REPORT FROM SRI CHINA VISIT, February 22-28, 2004 - Norman Uphoff

After a meeting of the international advisory committee for the College of Humanities and Development at China Agricultural University in Beijing, I flew to Harbin the evening of February 22, being met at the airport by **Prof. Jin Xueyong** from Northeast Agricultural University (NEAU). We had met previously at the international SRI conference held in Sanya, China, April 2002, and at the first national SRI meeting held in Hangzhou in March 2003.

Parallel Development of SRI in Heilongjiong Province
Monday morning we had a meeting at the university with faculty and students interested in SRI. I had been told previously by some Chinese colleagues that Prof. Jin had developed a system of rice cultivation quite similar to SRI, but I had not understood until we had an extended discussion just how similar they are.

The Three-S System: This is the name given to the system Jin is introducing in Heilongjiong, the northernmost province of China, with low temperatures and a short growing season. He started working on this system experimentally in 1994 at about the same time that CIIFAD started working with Tefy Saina in Madagascar on evaluating and spreading SRI there. Jin did not start introducing his methods to farmers until 1999, the same year that the first SRI trials outside of Madagascar were conducted (at Nanjing Agricultural University in China) confirming the merits of SRI methods.

SRI had been synthesized by Father de Laulanié in Madagascar ten years before Prof. Jin started to develop his alternative methods. But it did not become known in China until 15 years later, by which time Jin had worked out his system. So clearly, his was an independent creation, a kind of 'rediscovery' based on the same genetic potentials that have always existed in the rice genome.

Both SRI and Three-S change certain practices that have inhibited or suppressed these potentials for centuries. Having two separately developed alternative systems demonstrating that these potentials exist makes both more significant. I told Prof. Jin that just as we are learning that plant roots 'cooperate' rather than 'compete' when in close proximity, both systems can and should cooperate, with each informing and improving the other. The three elements of Three-S are:

(1) Spacing: Rows are spaced 33 cm apart with 16 cm between plants, though on better soil the spacing between rows can be greater -- 36 cm, and even up to 40 or 43 cm. In principle, as with SRI, single seedlings are planted, though sometimes 2 seedlings (or seeds) are planted together. The plant density with Three-S is 13-17 per square meter, which is essentially the same as with SRI -- 16 plants per square meter (25x25 cm spacing in a square pattern). Although with Three-S there is row rather than square planting, the principle and practice is virtually the same.

(2) Super-Rice Varieties: Farmers are recommended to choose whatever hybrid or improved variety gives best response to the growing conditions of Heilongjiong and also the other elements of the Three-S system. This differs from SRI in that we suggest farmers continue using whatever variety that they are already using, since SRI methods can enhance the yield for any cultivar. However, it makes sense to select a variety that is most responsive to the methods under local conditions so that farmers can get the best possible return from their investment of land, labor,

capital and water. We should be giving more emphasis to determining and suggesting the best available varieties for SRI use.

(3) Sustainability: With Three-S, farmers should prepare and add compost or other organic material to enrich the soil, though chemical fertilizer is also added to increase soil nutrient availability. (If I understood correctly, they are even experimenting with bear manure; I didn't know there were enough bears to have any significant supply.) There does not appear to have been any consideration of how inorganic fertilization may inhibit soil microbes, so the net gain from such amendments may not be as cost-effective as when trying to maximize/optimize the contribution from soil biological processes.

In China, inorganic fertilizer has largely replaced the use of organic-source nutrients, so it is hard to find anyone willing to rely entirely on organic fertilization even in experimentation. It is possible that given low soil temperatures and lowered microbial activity in Heilongjiong, there is more need to employ inorganic fertilization than in warmer growing environments. This is a question to be further examined. The Three-S promotion of adding organic matter to the soil is innovative under present conditions -- though not historically, as Chinese farmers have for millennia put organic matter back into their soil.[1]

(4) Water Management: This is essentially the same with Three-S as with SRI. Three-S fields are not kept continuously flooded. Water is put onto the field for 3-5 days, and then it is drained and left unflooded for 5-7 days. Land preparation is done by tractors without flooding. When in-season fertilizer applications are made, fields are flooded before this, and weeding is also done.

With Three-S, the reduction in water use is 50 to 60%, according to Prof. Jin. Water shortages are a major problem in much of China. In Heilongjiong, a maximum acreage has been set for rice, 1.5 million ha, because the water resources in the province are not sufficient to grow more rice than this without sacrificing other crops (see discussion of this below). Three-S (and/or SRI) methods should be able to relax this constraint on rice production.

