with rice roots under SRI practices and have identified the role of *Azospirillium* as a source for meeting plant nitrogen needs. This report will present some findings from this research. It is hoped that the existence of BNF effects will reduce the quantity of N fertilizer required and utilized. With better understanding of these dynamics and effects we should be able to move toward a replacement of inorganic fertilization with biological means.

Acceptance of SRI by the scientific establishment in Madagascar has been promoted by several research projects undertaken since 1997 by the Faculty of Agriculture (Ecole Supérieure des Sciences Agronomiques, ESSA) at the University of Antananarivo. Research on rice cultivation needs to take into account the socio-economic context in the country. The government's policy to date intended to develop the country's "rice baskets," where there are large stretches of ricefields held by big farmers, has not brought any viable solution for Madagascar, which still imports huge quantities of rice to feed its population. Most peasants, 80% of the population, are still living below the threshold of poverty, growing rice just for survival.

Two major constraints need to be taken into account in rice research and development: the small size of most exploited areas per farmer, ranging up to 0.25-0.30 hectare, and the low purchasing power of farmers. Increasing productivity without dependence on the use of chemical fertilizers and other purchased inputs should be a goal at least for the short to middle term. Our research has focused on the support and the validation of SRI, motivated by the facts outlined above.

The main factors affecting yield in SRI include water management, mechanical weeding (using a hand rotating weeder), and transplantation of single, young seedlings. These practices have been experimented with on different kinds of soil (clay, loam or sand), repeated over several years in different parts of Madagascar. We hope to develop more precise knowledge on the effects of using the mechanical rotating weeder and other weeding methods such as use of herbicides that can be compared with one another.

We have been working recently on understanding the phenomena that can support biological nitrogen fixation to contribute to high yield. Thanks to the iso-

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lation and identification of *Azospirillium* sp., which is associated with high yields, we want to suggest a concept of "incitement" for enhanced BNF which manure and/or compost can achieve in conjunction with SRI methods with different soils and in different ecological regions.

Objectives of Experiments

The main purpose of our research is to demonstrate that the high performance of SRI is linked to the activities of aerobic microorganisms located in the rhizosphere and root system. Different yields have been evaluated according to soil texture, which can be clay, loam or sand, which can play a role in BNF capacity. Considering all of the yield increase factors in SRI, we find a lot of similarities with the fundamental principles of organic agriculture that were described by Boucher (1961).

Water management practices with SRI allow for better oxygenation of the root zone during the growth cycle, leading to better development of the aerobic microbial environment. Mechanical weeding using a hand "rotating hoe" with small toothed wheels, following transplantation of plants in a square or rectangular pattern, increases the number of soil pores so that roots and microorganisms can more easily gain access to oxygen. Research by Puard et al. (1986) has underscored the importance of oxygen for submerged lowland crops.

Experiments in soils managed according to SRI principles were expected to show the presence of *Azospirillium* in the root system of the rice plant, which is able to fix nitrogen from atmospheric sources, the quantity of which according to Ladha et al. (1998) can attain 55-70 kg/ha.

Methods and Materials

Multifactorial and multilocal experiments with SRI (N=288 and 240)

1. The main controlled variables related to the availability of water and nutrients:
   - 1a: **Water management** and the use of **compost,** contrasted with
   - 1b: **Water management** and the use of **NPK fertilizer**.

These were combined with agronomic practices affecting the rice plants themselves:
   - 2a: **Age of seedlings** at transplantation (8 days vs. 16 or 20 days),
   - 2b: **Number of seedlings** per hill (1 vs. 3), and
   - 2c: **Spacing** (25cm x 25cm vs. 30cm x 30cm).

The experiments were laid out in Fischer blocs repeated 3 times, with control plots that were:
   - 3: Without water management, i.e., with continuous submergence of the crop, and
   - 4: Without fertilization.

2. The first set of experiments was carried out near Morondava on the west coast of Madagascar, a second at Anjomakely, south of the capital city Antananarivo on the high plateau, and a third at Beforona near the east coast. In each location there were soils with different structures: clay, loam, balanced, and sand.

To assess the performance of SRI, as well as the efficiency of organic inputs, these trials were undertaken in different agroecological areas: with semi-arid climate at Morondava in the west; with temperate climate at Anjomakely on the high plateau in the center of the country; and with hot, humid weather around Beforona in the eastern part Madagascar toward the sea.

Experiments with different weeding methods (N=72)

The following variables were evaluated at the Anjomakely site:

1: **Weeding**:
   - 1a: **Mechanical weeding**, using a 'rotating hoe' (2, 3, or 4 times);
   - 1b: **Use of a herbicide** — 2,4-D;
   - 1c: **Hand weeding** (once) supplemented by use of the herbicide 2,4-D;
   - 1d: **Mulching** with *Sesbania* leaves (with layers 5cm thick); and
   - 1e: **Interplanting** of *Sesbania* in alley cropping.

In the trials, 1a, 1b, 1c, 1d and 1e were combined with other key SRI practices:

2: **Water management**; and

3: **Plant management** — transplantation of single seedlings 8 days old.

The trials were conducted with variations also in:

4: **Compost** — 3 doses of 2, 3 and 6 t/ha each, treating doses as the experimental variable rather than compost vs. NPK fertilizer vs. no fertilization.

The experiments are laid out in randomized blocs with three repetitions, with a control plot where hand weeding was done as needed. There was no systematic weeding; weeds were only gathered manually.

Experiments with various doses of compost and their effects on tillering (N=18)

The variables controlled here were:

1**: Use of compost** (1, 2, 3, 4, or 6t/ha); combined with

2: **Water management** as recommended for SRI;

3: **Plant management** — transplantation of single seedlings 8 days old**;** and

4: **Three weedings,** all compared with a control plot **without compost**.

Multilocal trials were carried out in the Antananarivo, Fianarantsoa and Moramanga regions.

Counting and identification of *Azospirillium* colonies

Azospirillium colonies were isolated from extracts of rhizosphere and root solutions at the end of the tillering period using a "milieu Döbereiner." A litre of the solution can contain KH_2PO_4 (0.4g), K_2HPO_4(0.1g), $MgSO_4$-$7H_2O$ (0.2g), NaCl (0.1g), $CaCl_2$ (0.02g), $FeCl_3$ (0,01g), $NaMoO_4$-$2H_2O$ (0.002g), fumarate (1.0g), glucose (1.0g), H_2O (q.s.p: 1l), and agar (15.5g).

The number of bacteria in the extract solution is assessed by a comparison with the table of Grady. Once reproduced, *Azospirillium* sp. can be tested in various crops (Krieg and Döbereiner, 1984; Magalhaes et al., 1983; Reinhold et al., 1987; Martinez-Drets et al., 1985).

	A. brasilense	*A. lipoferum*	*A. amazonense*	*A. balopraeferans*
Pleomorphic cells in alkaline media	–	+	–	+
Biotin requirement	–	+	–	+
Use of glucose	–	+	+	–
Use of sucrose, maltose, trehalose, lactose	–	–	+	–
Use of keto glutamate	–	+	–	+

Glucose = D-fructose, D-galactose, L-arabinose, lactate, malate, succinate, pyruvate and fumarate. We have used D-fructose and lactose to identify our colonies.

Results and Discussions

Importance of oxygenation and organic inputs with SRI

Oxygenation of soil resulting from controlled water management and from use of a rotating weeder contributes to the high performance of SRI. Zhang Xi et al. (1999) showed that layers of ferro-hydroxide appear on the surface of paddy-field water under anaerobic conditions. When roots have insufficient O_2, this limits their access to nutrients. This can be a serious problem in Madagascar where, given its pedology, the majority of soils are ferralitic. Plants can consequently be affected by iron toxicity and aluminium saturation, which can form with available P_2O_5 a complex that is largely irreversible.

Research done by Revsbech et al. (1999) has brought some important precision on the amount of O_2 found in the rice root system. Multifactorial experiments conducted at Morondava on the west coast where reddish sandy soils are irrigated, and in other regions on clay and loamy soil under rainfed conditions, have confirmed not only the high performance of SRI methods but also the positive effect on yields from the use of organic fertilizers.

In Table 1 on page 151 we classify yields obtained in these trials according to soil textures and the type of fertilizer used. The table shows the results from experiments conducted by Rajaonarison (1999) at Morondava on the west coast, Raobelison (2000) at Beforona in the east, and Andriankaja (2001) at Anjomakely, 18 km south of Antananarivo on the high plateau, testing our hypotheses.

Water management kept water depth lower than 10cm, with alternation of wetting-irrigation every 3 days during 40 days from transplantation to the end of the tillering period. Three weedings using rotary hand weeders were applied at regular intervals.

Under the same cultural conditions, the best yields, over 10 t/ha, were obtained in clay and balanced soils with the use of compost (organic fertilizer), while medium yields, 5.3-7.9 t/ha, were obtained without any fertilization. Loam and reddish sandy soils gave poorer yields.

Our trials on the variation of tiller number under the influence of different weeding methods consequently showed the possible benefits of oxygen infiltration into the soil that can invigorate the root system. Compared to other rice cultivation systems, root development as well as nutrient assimilation is better with SRI. (This is seen from the preceding paper.) This ad-

Table 1: Average yields according to soil type and fertilization

	Yields according to type of soil (t/ha)							
Variables	Reddish Sand *(Morondava)*		Clay: Good soil *(Anjomakely)*		Loam: Poor soil *(Anjomakely)*		Balanced Soil *(Beforona)*	
Seedling age at transplanting (days)	8	20	8	16	8	16	8	20
No fertilizer	2.3	2.0	5.3	2.7	1.7	1.2	7.9	7.5
Fertilizers added:								
N P K	6.4	4.2	8.2	6.2	5.2	3.2	–	–
Compost	6.9	3.8	10.3	7.4	6.2	4.0	10.2	8.2

Table 2: Comparison of the structure of soils used for experiments

Ecological Areas	% Clay	% Loam	% Sand	Soil Structure
Morondava (semi-arid climate)	10-20	15-25	55-70	Sand
Anjomakely (temperate climate)	15-24	30-34	34-37	Loam
"	22-32	20-30	33-37	Clay
Beforona (humid warm climate)	30-34	34-38	34-40	Balanced

vantage is linked to the transplanting of very young seedlings, to water management that consists of alternately wetting and drying the rice paddies, and to early and frequent weedings with a hand weeder (rotary hoe).

This classification was done making a comparison between our soil analysis results and the soil texture table in *Le Memento de l'Agronome* (Ministère de la Cooperation Française, 1993).

Table 2 shows us that the three experimental areas each have different types of soil, which gives us some leads for understanding how the variation of soil oxygenation in each of them could affect plant performance. For loam, yields seem to be lower due to difficulties in oxygenation. This is linked to the fact that loam contains mostly small particles, which are more likely to settle after submersion and thus to limit soil porosity. Sands, although poor in nutrients, are actually moderately favorable to SRI according to our trials. The best oxygenation levels could be achieved when experiments were done on irrigated rice paddies that have very good water management, which made possible a doubling of rice production (Rajaonarison, 1999).

For clay with a larger proportion of sand, we could have the best yield since clay remains moist and retains water better, while sand contributes to drainage and soil aeration. An alternation of wetting and submersion as the pattern of water management leads to an increase in the exchange capacity of the soil, supported by the proportion of sand that allows infiltration after abundant rains.

Our observations on SRI are similar to ones by Wade et al. (1998) who explained the effects of water on the aeration of soils, as well as the loss of certain nutrients such as NO_3 (nitrate), according to differences in the soil structure and texture.

Oxygenation, as a result of SRI water management practices and repeated use of the rotating hoe with its wheels that aerate the top horizon of the soil, leads to better development of the rice root system. Armstrong and Webb (1985) made this same observation about the possibility of rice roots' extended growth under the influence of O_2. This root development becomes much more evident with SRI practices.

A measurement of root length by Raobelison (2000) showed lengths of 30-35 cm for SRI vs. 15-20 cm for traditional rice management. Research by Barison (2002) with 108 farmers who were using both SRI and traditional rice cultivation practices on their farms showed SRI rooting depth down to 50 cm, whereas traditionally grown rice had shallower rooting in soil that was kept saturated as much as possible rather than intermittently aerated, as with SRI.

Furthermore, Kirk and Solivas (1997) noted that "the upper limit of root length per soil volume is probably determined by transport of O_2 through the root and the ability of the root system to aerate itself." This is consistent with the results we see with SRI. Seedlings transplanted at 20 days have less root volume than those set out at 8 days. The latter have undergone less stress and have more favorable micro-organism development in, on and around the roots. The use of organic fertilizer like manure and compost that micro-organisms can easily degrade leads to the best yields when accompanied by other optimal cultural practices (Uphoff, 2001).

Tillering and yield variation according to weeding methods with SRI

Consideration of the effects of weeding using a hand rotating weeder, which oxygenates the rice paddy soil leads us to examine further the results of the factorial trials that used Fischer bloc design with 3 replications, so as to evaluate its effects on the evolution of tillering.

Our trials evaluating different weeding methods (Table 3) show that these methods can definitely affect tillering, and we think that the aeration of the soil makes a critical contribution for better development of the root system. This root development is very striking for SRI compared to the other systems of cultivation, giving plants easy access to nutrients. These results are due to the combined effects of transplanting very young plants (8 days), careful water management with alternate wetting and drying of the soil, and early and frequent weeding with a mechanical hand weeder.

There is a proportionality between the number of tillers and the number and frequency of weeding. The best yield was obtained with 4 weedings during the cycle of vegetative growth with rotary weeder. Yields can increase 1.2 t/ha from each use of the weeder. The use of *Sesbania* mulch is of less interest but still economic; it gives results similar to those with the use of the herbicide 2, 4D. This last can be compared with 2 times of weeding with the rotating weeder.

Note from Table 3, that when herbicide is used to control weeds, tillering is steady or even declines with an increase in the application of compost. This probably reflects an adverse effect of the herbicide upon the soil microbial populations that are otherwise stimulated by the addition of a greater amount of compost. Alternatively, the herbicide could have some direct effect upon the plant's growth performance.

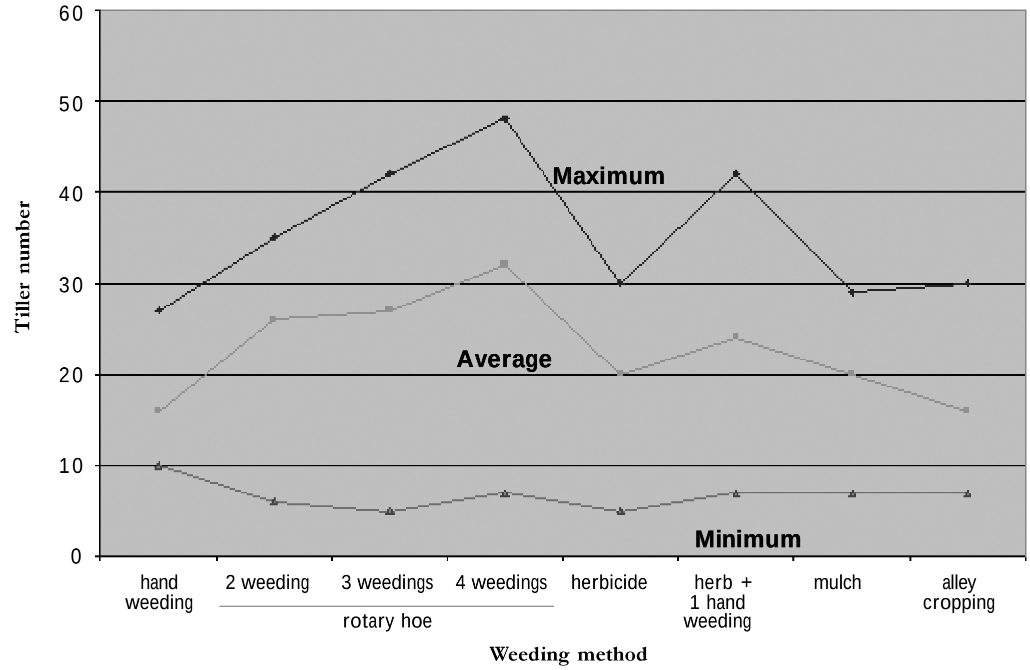
Yield data from these trials are analyzed in Table 4, showing tons per hectare for these weeding and compost practices varied with other SRI methods. The figures shown in tons per hectare are averaged for three plots that had different soil quality (two with better clay soils, and one with poorer loamy soil).

Table 3: Average minimum and maximum number of tillers by weeding methods and compost application with SRI

	Compost Doses								
	2 t/ha			3 t/ha			6 t/ha		
Variables	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
Hand weeding as needed	27	16	10	29	15	12	29	16	12
Weeding with rotary hoe:									
2 times	35	26	6	40	29	12	42	24	5
3 times	42	27	5	50	30	11	46	32	12
4 times	48	32	7	58	31	10	58	34	8
Herbicides 2,4 D	30	20	5	31	19	7	31	18	9
Herbicides plus hand weeding	42	24	7	36	22	10	38	16	6
Sesbania mulch	29	20	7	30	17	6	36	16	5
Alley cropping with *Sesbania*	30	16	7	33	17	7	34	17	10

Conditions: single seedlings aged 8 days; water management alternating drying and wetting soil, 3 days each period, with 10cm water level at most. Research done in 2001-2002.

Figure 1. Effects of weeding method on tiller number



The benefits of soil aeration from using the rotating hoe are very evident from the data in Table 4. Compared to hand weeding on an as-needed basis as the baseline, 2 mechanical weedings added 1.5 t/ha (41%); 3 mechanical weedings added 2.4 t/ha (63%), and 4 mechanical weedings added 3.9 t/ha (104%), other things being equal. Use of weedicide added only 1.3 t/ha (34%), and one manual weeding with herbicide added only 1.6 t/ha (41%), about the same increase as from two mechanical weedings. Use of sesbania either as mulch or intercrop added little to yield compared to hand seeding, though using this leguminous species gave about 20% more yield on average with ust 2 t/ha of compost compared with adding 6 t/ha. A small amount of organic matter added to the soil interacted favorably with this other means for enriching the soil.

Table 4: Yields (t/ha) with weeding methods and compost application with SRI

Weeding Methods	2 tons/ ha Compost	3 tons/ ha Compost	6 tons/ ha Compost	Ave.
Hand weeding	4.046	3.469	3.554	3.750
Rotary hoe:				
2 times	5.157	5.593	5.141	5.297
3 times	5.891	6.148	6.307	6.115
4 times	6.978	8.092	7.844	7.638
Herbicide	5.125	4.939	4.998	5.021
Herbicide plus one hand weeding	5.061	5.272	5.567	5.300
Mulching	4.421	3.142	3.800	3.790
Alley cropping	4.268	3.491	4.189	3.983
Average	5.119	5.041	5.175	5.112

Determination of an 'incitement' threshold for BNF when using increasing doses of compost, evaluated from tillering

In Madagascar, the recommended doses of fertilizer for rice paddies are 10t/ha of manure/compost, or 150 kg/ha of 11N-22P-16K and 120 kg/ha of urea. Nevertheless, from experiments at Beforona by Raobelison (2000), we have noticed that the yields with SRI did not depend upon the amount of compost applied. This means that high doses of compost are not needed, suggesting instead that low fertilizer dose can achieve almost the same result (Table 5 and Figure 2).

Experiments were undertaken to determine the fertilizer dose that can be considered as sufficient for 'incitement' of *Azospirillium* to contribute to a level of

Figure 2. Relation between tiller numbers and yields with applications of straw

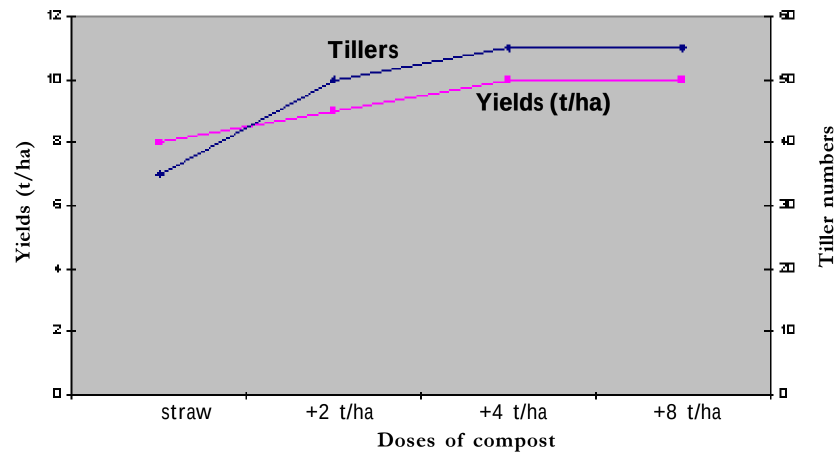


Table 5: Effects of increasing doses of compost on tillering

	8-day seedlings		20-day seedlings	
Treatments	Tillers (N)	Yields (t/ha)	Tillers (N)	Yields (t/ha)
Straw	20 - 35	7.9	20 - 35	7.5
Straw + manure 2t/ha.	45 - 50	9.0	40 - 45	8.0
Straw + manure 4t/ha.	50 - 55	9.8	40 - 45	8.1
Straw + manure 8t/ha.	50 - 55	10.2	40 - 45	8.2

Source: Raobelison (2000)

BNF, equivalent to 2 t/ha. This implies that a crop does not necessarily need a large amount of organic fertilizer to trigger a soil biological response.

A threshold for the amount of compost that can be considered as an 'incitement' for microorganism activity to accomplish BNF was determined from trials at Anjomakely, Beforona and Fianarantsoa (see Table 6 and Figure 3).

These results indicate an 'incitement' threshold for compost with SRI methods can be just 1 to 2 t/ha compared to the currently recommended doses of 5 to 10 t/ha, though younger seedlings gave better response to more compost applications than did older ones. This could be because with SRI plant, soil, water and management practices, the value of the compost is more indirect — for its triggering and sustaining soil microbial activity which produces or acquires nutrients for the plant, e.g., through P solubilization — than for its direct nutrient contributions assessed in terms of the amount of nutrients contained in the compost itself.

Assessing the effects of BNF with SRI

Stewart (1977) and Hamdi (1982) reported many years ago on the existence of different kinds of microorganisms in the soil (rhizosphere) that can fix nitrogen, residing around, on or in plant roots. These organisms can be either symbiotic or associative according to their fixation ability. If the nitrogen fixation occurs as a reduction of N_2 into NH_3, as in the case of rice plants, it is considered as associative fixation, and the energy for the reduction is provided either by carbohydrate from the soil or by root exudates. As a corollary, we can note that if carbohydrates are the dominant energy source, then fixation is low, and vice versa, fixation is higher if carbohydrates are not the dominant source of energy. This observation can be seen in Table 7.

Currently, our research is focusing on the importance of BNF to explain the high performance of SRI. We want to know whether the use of fertilizer in inorganic forms (NPK) as well as application of large amounts of such fertilizer will decrease, through competition from other microorganisms more benefited by the fertilizer, the number of *Azospirillium* that are located in the root system, which will then inhibit the process of BNF. The comparisons made are for:

Clay: no fertilizer, traditional cultivation, not SRI

Loam: no fertilizer, SRI

Clay: no fertilizer, SRI

Loam: with compost, SRI

Clay: with NPK, SRI

Clay: with compost, SRI

Table 6: Amounts of compost application indicating the 'incitement' threshold of microorganisms for fixing N and effects on tillering

	Average Number of Tillers								
	Anjomakely			Beforona			Fianarantsoa		
Compost applications	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
0 t/ha	42	23	10	44	32	26	35	20	14
1 t/ha	46	25	13	50	37	31	39	25	18
2 t/ha	60	30	17	47	33	25	42	29	15
3 t/ha	55	31	15	-	-	-	40	34	20
4 t/ha	52	32	16	48	35	27	38	32	23
6 t/ha	49	35	12	50	38	29	-	-	-

Conditions: Single seedlings aged 8 days at transplanting; water management: alternate drying and wetting of 3 days each with 10cm water level at most. Research in 2001-2002.

Table 7. *Azospirillium* sp. counts according to treatments

Treatments		Number of *Azospirillium* sp.			
Texture/method	Fertilizer	Soil near root system (10^3/ml)	Roots (10^3/mg)	Yields (t/ha)	Tillers (N)
Clay/traditional	No	25	65	1.8	17
Loam/SRI	No	25	75	2.1	32
Clay/SRI	No	25	1,100	6.1	45
Loam/SRI	Compost	25	2,000	6.6	47
Clay/SRI	N P K	25	450	9.0	68
Clay/SRI	Compost	25	1,400	10.5	78

Notes: These trials were undertaken at Anjomakely in 2001 with alternate drying and wetting every 3 days from transplantation to the end of the tillering period, and with 3 weedings with a hand weeder.

Control comparisons: Traditional rice cultivation (non-SRI): clumps of 30-day-old seedlings, no water management, no weeder operation but weeding by hand.

Retirement of Azospirillium *was by using Döbereiner's method (cf. Reproduction and multiplication environment in method and materials), and the obtained number of* Azospirillium *was derived by comparisons with Grady's table.*

Plant sampling was done at the end of the tillering period.

The concentration of *Azospirillium* in the soil (rhizosphere) remains low and constant ($n = 25x\ 10^3$/ml) no matter what are the soil texture and the fertilizer level. Very significant differences can only be noticed in the root system. From $n = 450 \times 10^3$/mg (for treatments with NPK), we can expect better yields and better tillering.

We find the number of *Azospirillium* sp. decreasing when chemical fertilizers are used (see Table 7 and Figure 4). This would explain the important need for nitrogen sources with other intensified systems of rice production such as the System of Rice Improvement (SRA), promoted by the Madagascar government. SRA demands two applications of urea (2 x 60 kg/ha), the first after transplanting, and the second before the end of tillering period.