(5) Weed Control: With no continuous flooding, there is the same need to control weeds as with SRI. In Three-S, they use the same kind of 'rotating hoe' that is recommended with SRI. There is some recognition that this aerates the soil, but that has not been emphasized. Now that they know about SRI and understand the explanations that we propose for its success, NEAU faculty will probably look more closely at effects of soil aeration.

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[1]Duck culture is also part of this third "S" as "sustainability" refers to making rice production more ecologically sound. It has often been reported that keeping ducks in the paddy field enhances productivity. Bill Mollison, the founder of Permaculture, discussed this in an interview about 10 years ago. Ducks keep down insect populations and add some manure to the field. Possibly their pecking into the plant culm in search of insects stimulates plant growth. This is suggested by Noel Magor, IRRI representative in Bangladesh, who has observed ducks in rice systems. Possibly their nibbling back some of the young tillers stimulates greater root growth in response, which then supports more productive tillering. An Indonesian farmer working with ADRA in West Timor, expected to get an 8 t/ha yield from his SRI field before it was eaten back by a horse before it was full-grown; his eventual yield, a little delayed, was 12 t/ha (reported by Bruce Ewart, ADRA). I was told in the Philippines that some farmers there mow down their rice plants at a certain stage to stimulate more productive regrowth. These observations from various colleagues are reported to encourage thinking about of how to explain and possibly benefit from such effects.

(6) Crop Establishment: Some differences between Three-S and SRI are necessary in this respect because of the different and very severe climatic conditions in Heilongjiong. I was shown pictures of the plastic-covered 'greenhouses' in which rice seedlings are started, with a foot or more of snow around them outside. This is far from the tropics.

Seedlings are grown in individual soil compartments on plastic trays (shaped like in egg cartons) with single seeds or two seeds put each into a separate 'plug' of soil that can be later removed from tray and put directly into the field with desired spacing. (Two seeds are planted when there is some doubt about whether single seeds will all germinate.) This technique is similar to the way that tree seedlings are often grown in plastic 'sleeves.' The roots are hardly disturbed by the transplanting process, and root tips remain pointed downward in a natural position, not inverted upward as happens with standard method of transplanting. With this planting method for rice, the soil medium is kept well-drained, never saturated as happens in flooded nurseries.

The question was raised whether with this system they are transplanting 'too late' according to our SRI understanding. If the transplanted seedlings experience no disturbance or trauma, it probably does not make much difference *when the transplanting occurs*, as long as it is before the seed root outgrows the separate space provided before it. Right now, transplanting with the Three-S system is usually done at the 6-leaf stage, when the plant has three tillers (about the fifth phyllochron). Whether productivity would be higher by transplanting earlier is an empirical question. Transplanting is now done between May 20 and June 2. Transplanting earlier than this would probably be harmful to the young plants given the cold temperatures in Heilongjiong.

The SRI principle is not: *one should always transplant when seedlings are very young, with only 2 leaves, before the 4th phyllochron*. Rather it is: *when transplanting, there should be minimum or no trauma to the young plant and especially not to its root system*. The use of containers for starting seedlings may make 'age of transplanting' irrelevant for SRI, since when the soil around the root is kept intact, there is no trauma, no inversion of root tips, and no loss of seed sacs.

Three-S transplanting is presently done with strings put across the field in parallel lines and spaced usually 33 cm apart. Knots every 16 cm apart indicate to transplanters where to place the seedling. The 'rake' method developed in Madagascar for marking a grid on the field and now used in other countries because it requires less time than stretching and moving strings may not be as much benefit in Heilongjiong as elsewhere, because spacing between plants within rows need not be so exact. However, the 'roller' that farmers in Andhra Pradesh have developed for SRI may be useful here, if Three-S fields are only muddy, not flooded, when transplanting is done. Right now they are transplanting into fields with more water than recommended for SRI.

Rice production has been greatly increased and improved in Heilongjiong since the Chinese Revolution. In the 1950s, the area under rice was 110,000-340,000 ha, with an average yield of 2.3 t/ha. In the 1960s, the area averaged around 200,000 ha, with a yield of 2.1 t/ha. The period 1970-83 saw yields begin to rise, to 2.9 t/ha, while area was 170,000-280,000 ha. Between 1984 and 1996, yield more than doubled, to 6.2 t/h, and rice area expanded to 780,000-1,100,000 ha. From 1997-2000, rice yield went up further, to 6.8 t/ha, with area reaching 1,700,000 ha. But this was more area than can be served by available water supplies, without reducing other, more valuable crops. So as noted above, rice area has now been officially limited to 1.5 million ha.