Rice plants that are provided with chemical fertilizer have less colonies of *Azospirillium* sp ($n = 450x10^3$/

Figure 3. Compost Incitement, Anjomakely and Beforona

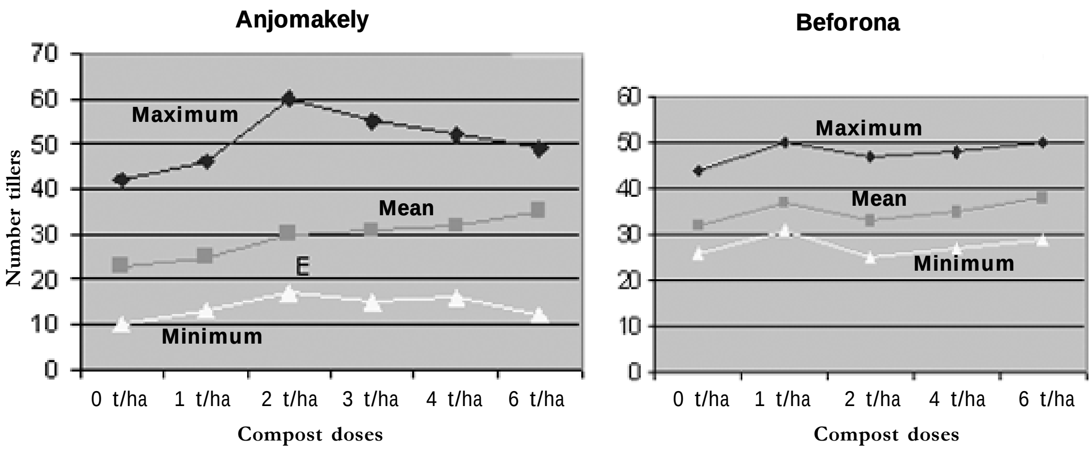
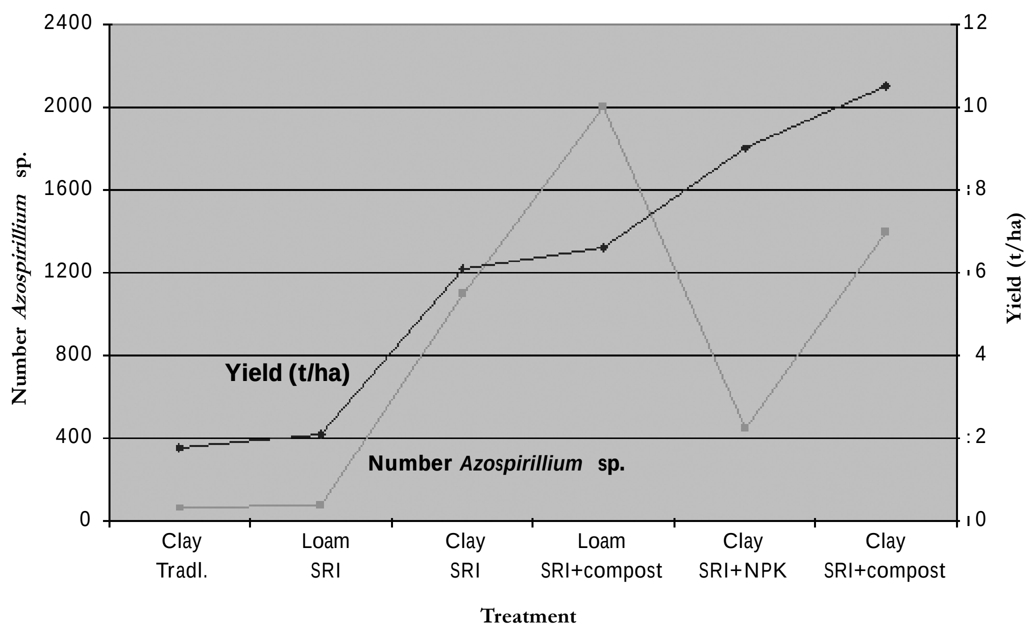


Figure 4. ***Azospirillium*** **number according to treatments**



mg), compared to those that were fertilized with compost ($n = 1400x10^3/mg$). Nevertheless, both of them brought the two highest yields (Figure 4). The three colonies that were retrieved from them and identified were: *A. brasilense*, *A. lipoferum*, and probably *A. amazonense*.

Discussion

Our trials consider SRI as a variant of organic agriculture practice. Use of compost and adapted seeds for each ecological region can give high yields with only a small dose of nutrients. Plants grown in on-farm SRI experiments were undamaged by diseases. Patterns of yield variation observed according to differences in the type of soil and the amount of fertilizer that was applied lead us to conclude that the reproduction and multiplication of microorganisms induced by inoculation of seeds or by compost amendments contributes to increased yield while cutting down on the need to use fertilizer. Further trials to establish a test for "effectiveness" regarding the consequences of soil and plant inoculation will be undertaken in future research.

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Group Reports

Technical and Biophysical Issues for Research and Practice

Methodology for Improving Evaluations of SRI

From a scientific perspective, more precise and better documented comparisons are needed both to gain a better understanding of SRI and more standard methods of evaluation and statistical analyses are necessary for scientific credibility. To the extent possible, when SRI results are reported they should include:

- **Plot size** for comparing results; results from very small plots can be hard to evaluate, so a minimum size of at least 100 m^2 (1 are) should be used for evaluations.
- **Sampling methods** should be specified whenever sample-based estimates are reported. Whole-field harvest results and resulting calculations of yield are always preferable.
- **Control plots** should be established wherever possible since comparisons with a country's national average are not very useful or valid given differences in soil, climate and other conditions that affect specific yields.
- **Moisture content** of rice should be measured and reported for the sake of comparison; this is not be so important where comparisons are made with a control plot where comparative measurements are made with the same methods.
- **Total biomass** should be recorded along with yield wherever possible, at least *above-ground biomass*, though roots can be weighed to give some rough measure of below-ground biomass. Other measures and comparisons of roots can give useful information if dried or wet weight of roots cannot be measured:

  • *root length* in cm;

  • *root volume* measured by water displacement; or

  • *root resistance* assessed by a pull test — kg of force required to uproot a plant where soil characteristics and wetness are reasonably similar for the plants being compared.

  This latter test gives data that are useful for *relative* rather than absolute comparisons.
- Components of yield **are always important to document, from a random sample of at least 10 plants:**

  • *tillers per plant*;

  • *effective tillers per plant* — and percent of effective tillers;

  • *grains per panicle*; and

  • *grain weight* — weight of 1000 grains in grams.
- **Soil organic matter content**, and **microbiological diversity and activity** should also be documented if possible, along with **standard soil characterizations** (pH, clay content, etc.). Soil biological factors are considered important with SRI, but there is little systematic data.

Cooperation with Farmers

The measurements and criteria listed above speak to the concerns of researchers. From the perspective of farmers and NGOs, we recognize that **participatory processes** are important for gaining wider understanding and acceptance. It is hoped that scientists can learn from farmers' and NGOs' experience and documentation even if this information is not as extensive or exact as scientists desire. Conversely, it is hoped that farmers and NGOs will help to generate more detailed and complete information on their SRI experience and performance that can be of use to scientists. Participatory processes and scientific investigation can and should be made compatible.

Issues for Assessment

From discussions of the technical aspects of SRI, a number of important concerns were identified for consideration and investigation. Because many of these practices are interactive, they need to be looked at from several vantage points.

Land preparation

- Although *no change* in land preparation practices is required for SRI, *good land preparation* is needed when planting younger seedlings. *Experimentation* with preparation and leveling techniques is advisable to get the most benefit from soil, water, plant and nutrient resources.
- Questions were raised about *puddling and groundwater recharge*: whether changes in land preparation would have a favorable or unfavorable effect on hydrology. Possibly plants would benefit from practices that eliminate any soil pan but this could change water dynamics. Research and experimentation should be done in this area of practice.
- With wide spacing of plants, *broadcasting of fertilizer* is less efficient. We need experiments and evaluation to find what are the most appropriate methods for application of fertilizer, e.g., granulated forms, wherever inorganic nutrients are used with SRI.
- Use of *raised beds* with SRI practices is very promising as this method of land use can maintain more soil aeration and use less water when flooding becomes unnecessary. Initial research supported by the Rice-Wheat Consortium with raised beds is very promising.

Nursery

- Evaluation and use of *seedling trays* is recommended as these can help to protect and preserve tender root systems intact during transplanting.
- Use of *bamboo trays* is a farmer innovation that can help with transport of tiny seedlings from the home to the field very efficiently.
- *Direct seeding* is an alternative to transplanting that should be experimented with. It can save labor if the seed germination rate is high enough.
- One way to improve germination is *seed priming*. Evaluation of methods for this practice was suggested.

Seed quality and crop establishment

- Quality of seed can be a problem for many farmers. They should be taught methods for good *seed selection*. This becomes more feasible with SRI since many fewer seeds are needed.
- With SRI practices, the *multiplication of breeder seed* can be much greater as many more grains can be produced from a single seed, 1,000-2,000 or more. Also the resulting seed is usually more uniform and of higher quality.
- *Optimum sowing dates* need to be evaluated anew with SRI practices. There is also much evaluation to be done of sowing under different conditions, comparing photosensitive and non-sensitive varieties, to understand their implications for optimum sowing dates.
- In some areas, there are problems with *cold temperature* that will slow seedling growth so much that the usual SRI recommendations on seedling age need to be adjusted (lengthened). Recommendations should be by physiological age rather than calendar age.
- *Optimum sowing rates* should also be evaluated. Usually these have been 5-10 kg/ha with SRI methods, reflecting the sparser planting of seedlings. Sowing so few seeds can be one of the hardest things to get accepted, though once demonstrated it is very popular with farmers.
- Methods of *direct seeding*, with primed or pregerminated seeds, should be experimented with to see what labor-saving might be achieved this way.
- It may be possible that *mechanization* of transplanting young SRI seedlings can save labor, perhaps with seedlings grown in plastic trays as presently done in China for the broadcast of seedlings.

Water management

- *Water control* can be a problem for farmers who want to use SRI but who get their water according to a fixed schedule rather than on demand, when needed. Adjustments in plant, soil and water management to accommodate *different kinds and degrees of water control* should be evaluated. Often the issue will be one of making investments in better water control facilities.
- How to deal with *excess water* during a monsoon season where these rains cause serious flooding is a particularly serious issue for SRI water control.
- *Field leveling*, part of land preparation, needs to be done well to get an even rather than a rough surface, so that the reduced water applications can be both minimal and effective.
- *Drainage methods* should also be reviewed and improved, such as the installation of in-field furrows or other means to keep the soil well-drained when it is not supposed to be flooded.
- *Alternate flooding and drying* of fields is another area for experimentation and evaluation, as farmers are finding this saves them labor compared to continuous (sometimes intermittent) application of small amounts of water to keep the soil moist but not

flooded during the vegetative growth phase. There is presently a wide range of cycles being used by farmers. What is the most productive cycle? How should the cycle be adjusted for different soils? We need considerable experimentation and research to answer these questions.

- *Water saving* — How much saving is possible with SRI? What are the agronomic and the economic implications of different methods for water management with SRI?
- *Varietal differences* surely will have some influence on alternative water management practices, e.g., interactions with water uptake that affect nutrient losses. So these should be considered in doing evaluations.
- SRI for *rainfed conditions* should be experimented with, using SRI principles as a guide. This work will intersect with nutrient management practices, particularly mulching.

Weed control

- Some weeds are very difficult to control without continuous flooding. Studies on the *use of herbicides* should be done: What are the agronomics and economics of this compared to soil-aerating manual weeding practices? What are the environmental implications? What effects on tillering? In Sri Lanka, they have found herbicides reduce rice tillering somewhat. Also, what are the effects of herbicide use compared to use of green manures and cover crops (GMCCs)?
- *Improvement of mechanical weeders* should be done, evaluating alternative designs for different soils and different users. One new design used in Sri Lanka can apparently reduce weeding time to one-two days per acre.
- *Access to weeders* is important to facilitate SRI adoption. What kinds of credit schemes can support wider access? How can local fabricators and merchants be gotten to make and distribute weeders at reasonable prices?
- *Coordination of water issues* (flooding) with weeding timetables should be addressed to gain water- and labor-use efficiency and for timeliness of weed control.
- *Water management* practices should be varied experimentally to see whether intermittent flooding during the early stages of rice plant growth, normally to be avoided with SRI, could accomplish an acceptable degree of weed control. We do not know how long rice plants can be flooded before their roots begin forming aerenchyma (air pockets) and begin the process of root degeneration due to hypoxia (suffocation).
- Use of *intercropping* or *cover crops/green manures* such as sesbania, cowpeas and other species to smother weeds is a practice whose evaluation is just beginning. This is an interesting approach from several perspectives as leguminous species could enrich soil nutrients, as discussed on page 181-185.
- *Rotational cropping* might also be undertaken with SRI to achieve a degree of weed control.
- *Mulching* could make manual weeding unnecessary, but there is little systematic experience with this practice in SRI.
- There could be *varietal differences* worth examining in terms of competitiveness with weeds that would reduce the problem of weed control with SRI methods.

Nutrient management

- What are the implications for nutrients of *alternate flooding and drying*? Is there *more loss*, e.g., due to leaching and volatilization of N, or *nutrient gain*, through processes such as biological N fixation and P solubilization? Little is known about this.
- How can *compost and other organic sources* of nutrients be best used with SRI practices? Some research reported to the conference suggested that only fairly small amounts of compost, e.g., 2 t/ha, may be needed to achieve significant nutrient benefit for SRI crops.
- How can *multiple cropping*, either through intercropping or rotations, contribute to soil nutrient status with SRI practices?
- What scope is there for use of *effective microorganisms* within SRI to improve soil fertility?
- The biggest question is probably *for how long can high productivity be maintained* with SRI practices? What soil, water, nutrient and plant management practices can best sustain productivity?

Labor

Many aspects of SRI require more labor. Finding ways to make SRI practices more *labor-economizing* will be important to make the system more widely acceptable. We need also to understand agronomic issues and dynamics better to know *how labor can be made most productive*.

- *Nursery preparation* — size and location of the nursery and soil mixtures are important but not well evaluated yet.
- *Seedling transport* — interesting farmer innovations are coming up in this area.
- *Land preparation* — so far SRI has not recommended any changes in this area, to avoid making SRI more complicated to adopt; but possibly improvements can be made in this area.
- *Organic matter use* — how can making and applying compost be made more efficient in terms of time and labor? Should legumes or other biomass be grown in arable or non-arable areas to make more organic matter available?
- Methods for marking fields for *spaced planting* — using a simple wooden rake, instead of using ropes tied to sticks, has become a labor-saving technique in several countries.
- *Planting practices and optimum spacing* — these should vary according to soil type and other conditions, but we have little systematic knowledge on what to recommend where.
- *Soil types* vary widely, so adjusting water and plant management practices accordingly is important. Farmers are making a lot of adjustment in this respect already, but we do not have good explanations or recommendations to offer. This calls for systematic evaluation.
- *Water management* at planting time and during the growing season — there is wide variation in farmer practices that remains to be understood in scientific terms.
- *Weeding methods*, including use of the mechanical push weeder — additional weedings appear to raise yields, but we have few systematic evaluations of how much return there can be to labor invested in soil-aerating weeding.

Biological problems and issues

A number of these issues were discussed to focus attention on matters that should be resolved or minimized to make SRI more feasible and attractive:

- *Unproductive tillers* — how to minimize? There is wide variation in this percentage, from 10 to 50%, which we cannot yet explain very well. One hypothesis that emerged during the conference was that large applications of N fertilize increase rather than decrease the proportion of unfertile tillers.
- *Large variations in yield* — how to explain these? Soil quality, assessed in biological as well as chemical and physical terms, seems an important area for investigation.
- *Organic vs. inorganic nutrient supply* presents many interesting issues, whether either gives superior results, or when and why? Quite possibly, *some combinations of nutrient sources* will be optimal.
- *Microbial activity* — how can this be evaluated and to the extent that it is found beneficial, how can it be increased?
- *Earthworms* — we know that these contribute to soil productivity in general terms. How can vermiculture be incorporated usefully within SRI?
- *Root damage* during mechanical weeding can be a problem — how can this be minimized? Or is there some benefit to root system development from having root pruning close to the surface, causing deeper root growth?
- *Varietal performance* with SRI practices — this is obviously an important consideration as we find considerable variation in growth and yield by varieties. How this can be assessed and addressed was taken up by a subsequent group.

Scale and transformation of production

- SRI is presently practiced mostly on a small scale. What practices would have to be changed or adapted for successful *larger scale production*?
- What are the opportunities for *mechanization* within the suite of SRI practices, and what are the economics and practical aspects of this?
- SRI should be seen and practiced within the context of *diversification and modernization* of the agricultural sector since as SRI raises productivity and yields, there should be less and less need to devote so much land, labor and other resources to rice production. SRI should be seen and evaluated within a farming systems framework, with objectives beyond just growing more rice.

SRI Adaptation and Diffusion Issues

Orienting Observations

Several premises were formulated at the outset of this group discussion to characterize the task of making SRI more broadly available and getting it utilized:

- SRI should be understood as a **complex system**, *even if its principles are simple*. One is not trying just to diffuse a few specific practices but rather to spread a more holistic understanding of how rice plants can be grown more effectively.
- SRI needs **adaptation** to local conditions according to farmers' preferences, observations and innovation. *Farmer experimentation* is an essential part of any strategy for the dissemination of SRI.
- Farmers' ways of practicing agriculture are as a rule **not easy to change**. There are many reasons, real or imagined, for what they are presently doing. Efforts to disseminate SRI must *fit within existing farming systems and within existing systems of thought.*
- SRI methods make **some drastic changes** in what has been the conventional system of irrigated rice cultivation. While the changes themselves seem simple enough, they are altering or even reversing some *long-standing practices*.
- Change always entails some **risk**. Given the small margin of resources that most rural households have to live on, they cannot afford to engage in risky behavior. So concerns about the possibility of crop failure and other problems must be addressed.
- There is much **diversity** in the conditions under which farmers operate in terms of socio-economic factors, soil capabilities, opportunity costs, etc. SRI needs to be varied not just to suit local biophysical conditions, but also to adapt to farmers' labor availability, tenure status, etc.

A Dynamic Process with Multiple Actors

It is important to understand that there are **feedback mechanisms** between adaptation and diffusion so that this process should be seen as *a single, continuous process of transformation* rather than as something linear:

$$\text{ADAPTATION} \rightleftarrows \text{DIFFUSION}$$

The success of SRI **diffusion** will depend on making appropriate adaptations, which in turn will make diffusion easier as SRI fits into various environments more productively and sustainably. The process should always be seen as one of *adaptation rather than adoption*.

The three main sets of actors who need to interact in SRI adaptation and diffusion are:

- **Farmers** as users of the methodology and as innovators who modify SRI in an ongoing process of change and evolution;
- **Extensionists and promoters** who provide knowledge about SRI to farmers and facilitate the process of adaptation and diffusion; and
- **Researchers** who provide knowledge to extensionists and promoters as well as to farmers, and who are building up a better understanding of SRI, both through their own experimentation and by learning from practice in the field.

  Conventional R&D approaches are not likely to be well suited to SRI dissemination, but experience is still limited on this. Effective linkage among these actors will be crucial, rather than follow the usual *linear strategy* of transmitting information from researchers to extensionists to farmers, with farmers as "recipients" of new technology rather than as innovators and partners in this process of technological change.

Operational Issues

Several key issues related to *adaptation* were identified during group discussion:

- Correct identification of the **limitations** of SRI under various conditions is important — where is it more likely to be productive, and where not? For what reasons?
- Farmers should be offered **options** for their very different biophysical conditions and socio-economic endowments, letting them experiment, evaluate and choose.
- Established institutions need to learn to work with **more flexibility** as they become engaged with SRI, being open to new ideas and approaches.
- Successful adaptations require more knowledge about how the SRI system works and why. We should not rely just on *trial-and-error methods* as these are risky and have their costs. They can sometimes add useful insights and practices, but as much as possible SRI should be advanced with *systematic understanding* developed by scientists, **extensionists and farmers.**
- **Participation** of farmers is crucial in this process, as farmers experiment, modify and observe all the time. Provision should be made for reseaarchers and promoters to engage with farmers in these activities, and together they should construct their shared learning into something systematic.

Additional issues highlighted relating to *diffusion*:

- **Credibility** for the diffusion process needs to be created and maintained:

  —The **limitations** of current extension systems must be recognized by all. Farmers probably know these better than anybody else so they will have to be persuaded that the source of new information is credible.

  —Most extension systems have **limited manpower**, and they have limited knowledge about SRI, so there are very real constraints on what formal institutions for diffusion can do.

  —**Physical mobility** of personnel is a major constraint for extension efforts in many countries. Too often, promoters are not able to spend much time in the field due to logistical and financial problems. SRI diffusion requires much direct contact with farmers.

  —**Farmer-to-farmer approaches** generally have more credibility with farmers. There need to be improvements in extension-to-farmer relations. As much as possible, the process of SRI diffusion should be carried out on a *farmer-to-farmer* basis.

- The **message** being communicated to farmers has to be intelligible and effective:

  —Much effort should be made to ensure that the **quality and content** of the message is very well conceived and well presented.

  —**Means and methodologies** for communication need to be developed that are appropriate, taking into account that lack of literacy can be a limitation in some places as well as the frequent fact that there are limited resources for dissemination.

  —**Bad news travels fast** — often faster than good news. Care must be taken to proceed with a solid foundation of knowledge and experience so as to minimize failures. Also, there must be scrupulous reporting of information and experience, since bad news, especially if true, has a way of getting disseminated one way or another.

  —**Conflicting messages** can be a problem when several agencies work in the same area and say different things. Efforts must be made to have consistency in SRI communications.

  —Since SRI is not a 'fixed system' but rather a **set of options**, farmers need to understand the principles, not just practices. The SRI message is of a different nature than most extension messages conveyed in the past.

Strategic Issues

Various elements of a strategy for SRI diffusion seem most promising:

- Seeking **step-by-step adoption**, rather than promoting a mass campaign. Select entry points carefully, identifying niches, and starting with areas that are most suitable for SRI practice, to build up solid impressive performance and farmer knowledge that can be disseminated.
- Starting on a **small scale** to be sure of the program's ability to deliver success, remembering that bad news travels fast.
- Understanding the **socio-economic conditions** of farmers and what constraints these may introduce, to adjust messages and techniques to suit different locations.
- Working wherever possible with **farmer groups** that are already organized and functioning.
- Showing **respect** for farmers' knowledge and responsibility, avoiding any paternalistic approaches.
- Using demonstrations as much as possible. Often farmers need to see in order to believe, especially with something as unusual as SRI.

—**Field days** have been a good method for dissemination, as well as

—**Demonstration plots** on farmers' fields or in villages.

—**Mass communication** methods can also be important in dissemination efforts.

- Paying attention to the **input requirements** for SRI, particularly labor, as these are often a barrier to experimentation and adoption. Farmers need to have a full understanding of the costs involved with SRI.
- Considering **gender issues**. Although initial feedback from farmers in several countries has suggested that women find SRI a more satisfactory method for various reasons, continuing assessments need to be made of gender impacts so that SRI contributes to gender equity rather than worsens inequity.

Institutional issues as part of this strategic approach include:

- Conflicts and problems of **inter-institutional coordination** among agencies and donors need to be avoided, and if they occur, they should be resolved quickly.
- **Greater training capacity** for SRI dissemination, particularly for the training of trainers.
- **Monitoring capacity** has also to be created and maintained, to be able to correct any mistakes and build upon opportunities.

Experience with Adaptation and Diffusion

Several participants reported on how the process of diffusion has proceeded thus far in their countries. These experiences differed considerably from one country to the next:

- In **Madagascar**, SRI was introduced first by an NGO, Association Tefy Saina, doing training and farmer-to-farmer extension, supplemented by booklets and radio (see pages 90-93). Subsequently there was also involvement from the university and government research agency, but most farmers have still been hesitant, and spread has been still slow. It is accelerating now that a larger and better funded and equipped NGO, Catholic Relief Services, is involved in SRI dissemination, with more donor support.
- In **Indonesia**, dissemination is now starting after three years of evaluation by government researchers (see pages 58-63). It has been incorporated into a new official strategy for increasing rice production (Integrated Crop and Resource Management, ICM) being spread now on a national basis, expecting to make local adaptations as appropriate. This country's IPM program is also starting to work with SRI as this methodology is very consistent with the approach of that program's Farmer Field Schools.
- In **Sri Lanka**, SRI is spreading fast, with about 4,000 farmers using it. Dissemination started with an article on SRI experience in Madagascar printed in the Ministry of Agriculture's extension magazine (30,000 copies were distributed). This was after a researcher from Madagascar, Joeli Barison, came to Sri Lanka in January 2000 to share knowledge about SRI. Those agricultural officers and extensionists who tried SRI on their own accord got good results. TV and radio became interested, creating a process of dissemination that could not be stopped any more.

  Unfortunately, some researchers in Sri Lanka have been opposed to SRI, and it has not yet gotten official approval for dissemination from the Ministry of Agriculture. The Minister of Agriculture and a previous Deputy Minister have been very supportive, however, so efforts to disseminate SRI have proceeded without formal endorsement. The current Minister is interested to try SRI on his own farm, and the former Deputy Minister has used SRI on his own farm for three years with much success (see pages 26-28). Rotary weeders, introduced some years ago, have been reintroduced to support SRI dissemination, with information on how to fabricate them spread to local blacksmiths. A green light from the government is expected once more research confirmation is in hand. Opportunities to *export* organically-grown rice that uses SRI methods (as "eco-rice") have helped to raise interest in SRI among farmers and officials.
- In **Laos**, there has been some small-scale NGO experimentation and evaluation with farmers to begin with (see pages 86-89). The IRRI program in Laos has now taken initiative to launch a national evaluation effort starting in June 2002. It expects three seasons of testing will be needed before recommendations are made, but some farmers are likely to start using it more quickly if the initial results are good. Possibly donor funding can be obtained for a national dissemination project if SRI proves to be successful in the evaluations.
- In **Cuba**, some top-level officials became convinced about SRI's potential at an early stage. Dissemination can go very fast here because of farmers' literacy and because of their need to find ways to raise rice production without requiring expensive inputs based on petrochemicals. Initial results have been very good (pages 52-55).

Recommendations

- It is very important to convince **top-level** people and where possible to get policy-level promotion of SRI. This has been very helpful in Sri Lanka, where, for example, even the President has become interested in SRI after the farmer cultivating her land using SRI methods got a much higher yield.
- There should be special strategies to convince **professionals**, who often find it hard to accept this new methodology. The mention of super-yields attained with SRI (e.g., 21 t/ha) is often not believed by researchers even when yield component information is provided, so it may be best to put more stress on *average yields*, not those that are attainable with best SRI practices.
- As long as SRI is not accepted by government, there is need for alternative strategies of dissemination. Even where there is government acceptance, these can be complementary.