The Three-S system is expanded to about 500,000 mu (over 30,000 ha) in Heilongjiong, still a relatively small share of its total rice area. But the benefits are definite: an average yield of 7.5 t/ha, with a 60-60% reduction in water requirements. The goal of Prof. Jin's program is to reduce costs of production by 10% while raising yield by 20%, with higher quality grain produced. The Three-S method is being extended also in Liaoning Province and Inner Mongolia.

Despite our limited respective knowledges of Chinese and English, we had some good conversation. Northeast Agricultural University will host the second Chinese national SRI meeting in August, 2004, at a location where Three-S fields can be seen, about 300 km from Harbin. Most other institutions in China that are interested in this kind of innovation are using SRI methods, or variants thereof. But there is a very close affinity between SRI and Three-S, so the similarities, convergences and differences should be interesting to observe and discuss.

At this meeting, there should be opportunity for exchange of ideas and experience from all over China since SRI is being tried out now in the south, east, west and center as well as north. Knowing that the principles and techniques of SRI can be productive under such difficult conditions as in Heilongjiong should give impetus to the further evaluation, modification and dissemination of SRI and related practices throughout the country, as well as elsewhere.

Visit to the China National Rice Research Institute

I flew back to Beijing that evening and stayed overnight there to be able to take an early flight the next morning to Hangzhou, where the China National Rice Research Institute is located. This was my third visit to CNRRI, and **Dr. Zhu Defeng**, senior agronomist at the institute, met me for lunch at the hotel he had arranged for me near the Institute. A colleague at nearby Zhejiang University who has started SRI evaluations had had to travel to Beijing, so my earlier plans for a visit to that university had to be shelved, and I had the afternoon to work on a short article on SRI for IRRI's *Rice Today* magazine.

Next morning, Zhu met me at 7 to go out to the Institute's research station located outside of Hangzhou. A 50-minute bus ride gave me an opportunity to learn more about how he and others got interested in SRI. My direct knowledge of how SRI got started in China was that Nanjing Agricultural University had tried out SRI in 1999, under the direction of **Dr. Cao Weixing**, following a seminar I gave on SRI at NAU in December 1998. Yields of 9.5-10.2 t/ha with different SRI spacings provided the first evidence that the methods would work outside of Madagascar. Cao told me that such high yields could be obtained with the practices and improved or hybrid varieties already being used in China. But SRI reduced water requirements by about half and lowered production costs, so this made SRI interesting to Chinese researchers.

It turns out that Zhu had also started working on SRI at NCRRI in 1999 after reading the article on SRI by Justin Rabenandrasana, secretary of Association Tefy Saina, that was published in the *ILEIA Newsletter* from the Netherlands. About the same time, **Prof. Yuan Long Ping**, known in China as 'the father of hybrid rice,' started some SRI trials at his China National Hybrid Rice Center after attending a seminar that I gave at IRRI in Los Baños in February 1999. Since I did not know him at that time, I had no idea he was in the audience.

Prof. Yuan took an immediate interest in SRI, seeing in it possibilities for raising further the yields of his hybrid varieties and for addressing challenges in the Chinese rice sector. He learned more about SRI the next year when he received a paper I had written on SRI by a circuitous route. I had given the paper to Dr. Henry Beachell, a retired IRRI rice breeder when he attended a symposium on rice at Cornell in June 2000, and he passed it on to Dr. Xie Fangming, a former student of Yuan's now working with RiceTech, an American company in Texas, who sent it to his former teacher.

This route is mentioned to show the kind of webs of acquaintance that have supported SRI's spread. When I attended a meeting at Nanjing Agricultural University in April 2001, where Chinese, Indian, Indonesian and Madagascar colleagues got better acquainted with SRI and with each others, I visited Yuan's hybrid rice experiment station at Sanya on Hainan island and gave a seminar to his staff on SRI. Yuan subsequently began publicizing SRI and getting other researchers in China to do their own evaluations. From the bus ride with Zhu I now understand better how SRI got started in China at about the same time by three separate 'paths' -- Nanjing Agricultural University, CNRRI, and the China National Hybrid Rice Center.