  —**NGOs** offer many opportunities for SRI dissemination work, and they are likely to be attracted to SRI for its pro-poor, environmentally-friendly features.

  —**Farmer groups** if they can be informed about SRI can also experiment with its methods and help these to spread. A farmer NGO in the Philippines, MASIPAG, is currently evaluating SRI methods.
- **Practical training** should be provided and communicated by farmers who have personal experience with SRI methods and principles.

  —**Farmer-to-farmer** training is likely to be most successful. Conversely, the Training and Visit (T&V) system of extension is not likely to be suitable.

  —Wherever possible, SRI should be linked with **Farmer Field School** (FFS) programs on rice which give IPM training. The FFS approach and philosophy are very well suited for SRI. We should try to get FAO and its IPM programs around the world interested in SRI.
- There may be need for **credit facilities** for tools, in particular, for purchasing the rotary weeder. These weeders can be very cheap, but poor farmers can find even small expenditures like this a barrier to use of SRI methods. Otherwise, SRI has no credit requirements.
- All available information should be made accessible on a **homepage** on the Internet. The use of electronic communication is spreading rapidly. Year by year, more government researchers, NGOs and others, even farmers, in developing countries are gaining access.
- **Donor interest** in supporting SRI dissemination should be explored and increased. Funding is needed for getting more rapid spread of these opportunities to farmers around the world.

Chinese Perspectives

While international participants discussed technical/biophysical and adaptation/diffusion issues, the Chinese participants met together in order to have more free-flowing discussions in their own language. Their reports emphasized the need to have a combination of scientists, policy-makers, extension workers and farmers from rice ecosystems all working together to have more effective dissemination as well as for getting better research.

In general, there was agreement that the SRI concept should be accepted as a good one for rice production in China. Chinese scientists are very interested in SRI.

- There is *greater efficiency of water utilization*, commonly savings of 40% or more.
- There is *high yield potential* with these methods, especially in conjunction with hybrid rice. Using younger seedlings does have certain advantages for subsequent plant performance, contributing to higher yield.
- There is *better light interception* by SRI plants, and their *stronger root system* leads to stronger individual plants that can resist pests and diseases and lodging.
- The use of organic fertilizer adds to *soil fertility and plant health*.

There are some problems noted, however:

- The practice seems *too complex* for easy adoption. In particular, it is often difficult for farmers to handle young seedlings as young as 8 to 12 days old.
- *Weed control* is difficult if the fields are not being kept continuously flooded.
- *Effective tillering* is often low, around 50% instead of the desired >70%.
- Sometimes certain *yield components* are less, such as panicle size (though this was seldom reported from other countries).
- *Organic sources of nutrients* are often not available or are costly in labor terms. Farmers are used to using chemical fertilizer, and it may be difficult for them to return to organic sources.
- There is more *labor-intensity* with SRI and thus higher labor costs. These can be compensated by higher yield, but most farmers are hesitant to become more dependent on labor inputs when the agricultural economy as a whole is becoming more labor-scarce.

Suggestions

- There should be *domestic and international cooperation* to advance the theory and practice of SRI. This should include programs that seek and provide effective financial support.
- In particular, there should be research to *localize and adapt SRI* according to local soil, climatic and other conditions, with attention given to the most responsive varieties.
- SRI methods should be used together with *super hybrid rice varieties* for best results.
- *Rice breeding* programs should continue with SRI methods in mind, aiming, for example, at improving the drought-tolerance of new varieties.

Various specific issues were raised based on Chinese evaluations to date.

- *Planting density* should be carefully studied and varied to find the optimum.
- *Chemical fertilizers* should be used along with organic fertilizers. There are limited supplies of the latter, and farmers are used to applying inorganic fertilizer. It seems desirable to make N applications at the heading stage in particular.
- New methods for *seedling raising* should be tried, e.g., tray planting or direct seeding.

Extension

So far, SRI evaluations in China have been done entirely by researchers at various institutions. A next step will be to encourage farmers to try SRI methods for themselves.

For successful extension, SRI will need to have various **adaptations and options** for:

- Cropping systems;
- Rice season;
- Appropriate variety/hybrid types;
- Spacing; and
- Water management possibilities.

For successful spread, it will be important to have **demonstrations** in selected sites to start out, supported by:

- Networks;
- Training; and
- Farmer participation.

These can then be expanded into a broader and more effective program of **extension**. It will be important to have better **knowledge, skill and practices** regarding:

- Optimum seedling age;
- Best transplanting techniques;
- Land-leveling requirements;
- Water management practices; and
- Pest and weed control.

There should be **risk analysis** to have fuller information to give to farmers on:

- Percentage of *productive tillers* (this can vary widely);
- *Fertility of spikelets* as affected by temperature and drought;
- Variation in number of *grains per panicle*, leading to yield variation;
- *Economic analysis* of profitability, labor requirements, etc.; and
- *Environmental impacts* — there is growing government concern with a healthy ecology.

Anticipated **problems** in extension are:

- *Organic manure* is not widely available; use straw and green manures in cropping system.
- *Weeding* — labor may not be available for hand-weeding, so would need to use herbicides.
- *Transplanting* — difficult by hand, but raising seedlings in plastic trays can make this easier.
- *Low percentage of productive tillers* in many Chinese trials. This could be raised by:

  — Raising stronger seedlings with good tillering ability;

  — Promoting tiller emergence in the period of unproductive tillers; and

  — Controlling plants' tillering in the period of nonproductive tillers.

The conclusion is that Chinese rice scientists and practitioners should take advantage of SRI and localize its methods to adapt to Chinese conditions. At the same time, the productive opportunities created by Chinese super high-yielding varieties should be incorporated.

User and NGO Perspectives

A group of farmer and NGO participants put these ideas forward. To play more effective roles in the process of SRI evaluation and dissemination, they need more **information** about SRI — its practices, its results, its limitations — and more **knowledge** about how SRI works and how it can be made to work best so that rice production can be improved. There is a real need for scientists, extensionists, NGOs and users to work together for advancing the application and benefits of SRI.

Examples of knowledge and information that users and NGOs would like to have are:

- How to increase the number and proportion of *effective tillers* in terms of plant, soil, water and nutrient management practices with SRI.
- How to optimize *spacing* to get best results. The Chinese innovation of "triangular" planting (page 00) elicited considerable interest among participants.
- What *varieties*, improved or traditional, respond best to SRI practices. This could be established by research programs or by users exchanging information about their experience.
- Use of *herbicides* vs. use of hand weeders to control weeds, considering the effects of each on the soil and ecosystem. What are the critical times for weeding, and how often is it necessary?
- What options are available for *improving soil fertility* — methods, timing and benefits of adding organic matter through compost, green manures and other means, and the use of inorganic fertilizers separately or in conjunction.
- How to monitor and assess changes in the *rice field ecosystem* in terms of pests, nematodes, microbes, nutrient availability, etc.
- What are the best methods for *raising seedlings*. A number of methods have been described, e.g., use of plastic trays to facilitate transplanting seedlings without root trauma, but without assessments of their cost-effectiveness.
- How can the *labor-intensity* of SRI be reduced, such as with redesigned weeders, or easier water management methods.
- What are the possibilities for combining *zero-tillage* with SRI practices.

Promotion of SRI

There is need for simple extension materials. These could be shared among countries, with instructions, pictures and information put into the local language. Also, materials need to be differentiated between those intended for farmer users and those for NGOs or government facilitators. Farmer suggestions should be sought on how to make these materials and the associated communication processes most effective. The communication process for SRI should itself be participatory rather than being top-down.

In general, farmer-research-extension linkages need to be improved, with more of a bottom-up approach. This should be supported by staff development initiatives for government agencies and NGOs since SRI requires new ways of thinking and of approaching farmers.

Recommendations

- The efforts of users and NGOs can be more effective if there is **policy advocacy** on behalf of SRI at higher levels of authority.
- A **family approach** should be tried, involving women as well as men, and also youngsters who are involved in paddy cultivation. This approach has been shown to be more effective in Bangladesh.
- Rather than focus just on *individual users*, there should be a **group/community approach**, seeking to raise interest in and knowledge of SRI for *sets of people*.
- Individual decisions and practices are invariably influenced by what others around them are thinking and doing.

- In presenting SRI to users through public, private or NGO extension efforts, it should not be described as a *single, set package* but rather as a **set of options**, justified with reference to certain understandable principles. Local conditions vary, such as when good water control is difficult or even impossible. Practices need to be altered appropriately.

Research Issues

SRI raises a great number of interesting issues and opportunities identified in several group discussions among researchers at the conference.

Plant Research Issues

At the plant level

Preferred plant type characteristics for SRI have not been established in any systematic way, so this is a promising area for investigation. There needs to be evaluation of factors such as:

- **Plant height** — balancing good straw yield with lodging resistance.
- **Tillering capacity** — having optimum plant tillering that gives maximum number of productive tillers per unit area, with minimum negative competition among tillers within the plant.
- **Effective tillering** — ensuring that this is over 70% to have efficient plant performance. One hypothesis that emerged from discussions was that with SRI practices, the heavy application of N fertilizer may reduce rather than enhance effective tillering. This should be evaluated systematically because if correct, one can save costs and increase output.
- **Panicle size** — having maximum grain filling with good grain weight.

At the population level

It will be important to know more about:

- **Seedling growth and crop establishment** — manipulation of nursery temperature, spacing and soil characteristics to create vigorous seedling growth and best growth in the field.
- **Varietal response** under SRI methods — evaluating compatibility of photoperiod-sensitive vs. photoperiod-insensitive varieties with SRI management practices; also responsiveness of glutinous vs. nonglutinous varieties, and of inbreds vs. hybrids.
- **Planting geometry, plant density and seedling age** interactions for SRI in different locations under varying climatic and soil conditions.

Soil, Water and Other Management Issues

- **Most effective water management** for SRI under different soil conditions should be studied, and also the advantages and disadvantages of moist and cracked soil.
- **Nutrient applications and soil fertility maintenance,** with and without organic manure or compost, should be evaluated in terms of **integrated nutrient management.** There is need to understand better the effects of different **timing and amounts of nutrient amendments,** and to improve **composting techniques**. There may be advantages with slowly-released, coated N fertilizer. Also, as suggested by research from Madagascar, **small amounts of organic matter** added to the soil may be able to produce good results with SRI practices.
- **Effective weed management practices** — possible use of non-persistent herbicides; costs and benefits of crop rotation and of green manure and cover crops (GMCCs).
- **Enhancing soil microbial activity** to promote SRI performance — possible species manipulation, and management opportunities, such as soil or seedling inoculation.
- **Differential response to pest and disease attacks** between SRI and conventional rice cultivation practices — understanding dynamics and principles to take best advantage of the insights SRI can provide for pest and disease reduction.

Ecological and Physiological Issues

- **Soil chemical changes and microbial dynamics** under the intermittent irrigation system used with SRI. The effects of **soil aeration** need to be better understood.
- **Nutrient-use efficiency** is a related matter of interest, as some research shows SRI plants being more efficient in their uptake of N, P and K compared to conventionally-grown rice.
- **Light interception and photosynthetic activity** are important for yield — what are the impacts of SRI practices on these.
- **Impact on rice grain quality** from SRI practices — grain weight, resistance to shattering, attachment of grains to panicles, and nutritional content. Some data from Sri Lanka suggest heavier grain weight per unit of volume resulting from SRI practices, apparently due to a reduction in unfilled grains.
- SRI was developed for irrigated lowland production, but its principles should be adaptable, at least to some extent, to **rainfed areas.** Some experiments in Madagascar, doing direct seeding instead of transplanting, and using leguminous shrub cuttings as a mulch instead of doing mechanical hand weeding, have given good results (4 t/ha) in an upland rainfed area. This could be a new direction for SRI research.

Economic Issues

- Socio-economic analysis of **rotational practices** in SRI-based cropping systems to understand the net benefits of different combinations and sequences, evaluated over time.
- Systematic evaluation of **costs of production** that affect the profitability of SRI adoption.
- Opportunities for **diversification** of smallholder farming systems once sufficient rice can be produced with less land and other resources to attain greater income, stability and nutritional benefit.
- With all of the above information, it should be possible to identify **the most suitable areas** for SRI practice, based on climate, soil, economic and other considerations. This will enable government agencies and NGOs to focus their efforts where the uptake of and benefits from SRI can be most rapidly and cost-effectively obtained.
- There is also need to begin now to establish **benchmark studies**, analyzing soil status and quality in chemical, physical and biological terms, and then collective agronomic and economic data as well as soil data over time, to monitor and understand **long-term effects** of SRI.

A further suggestion by researchers was that **their category** should be understood as **including farmers** who are interested in determining systematic cause-and-effect relationships with rice. With SRI, some very fruitful partnerships for advancing knowledge should be possible and should be promoted.

Roles for the Public and Private Sectors

The **orientation and capabilities of public sectors** vary across countries as governments range from being quite effective and functional to being, at least at present, much less so. Some are very focused on promoting and achieving development, including for the poorer and more vulnerable sectors of their societies, while others show less concern. Where public sectors are not very capable or seriously engaged with development tasks, the roles of NGOs and of the private sector in development — and specifically in SRI dissemination — will have to be greater.

SRI offers government agencies an **unusual opportunity** to assist rural households to improve their food security and also to benefit urban populations as well, by raising productivity and eventually lowering real food prices. Whether this opportunity will be seized remains to be seen.

SRI is a **holistic approach**, with a number of components having synergistic effects. When taken up by governments, the system is likely to be "pulled apart" by bureaucratic interests that emphasize one practice over others. Examples would be the water-saving interest of the irrigation department, extension programs' preoccupation with achieving high yields, and the food security impacts being of most concern to a planning office. NGOs and the private sector may find the holistic approach of SRI more feasible than do government agencies, but efforts should be made to persuade the latter of SRI's synergistic aspects as well as potentials.

Government agencies relevant for promoting SRI include: the Ministry of Agriculture and relevant research departments; publicly-funded universities; parastatals in the agricultural sector; the Irrigation Department which should be interested in water-saving methods and which should be involved in efforts to conserve water; Agricultural Promotion Boards, etc. Governments are used to thinking in terms of "**projects**" that can be specially funded by a donor or finance ministry and are usually implemented by one particular government agency. It will be a challenge to undertake SRI through "projects" without losing its integrative core

Getting government cooperation and initiative is most likely to come through **interested and supportive individuals**, building on personal contacts and networks. There can be some slowness and resistance emanating from governments' "standard operating procedures," such as their requiring three years of formal testing before "approval" is given (even though SRI does not present any environmental risks). Agencies often feel a proprietary interest in controlling innovations and taking credit for them, which could retard SRI acceptance or promotion. Motivated individuals who understand fully the opportunities and intentions of SRI should be able to minimize such impediments.

SRI will often have to be "sold" in terms of certain **policy objectives** that are currently attractive to donors or government decision-makers, e.g., poverty reduction or conservation of natural resources. The fact that SRI is a low-input approach could make it less attractive to some donors that prefer large, expensive projects that "move a lot of money." Conversely, SRI could be very attractive to those donors that put a high value on environmental protection or food security. The treasury department might consider the low financial requirements of SRI a positive feature.

It may be attractive to combine SRI with "organic" approaches to agriculture. From Sri Lanka it was reported that producing "eco-rice" for export, thereby earning foreign exchange, has made SRI more attractive to government officials as well as to environmentally-conscious farmers.

Rather than stress yields, **increased total factor productivity and farming profitability** with SRI with **reduced costs of production** will probably be the strongest selling points. Under present economic circumstances where farmers get a low price for their rice and they are financially squeezed by high costs of production, a low-input approach like SRI may appeal to politicians as well as farmers (page 26). The lower cost of production with SRI methods needs to be thoroughly evaluated and well documented.

There may be some **vested interests** that resist SRI, e.g., ones opposing its reductions in the use of agrochemicals. However, it should be possible to mobilize strong countervailing interests in favor of cost-reduction — and environmental and human health advantages.

Political backing for SRI will probably be gained most quickly and strongly where there are **enthusiastic farmers** who support its use based on their personal experience and who are able and willing to lobby on its behalf. Successful SRI farmers will be more effective in talking to politicians than researchers can be.

The **cooperation of universities** should be fairly easy to enlist as they are likely to be interested in the many research opportunities and challenges that SRI presents, especially if funding for such research and evaluation is likely to be forthcoming. Research on SRI has the advantage of being fairly inexpensive, especially if done in a participatory way on farmers' fields, just varying management practices as farmers proceed to do what they would have done anyway to grow rice. Many of the subjects for SRI research should be quite amenable to Master's or Ph.D. thesis projects as they can be finished in one season, though some multi-year research should be done to **assess changes over time,** for better or for worse. Universities are in a good position to follow such changes if encouraged to do so.

The role of the **private sector** will vary by country. Private companies and organizations are necessarily profit-oriented. Since SRI does not involve new capital expenditures or any innovations that are patentable, it may be less attractive to private sector actors than are some other innovations in agriculture. However, the private sector can benefit from SRI innovations such as their water saving or from greater efficiency in seed multiplication. Such opportunities have already proved attractive to Syngenta in Bangladesh.

There should be some **profitable opportunities** for SRI services such as providing high-quality young seedlings or plastic trays for growing seedlings with minimum root trauma. In Sri Lanka, some grain millers have begun offering a higher price per bushel for SRI rice because their outturn is higher (fewer unfilled grains). Agricultural promotion companies may take an interest in SRI for increasing the profitability of their production operations. While this would not be of particular benefit to farm households, it should benefit urban consumers, including the poor. Where the private sector enterprises cooperate with NGOs in philanthropic undertakings, SRI could be provide them a new opportunity for beneficial collaboration.

Topical Reports

Water Management

Much needs to be better understood about water management as part of the SRI strategy. The presently recommended practices were developed entirely empirically, and with the aim of introducing minimal changes in farmers' operations since SRI was already making a number of rather radical departures from usual practice. The group considering these issues underscored that we need to start with a better idea of *what works* as a basis for understanding *why it works*, and *what might work even better*.

Water Application

One of the most promising adaptations of SRI ideas to new water and soil management practices appears to be the use of **raised beds** being experimented with under the Rice-Wheat Cropping Systems Consortium.[1] These beds are elevated 10-15 cm above the bottom of furrows in which irrigation water is intermittently issued. Their length and width will vary depending on available land, labor and implements. This can give water savings of 25-30%, with positive effects on yield due to soil aeration plus retention of adequate moisture.

The standard SRI practice recommended from Madagascar experience has been to keep the soil **moist, but at least intermittently aerated**, during the vegetative growth phase. This involved small daily applications of water (if there was no rainfall that day), with drying out of the field to the point of surface cracking several times during this period. After panicle initiation, 1-2 cm of water is kept on the field up to 15 days before harvest. A similar regime is followed in Sri Lanka. In both cases about a 50% of saving in water is attained.

A study of 108 farmers in Madagascar who were using both SRI and conventional methods on their farms found that most of them were not managing water on their SRI fields as carefully as recommended. Instead, they were flooding their fields for a period of time (ranging from 1 to 10 days) and then draining it for a similar period (the average was 4.4 days of flooding, followed by 4.8 days drained, alternating throughout the vegetative growth period), with sometimes some variation in length of the periods during the growing season. This **alternate wetting and drying** (AWD) is certainly labor saving, and it may increase farmers' returns to their labor. Whether it increases their returns to land and water is not known.

Coordination with Transplantation

In Cambodia, timing of seedling raising in the nursery and transplantation is matched with the timing and concentration of rainfall, given that country's monsoon climate. Water can be stored in canals to be used during low rainfall periods. Early transplanting of seedlings is done several months before the monsoon in order to give the rice plants time to get well established and to accomplish abundant tillering before the rains start. This way the plants can better withstand the monsoon flooding and do not elongate as much as when less mature plants are submerged.

Timing of Irrigation

The duration of time for keeping a field saturated with water should depend on the relative effects of flooding on weed control (standing water inhibits weeds) and on the growth of the plant's roots and tillers (standing water inhibits the plants). Research should be con-

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[1] *This includes the national agricultural research systems (NARS) of India, Bangladesh, Nepal and Pakistan, and the international agricultural research centers IRRI, CIMMYT, IWMI and ICRISAT, plus some individual members, including Cornell University (CIIFAD). The consortium was represented at the Sanya conference by its coordinator, Dr. Raj Gupta.*

ducted on the timing of irrigation to determine the best/optimum times and levels of flooding to strike a balance between these two objectives: suppressing weeds and promoting rice growth. At the same time, potential water savings under different water regimes and irrigation practices should be evaluated.

Water-Use Efficiency

This is an important concept and measure for assessing the potential efficiency of the SRI technique. Studies should be conducted (on-farm) on different aspects of irrigation water management in terms of efficiency of water use. Also different methods may be beneficial under various agroecological, biophysical or socioeconomic conditions. In Sri Lanka, some farmers have experimented with a **sprinkler system** to sustain their SRI crop during a period of drought. Yields were in the 3-4 t/ha range, not high by SRI standards, but at least these farmers got a crop, whereas their neighbors' crops failed completely.

SRI methods encourage rice plants' roots to begin growing deeply into the soil during the first few weeks. If these roots get well established, they can withstand subsequent drought conditions by tapping residual soil moisture at lower horizons. When seedlings are transplanted into a hypoxic flooded environment, their roots remain close to the surface, and such plants are very vulnerable to water shortages later during the growth cycle.

Not every rice farmer faces water constraints. The importance of water-use efficiency depends on whether water is relatively scarce. For many farmers, water saving is not a consideration. Increasingly around the world, conditions of scarcity are arising or getting more severe, however. In such situations, the evaluation of water management should be in both *agronomic* terms — what timing and amounts of water application will best meet the plant's needs — and *socio-economic* terms — what are the net benefits of different water regimes considering opportunity costs for water being used in rice production, and what are the *distributional effects* of costs and benefits associated with the use of water for rice compared to other uses.

Plant Management

The discussion group dealing with plant management practices for SRI emphasized that as experience is gained with these methods under various conditions, it becomes more important that there be a number of ***options*** that users have with regard to plant management, rather than to prescribe fixed practices. Examples and questions discussed were:

- **Age of seedlings***:* What are the merits of 5-day vs. 8-day vs. 12-day vs. 15-day seedlings? The only large-scale evaluation of seedling age with respect to yield done under on-farm conditions found a slightly negative correlation over the range of 5 to 15 days, but given the greater difficulty and possibly more time involved in transplanting very young seedlings, it was not clear that there was any economic benefit to compensate for the possible agronomic benefit.
- **Spacing***:* How can one know whether 25x25 cm spacing is optimal to begin with SRI, or possibly some wider or narrower spacing? The 25x25 cm recommendation is a general one, based on experience in Madagsacar. But with more knowledge of soils and their response to SRI management, especially if we can assess soils better in microbiological terms, one should be able to suggest a spacing closer to the optimum for that particular field — and variety. Another area for research is how this optimum may change over time, under what kinds of conditions, or according to what kinds of indicators.
- **Seedlings per hill:** While the logic of planting 1 per hill is clear, we know that sometimes **2 per hill** can give better yields, because this gives more fertile tillers per m^2. When is it advisable to plant 2? This is something that can be rather easily evaluated by farmers who can vary the number of seedlings per hill within their fields and then assess the results.
- **Weeding***:* Since weeding requires labor that usually has significant **opportunity costs**, it would be good to have more precise data on the likely **net benefits** of additional weedings beyond the minimum of 2 weedings usually needed to reduce weed competition sufficiently. A number of analyses have indicated that additional weedings are very cost-effective,[1] but we do not have enough systematic data to be able to advise farmers on what would be the likely net returns from doing a third or a fourth or a fifth weeding before the canopy closes too much for further weeding. The benefits of weeding, it should be stressed with farmers, include **soil aeration** as much **the elimination of weeds** and the **incorporation of weed biomass** into the soil.

Actually, the best answers to these questions will usually be very site-specific. Users should be encouraged to do some experimentation on their own fields with one or more of these variables on their own fields. For example, a farmer may think that he only has enough labor time to weed his field twice. But it would be a worthwhile investment of a little additional time and effort for him or her to do a third weeding along one edge of his field (e.g., four rows), and then a fourth weeding on half of that (i.e., two rows). From such a simple experiment, he or she should be able to see whether there is enough resulting increase in grain production from plants in these test rows that additional weedings would be economically profitable. Similar tests can easily be done on any field for seedling age, spacing, and number of seedlings per hill.

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Soil and Nutrient Management

The discussion group on these issues addressed a set of practices that are central to the success of SRI. This area included implicitly and often explicitly the ***management of soil micro-organisms*** that constitute a separate but interdependent domain in the complex SRI universe.

Land Preparation

Good land leveling is important to facilitate successful transplanting and to produce vigorous stands of young plants. At the same time, a proper drainage system for the field should be established so that alternate wetting and drying of the soil can be done effectively.

Proper land preparation and plant spacing also can provide an opportunity to sow a green manure/cover crop (GMCC) within rows of rice plants and to incorporate it into the soil with a mechanical hand weeder 30 days after sowing. This has been done by researchers at the Tamil Nadu Agriculture University. A paper on **green manures and cover crops** that was prepared by Roland Bunch for the Sanya conference follows this report to provide more detailed information.

Nutrient Management

SRI has been found to give best results with organic fertilizer. But under poor soil conditions, inorganic fertilizer may be used in combination with organic fertilizer to provide higher biomass production. Once organic matter in the soil is built up, inorganic fertilizer use can be reduced or even ended.

Sources of organic inputs are many. The management principle is to trap nutrients in the biomass and localize them in one place. The movement of organic matter such as compost over long distances to fields is not economically viable and constrains the adoption of organic inputs. GMCCs need not be restricted to leguminous species. Any species that provide large amounts of biomass that can be incorporated into the soil can be used. For instance, in Brazil, about 200,000 ha of soybean fields are planted with millet as a GMCC.

The use of GMCCs should be considered in relation to their effect on microbial activities. Leguminous GMCCs fix nitrogen and create additional organic matter. The wetting and drying of soil will affect survival of microorganisms, since some are aerobic and others are anaerobic. Effective micro-organisms (species and populations) are important elements affecting the decomposition of GMCCs and their release of nutrients.

The use of compost in rice production should link up with the livestock component in farming systems wherever possible. Animal manure and crop residues are commonly used as raw materials to produce compost. Many technologies for effective compost production are available, and effective micro-organisms (EM) as a supplementary technology is being used with SRI in Sri Lanka to many farmers' satisfaction.

Other sources of organic inputs found on farm that can provide significant contributions to improved and stable rice yields are dispersed tree stands or trees in the paddy fields as commonly seen in the rainfed lowland rice areas of India and northeast Thailand. Trees such as *Glyricidia septum* on paddy bunds are proving beneficial in Cambodia. Tamarind and neem are commonly found associated with rice lands of India.

The potential contributions of GMCCs to improving crop yield are many. However, farmers' adoption and adaptation of GMCCs varies. A suitable niche of GMCCs has to be found on land that has no opportunity cost, such as wasteland, fallow land, land along roads and paths, etc.

The introduction of GMCCs should not compete with the production of cash crops. The most sustainable systems incorporating GMCCs are those developed by farmers themselves, for instance, using species that are multipurpose and edible. The use of GMCCs should not be restricted to just one species. Rotational use of species is recommended to avoid building up nematode populations, in particular with leguminous species. Fortunately, in the rice ecosystem, nematode populations are suppressed by periods of submergence.

SRI is a high-performing system that needs nutrient inputs. Therefore, SRI will often best be undertaken in a rotational cropping system. Incorporation of GMCCs either before rice (e.g., *Sesbania rostrata*, mung bean or bush bean) or after rice (e.g., jackbean, mung bean or rice bean) could work well with SRI. The high-yielding performance of SRI provides opportunities for crop diversification that will make SRI itself more sustainable as a production system. GMCCs are discussed more in the next section.

Nitrogen Management

Two approaches to improving N management were identified:

- Adding more nitrogen into the system, such as application of inorganic and organic fertilizers, incorporation of GMCCs, or adaptation of crop rotations, as described above.
- Preventing or stopping losses and leakages from the system.

The latter set of options was focused on in the group discussion, since activities under the first set had already been considered.

Combining SRI with zero or minimum tillage

With the transplanting methods generally used in SRI, this is not practical. In a broadcast rice system, however, a legume such as mungbean could be planted (broadcast) as a green manure crop before the rice crop. After the legume has been growing for 30-40 days, the field is flooded to stop the legume's growth. Pregerminated rice seed is then broadcast. This practice is considered as a kind of natural farming for rice, particularly in rainfed lowland environments. This method will not achieve the soil aeration accomplished by weeding with a rotating hoe. However, if there is a build-up of earthworms in the absence of plowing or other soil disturbance, they could contribute to this effect.

Incorporation of rice straw without burning

Rice farmers commonly burn rice straw as part of their land preparation. Other uses of rice straw in the tropics include: rice straw mushroom production; straw mulch for vegetable production; conversion to improved livestock feed with addition of urea, etc. If sufficient yield improvements can be achieved by incorporating straw into the soil, this will improve soil nutrient status. Growing legumes such as *Sesbania rostrata* in among standing straw makes the straw decompose more rapidly.

Use of slow-release nitrogen

Urea granules coated with neem powder to slow down the release of N have been used in India. This is a possible variation on SRI nutrient management methods.

Nutrient Dynamics

Improved nutrient-use efficiency is observed in SRI, particularly in soils with low phosphorus. The productivity of P thus appears high in SRI, offering a possible explanation for the high performance of this system.

Alternate wet-and-dry irrigation management will affect the survival and balance of micro-organisms in the soil, given different responses from aerobic and anaerobic microbes. The process and consequence of biological changes under such conditions are not well understood. In acid sulphate soils, wet/dry irrigation systems can cause the release of toxic substance, sulphuric acid, which damages rice plants. So SRI might not be so successful in acid sulphate soils.

The suppression and survival of different species of micro-organisms as a result of a wet/dry irrigation management regime should end up releasing various nutrients (contents of the lysed microbes) within the root's rhizosphere. Soil cracking would cause dislodging as well as renewal of plant roots. Thus, soil cracking can facilitate decomposition processes and the release of plant nutrients, in addition to facilitating the exchange of oxygen.

Knowledge Needs

Much more needs to be known about soil and nutrient management with SRI. We are presently forced to draw upon knowledge of soil and nutrient dynamics, still limited, from other cropping systems with quite different soil and water conditions and accordingly different plant, water, soil and nutrient interactions and interdependencies. Little work has been done on processes of biological nitrogen fixation (BNF) or P solubilization in paddy rice, and what has been done has usually been carried out in continuously flooded environments, unlike those created by SRI practices.

Very little is known about **micronutrient dynamics and availability** in soils that have alternating aerobic and anaerobic conditions. While macronutrients (N, P, K) are important, some of the success of SRI may be due to its acquisition of micronutrients (B, Cu, Zn, etc.) when the root system is much larger and accessing a greater volume of soil. At the same time the rhizosphere is made larger and more active microbiologically. There are thus many new horizons of research and experimentation that SRI opens up for the study of soil and nutrient interactions and effects.

Use of Green Manures and Cover Crops with SRI[1]

In this discussion of green manure/cover crops (GMCCs), we are not referring to the use of legumes that are monocropped on good farmland and then incorporated into the soil at the flowering stage to improve soil fertility. This is a valid use of biological resources, but by and large, it has not worked for small farmers. A growing number of small farmers are finding it beneficial to grow plants that not only improve the soil but at the same time provide other benefits. These plants may be intercropped with regular crops, or they may be grown in the shade of trees or during the dry season, for instance, and are often harvested before being used as a mulch. Thus, the GMCCs discussed here refer to any crops that have some useful purposes (e.g., weed control, food, fodder, or fuel) in addition to the improvement of soil.

GMCCs have often proved to be very popular when introduced. In southern Brazil, nearly half a million farmers are now using introduced GMCCs. But more important, GMCCs are being developed by farmers themselves all over the world, including virtually all of the countries represented in this conference. At present we know of more than 195 such systems being used around the world sustainably by small farmers, employing some 70 different species of GMCCs, many leguminous but some non-leguminous. Mathematical extrapolation indicates there are probably over 500 such systems. Of the species used, many such as the velvetbean (*Mucuna* spp.), jackbean (*Canavalia ensiformis* or *gladiatus*), lablab bean (*Dolichos lablab*), tefrosia (*Tephrosia candida*), pigeon pea (*Cajanus cajan*), wild sunflower (*Tithonia* spp.), the sesbanias, and the vignas already exist in much of Asia.

Problems to be Solved for Wider SRI Utilization

From the reports for this conference, we see that two of the most important disincentives to the adoption of SRI are (1) the increased weeding problem, and (2) the need to find more plentiful, and less expensive, sources of organic matter for application in the paddies to build up soil quality and microbial populations.

When visiting Madagascar, for instance, I found farmers spending as much as 100 days of labor per hectare per year, transporting organic matter from and to their fields. This is bound to slow down SRI adoption there. In many other areas where paddy rice is produced, there are no nearby wastelands (as there are in Madagascar) where people can gather biomass. The biomass is just not available. Therefore, if SRI is to be a sustainable intervention that does not depend totally on chemical fertilizers, we need to help farmers produce large amounts of biomass in the paddy fields themselves and/or along the bunds.

The Potential Role of GMCCs

GMCCs are an ideal way of overcoming both of these constraints — the weeding problem, and the lack of *in situ* organic matter. We do not have already proven GMCC technologies that we know can be used in every location. The efficient use of GMCCs in SRI fields will depend on plant varieties and practices well suited to the local situation. A good amount of research is still needed to know how best to control weeds and en-

[1]*This note was contributed by Roland Bunch, COSECHA. For more information on GMCC opportunities, species and practices, he can be contacted at rolando@cosecha.sdnhon.org.hon. A paper entitled "A Proven Alternative to Shifting Agriculture: The Worldwide Experience with Green Manure/Cover Crops," written for different kinds of farming systems is available. This information can be made relevant to SRI improvement.*

hance soil organic matter with selected species. Nevertheless, a number of systems already exist and are available, and many others should be feasible and productive if evaluated and adapted appropriately.

We know that the use of GMCCs is a major need from the fact that farmers are already developing and adopting such systems. In Madagascar, farmers using SRI have already moved in this direction. Many are planting GMCC species such as cowpeas (*Vigna unguiculata*) and mungbeans (*V. radiata*) in their paddies during the dry seasons, and others have begun planting a clover species intercropped with their SRI rice. Other farmers who are not yet using SRI have begun using GMCC species in their paddy systems.

In Vietnam, we find farmers often planting rice bean (*V. umbellata*), soybeans (*Glycine max*) and cowpeas in their paddies during the dry season to improve their soils. On Sumatra and Bali, farmers use cowpeas and mungbeans in the same way, consciously recuperating traditional practices of soil fertility maintenance now that chemical fertilizer has become "too expensive." In central Cambodia, a few farmers have begun broadcasting jackbean seed on their paddies during the dry season — in spite of the seasonal drought and the heavy degradation of their soils with a pH of 3.8 — in order to have biomass when the rains return.

The development and use of these technologies on a serious scientific basis is just beginning. If we are to raise present crop yields, we need to find more species that can be grown during the dry season and, if possible, that provide food and fodder as well as biomass for soil recuperation. This will be important for making SRI sustainable, both economically by reducing costs of production as well as ecologically by maintaining soil fertility and biological activity.

Furthermore, we must do it for reasons of human nutrition. The Green Revolution with its positive impact on cereal production has had the side-effect of drastically reducing the availability of pulses and other grain legumes that provide protein in the rural diet. GMCCs can provide dietary, non-animal-based protein that is sorely needed.

Further Development

Even more beneficial than food crops that can be grown during the dry season on paddies, or non-food producing GMCCs that can be intercropped with rice, will be to find food legumes that can be intercropped with SRI rice. This would enrich the soil at the same time it adds to the agricultural productivity of fields, contributing high-quality food to the diet. If this were possible, the overall productivity of the SRI system would greatly increase once again.

Is this possible? We do not presently know. In Latin America, we say that wherever weeds can grow, GMCCs can grow also. The environmental "niche" that is opened up for weed growth with SRI practice — due to wider plant spacing, reduction in standing water, and more sunlight penetration — could be the very niche that allows the intercropping of food-producing GMCCs with rice (as was traditionally done in Japan). What has been seen as a problem with SRI — its susceptibility to increased weed problems — could become one of its major attractions: controlling weeds in a way that produces high-protein foods, along with fish, eels and other species, together with rice in SRI paddies. We will only know if this is possible if we do the necessary farmer experimentation and research.

Contributions of Varietal Development

Given the interests and accomplishments of the conference's host institution, the Chinese National Hybrid Rice Research and Development Center, there was a lot of concern with how SRI practices might relate to and reinforce the genetic improvements that rice breeders in China and elsewhere have made. The discussion group on varietal development offered the following points for consideration:

- Breeding for high **productive tillering** ability of the genotype is now more important with SRI practices available since these can capitalize upon such potential.
- The development of varieties with **medium growth duration** (120-140 days) is likely to be the most beneficial with SRI, though in Madagascar, the highest yields come with long-duration varieties.
- Breeding should continue to seek to produce varieties with **high panicle weight**. With SRI methods, there are few problems with lodging, so greater panicle weight does not diminish net production. There is no particular advantage in using short-stalked varieties with SRI.
- There should continue to be breeding efforts to develop varieties that have **resistance and/or tolerance for pests and diseases**, such as for leaf blast, sheath blight, and BLB.
- Likewise, breeding efforts should continue to try to achieve **good grain quality** — slender grains, translucent, high amylose content, and good aroma.
- Work should continue for development varieties that have **drought resistance and/or tolerance**.
- Breeding for **lodging resistance in traditional** varieties may be a useful undertaking. With SRI methods, traditional varieties' yields can be doubled or tripled, making them quite profitable where their market price is higher than that for improved varieties. Usually, however, farmers using SRI do not report much of a lodging problem with either traditional or improved varieties, even when yields and panicle size are increased.
- Improvement of traditional cultivars to reduce their **photoperiod sensitivity** could be a useful contribution to the utilization of SRI methods.
- **Synchronization** of flowering among tillers is important for high yield. With SRI methods, even with a much larger number of tillers per plant, this has not been reported to be much of a problem. One explanation could be that the large and intact root system when growing in aerated soil supports simultaneous flowering and maturation. Rice scientists should examine the possible problems and solutions for *non-synchronization* as presented by SRI.

Economic and Social Concerns

No agricultural innovation can be understood or promoted independently of the socio-economic context in which it is introduced or made available. The discussion group on economic and social aspects of SRI focused on four areas of concern. Rather than just identify problems, it tried to make suggestions that could be useful or at least tried out with SRI.

Gender and Household Considerations

Most agricultural innovations affect the **gender division of labor** within households. We do not know whether or how much SRI affects this, so this should be evaluated as a matter of some priority. Since SRI requires more labor per hectare, at least initially, there was concern that this could increase the labor burden on women, who usually do the transplanting. Labor savings in terms of time spent on nursery construction and management with SRI would accrue usually to men.

Conversations with women doing SRI transplanting in Sri Lanka have indicated that they found SRI methods easier and quicker after the first year, once they became comfortable with handling tiny seedlings. Because many fewer seedlings need to be transplanted, they reported that SRI transplanting has become quicker for them, and they find the technique more comfortable ("no backache," they said).

In Madagascar, there are still complaints about the method taking extra time and effort, but there transplanting is still being done with ropes stretched across fields, rather than a simple wooden rake to score the surface of the fields with lines. With increased yield, women's burden at harvest time is probably increased, though a larger harvest helps maintain household food security, which is a major responsibility and burden for women, so complaints are not likely to be many.

Some suggestions were that:

- Women might have some **comparative advantage** for SRI transplanting because the smaller seedlings require more delicate and deft handling. Also, with less irrigation water required for SRI, small treadle pumps that women can operate become more feasible to use.
- **Training programs** for SRI, including Farmer Field Schools where they become involved with SRI, need to be adjusted to the time and other needs of women.
- To the extent that local farming systems can become more productive with better opportunities for earning income locally, this can **reduce male migration** to cities, which creates burdens for women.

Cultural Considerations

There are likely to be differing responses to SRI opportunities according to national or local cultures. In Madagascar, most rural households are strongly attached to "the ways of the ancestors." This reverence has been an inhibition against adoption of (or continuing with) SRI methods, as these can be seen as derogating the practices followed for generations. An opposite situation was reported in Cuba, where rice culture has become so "modern" that seed sowing is done in some places from airplanes. "Going back" to transplanting, rather than "forward" to it, presents another kind of cultural inhibition. Because of a strong attachment to animal traction in Cuba, the spacing of plants should probably be adjusted to widths that lend themselves to this mode for planting and weeding.

Some suggestions were:

- SRI should be linked in people's minds with **sustainable development** and the **conservation of biodiversity**, two values that are "modern" but that also resonate with "traditional values." This is a legitimate dual identification.

- Especially because young people are finding many reasons to exit from agriculture, SRI should be presented as an opportunity for **agricultural entrepreneurship**, giving personal recognition for innovative achievements. SRI practices that are indeed soundly based on biological science should be presented and characterized as "advanced," though at the same time they build on past experience.

Economic Considerations

These incentives are pretty strong and clear. That the productivity of land, labor, water and capital can all be increased, with reductions in the cost of production and thus an increase in profitability, means that economic factors are — or should be — very favorable to SRI's spread.

Some specific ideas suggested that add to its merit included:

- The possibility of **ratooning**, which can give substantial saving of labor saving from a second crop that does not require any additional labor for land preparation or transplanting. This should be evaluated under a variety of conditions to know where and how widely it can be economic.
- **Seed saving** is a small but very visible incentive, particularly important for poor households who see a tradeoff between using rice for seed or for food. Seed requirements with SRI can be reduced by 80 to 90%, depending on initial sowing rate.
- The possibilities for greatly increasing **seed multiplication** with SRI are attractive. A Laotian farmer who only got a 20% increase in yield with SRI commented favorably upon a five-fold increase in his seed:harvest ratio. Seed multiplication of 1,000 to 2,000 times has been achieved with SRI methods. This would be particularly important for production of high-quality seed paddy.

Social Considerations

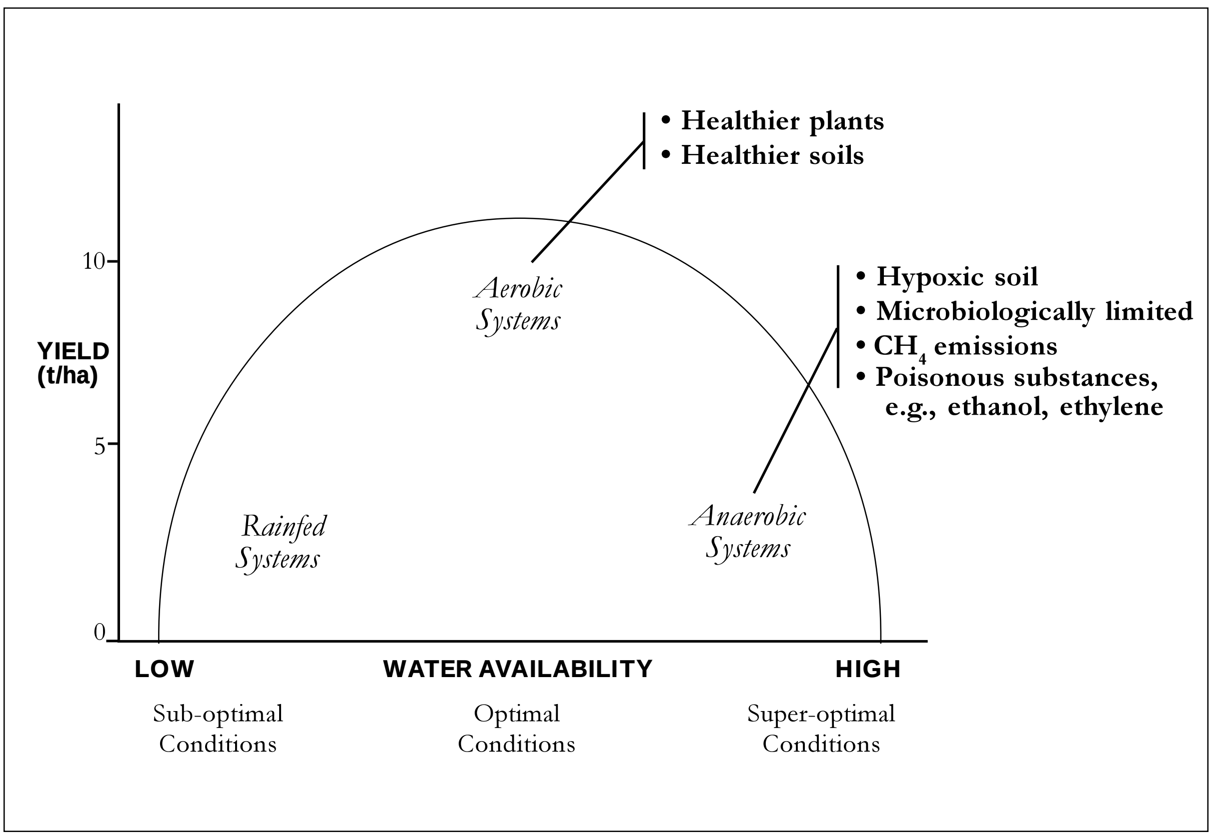
Broader benefits were also noted by the group in its discussion of social impacts:

- There is potential for **improved health** resulting from more food production and from production of food containing fewer toxic chemicals.
- There should be an increase in **employment opportunities** locally, noted above with regard to gender and family considerations, but broadly important for social stability and the preservation of rural communities.
- That SRI is more **skill-intensive** can be seen as a societal benefit, not just an individual cost, because it helps to upgrade the productivity of the farming community more generally.
- One impact of SRI observed in several countries is that once farmers become involved with SRI, their interest and enthusiasm for **agricultural innovation** in general grow. They like the experience of doing experimentation and evaluation and like being "farmer-scientists," as SRI farmers at one meeting in Bangladesh described themselves.
- SRI has been described as much a methodology for **human resource development** as for increased rice production. Both are legitimate objectives, and SRI proponents should seek to keep both outcomes in mind as they plan and support programs to extend this methodology.

Summary Representation

One of the participants sketched and submitted at the end of the conference a "graph" reproduced below that was entitled "A Phyllophysical Explanation for the Superiority of SRI against Conventional System, in terms of Ecosystem Analysis." This two-dimensional graph had *Water Availability*, from low to high, on the X axis, and *Yield* on the Y axis.

In his view, this representation summarized what he and colleagues had learned about SRI from their three years of evaluations. A footnote added to the diagram said: "If we could hear the rice plants crying out, our lowland rice would be begging us: '*Help me! Do not flood me anymore…*' "



Conference Information

International Organizing Committee

Chairman	Prof. Yuan Longping, Director China National Hybrid Rice Research and Development Center (CNHRRDC)
Co-Chairman	Prof. Norman Uphoff, Director Cornell International Institute for Food, Agriculture and Development (CIIFAD)
Co-Chairman	Dr. Cheng Shihua, Director-General China National Rice Research Institute (CNRRI)
Co-Chairman	Mr. Sebastien Rafaralahy, President Association Tefy Saina, Madagascar
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Schedule

International Conference on the System of Rice Intensification

Landscape Beach Hotel, Sanya, China
April 1-4, 2002

Monday, April 1

8:30-9:00	Registration
9:00-10:00	**Opening Session** *Dr. Norman Uphoff, CIIFAD* — introductions and discussion of objectives Dr. *L. P. Yuan, CNHRRDC, and Dr. Cheng Shihua, CNRRI* — welcome by hosts Welcome from provincial and local government representatives
10:00-10:30	**The Development of SRI in Madagascar: An Historical Overview** *Sebastien Rafaralahy, Association Tefy Saina, Madagascar*
10:30-11:00	**A Scientist's Perspective on Utilizing Genetic Potential with Better Management Practices for Rice** *Dr. L. P. Yuan, Director, China National Hybrid Rice Research and Development Center*
11:00-11:30	**A Policy-Maker's View: Opportunities Created by SRI for Agricultural Development, Food Security, and Poverty Alleviation** *The Hon. Salinda Dissanayake, Former Minister of Lands, Government of Sri Lanka*
11:30-12:00	**A Farmer's Perspective on SRI: Economic and Ecological Benefits** *H. M. Premaratna, Ecological Farming Center, Mallawalana, Sri Lanka*
1:30-6:30	**Country Reports:** ***Bangladesh**: Muazzam Husain, BRAC* ***Cambodia**: Yang Saing Koma, CEDAC* ***China**: Cao Weixing, Nanjing Agricultural University* ***Cuba**: Rena Perez, Ministry of Sugar* ***Gambia**: Mustapha Ceesay, National Agricultural Research Center* ***India**: T. M. Thiyagarajan, Tamil Nadu Agricultural University* ***Indonesia**: Anischan Gani, Agency for Agricultural Research and Development* ***Laos**: Sengthong Vongsakid, Oxfam/Community Aid Abroad* ***Madagascar**: Bruno Andrianaivo, FOFIFA* ***Myanmar**: Humayun Kabir, Metta Development Foundation* ***Nepal**: Shyam Shrestha, Sunrise Farm* ***Peru**: Angel Hernandez, LaMolina University* ***Philippines**: Roberto Gasparillo, Broader Initiatives for Negros Development* ***Sierra Leone**: Abu Yamah, World Vision/Sierra Leone* ***Sri Lanka**: Gamini Batuwitage, Ministry of Agriculture* ***Thailand**: Phrek Gypmantasiri, Chiangmai Univesity* ***USA**: Xie Fangming, RiceTech* ***Additional Chinese Reports**:* *Ang Shengfu, Anqing Research Institute* *Zhu Defeng, China National Rice Research Institute* *Tao Longxing, China National Rice Research Institute* *Yan Qingquan, Hunan Agricultural University*

Tuesday, April 2

8:30-9:00 **Opening Plenary Session**
Summary of country reports — *Dr. Erick Fernandes, Cornell University*

9:00-11:00 **Technical/Biophysical Problems Encountered with SRI, and Steps Being Taken or Proposed to Deal with Them**
Participants meeting in six groups

11:15-12:30 **Plenary Reporting Session**

1:30-3:30 **Problems Encountered with Adaptation and Diffusion of SRI, and Steps Being Taken or Proposed to Deal with Them**
Participants meeting in same groups

4:00-6:00 **Plenary Reporting Session**

Wednesday, April 3

8:30-12:00 **Field Visit to Hybrid Rice Research and Development Center trial plots**

1:00-3:00 **Functional Discussion Groups**
Groups constituted according to participants' roles

1. **Extension and Utilization: Farmers, Extension Personnel and NGOs**
2. **Knowledge Generation and Evaluation: Scientists and Researchers**
3. **Policy Environment: Policy-makers and Donors**

3:00-5:30 **Topical Discussion Groups**
Groups constituted according to participants' expertise

1. **Water management** — what are best practices, under various conditions; what are the knowledge needs for research and experimentation on *timing and amounts* of water application.
2. **Plant management** — what are best practices, under various conditions; what are the knowledge needs for research and experimentation on *nurseries, transplanting, spacing, weeding,* etc.
3. **Soil and nutrient management** — best practices, and needs for experimentation and research on *BNF, composting, mulch, green manures, cover crops, promoting microbial diversity and growth*, etc.
4. **Varietal differences and SRI development** — rethinking breeding *programs and criteria* to take advantage of new opportunities.
5. **Economic and social aspects of SRI** — consideration of *labor requirements, land and labor productivity, incentives, marketing*, etc.

5:30-6:30 **Plenary session for group reports**

Thursday, April 4

9:00-11:30 **Reports to the plenary** from drafting committees composed of:

- Farmers/NGOs/extension participants, giving user perspectives;
- Research scientists, giving knowledge perspectives; and
- Policy-makers and donor representatives, giving development perspectives.

11:30-12:30 **Closing session** — *Statements by Prof. Yuan, CNHRRDC; Dr. Peng, IRRI; Dr. Ruben Puentes, Rockefeller Foundation; and Dr. Uphoff, CIIFAD*
Approval of conference communication; votes of thanks and exchange of gifts