Zhu said that the climate for acceptance of SRI was favorable because a number of researchers had already been moving toward wider spacing between plants, and using single seedlings, because hybrid varieties had larger panicles. There was also some reduction in water applications being made in some rice trials as it was becoming ever clearer that China needed to conserve water use wherever possible. Also, there were some experiments with green manures to raise soil organic matter, which was declining with prevalent practices and high fertilizer use. Thus, the elements of SRI all made sense to a number of Chinese researchers when they read about it, although the beneficial effects of using 'young seedlings' came as a surprise.

Behind the interest in SRI is the fact that rice yields have been stagnant or even declining in China over the past five years. The area planted to rice has also been declining, due to urban expansion and land degradation as well as the low prices paid to farmers. So rice production has been falling since 1998. There is an urgent need to get rice yields increasing again to offset area decline. The falling rice production in China is a cause of official as well as scientific concern.

Last year, there were SRI trials on over 50 ha at seven locations in Zhejiang Province where NCRRI is situated. Average SRI yields were 10.2 t/ha, compared with control yields of 8.7 t/ha. The average increase ranged from 0.5 t/ha in Panan to 2.3 t/ha in Wenling. Given the water saving, these results are very encouraging. I think that the results could be even better if there is less use of inorganic fertilizer and more of organic material. The average SRI yields from trials managed by the Sichuan Academy of Agricultural Sciences last year in four locations was 13 t/ha. The soils in Zhejiang have had rather heavy use of agrochemicals for some years, so their microbiological condition may be less than desirable for best SRI results.

As a number of staff and students at CNRRI have begun working on SRI, there were about 20 persons who gathered at 9 for a seminar and discussion on SRI. It was coincidence that four rice specialists from the Democratic People's Republic of Korea were at the Institute for a three-week short course on rice technology, and they also attended the presentation.

When Zhu was in North Korea in September 2003, he had talked about SRI, and the government sent this team to Hangzhou for more information on new rice technologies, including SRI. Among other things, the seed application rate in North Korea is about 130-150 kg/ha. Zhu suggested they could save at least half of that (for consumption) without sacrificing yield. Probably no country in the world could benefit more from SRI given the severe food shortages in North Korea and the severe economic constraints limiting use of fertilizer and agrochemical inputs. One member of the team told Zhu after the seminar that they are interested in trying SRI. (I might note here that SRI is currently spreading rapidly in Cuba and in parts of Myanmar, and that evaluations should start this year in Iran; so SRI is diffusing in a very non-political manner.)

The most interested participant in the seminar was a rice biotechnologist, whom Zhu told me has an international reputation for his work. He showed the most knowledge of soil biota and of their contributions to rice productivity. In the discussion period, he volunteered that the seminar had given him some new ideas to pursue in his breeding program, looking more closely at roots and at what could be done to capitalize upon symbiosis with soil microorganisms.

The most extended discussion was on the differences between SRI and the thinking that has gone into development of the 'new plant type' (NPT) that IRRI has been working on this for the past 15 years. Researchers there had concluded, based on sophisticated modeling, that the existing 'architecture' of the rice plant cannot support a yield beyond a 'biological ceiling' of 12 to 15 t/ha. So they have tried to breed a rice variety that has very few tillers (8 to 10) but all of them are fertile and with big panicles (100-250 grains). Such a variety should be amenable to close planting and direct seeding to give maximum yield with minimum labor requirements.

The NPT program has proceeded on the assumption, contradicted by SRI experience, that there is an inverse correlation between panicle number and panicle size. In the current rice literature, profuse tillering is disparaged on the grounds that there are diminishing returns to more tillering: when the number of panicles per plant increases, the number of grains per panicle will decrease. That the plants for which this relationship is observed had been grown under hypoxic soil conditions, with continuous flooding so that their roots diminish, was overlooked.

A lot of time and money has gone into producing this new plant type, but unfortunately it has not yet yielded a cultivar that is reliable and beneficial enough for release. I explained our experience that when SRI plants have larger root systems, easily demonstrable by visual inspection, the plants become 'open systems,' able to have more roots, more tillers, larger leaf area, more grains, larger grains, etc.

Plants with impaired roots due to continuous flooding are 'closed systems,' requiring tradeoffs between these various components of growth. More tillers come at the expense of more grain. Measurements of Harvest Index (HI) with SRI have shown no change; all plant components are increasing, more or less to scale. Zhu and I speculated later that probably a certain physiological constraint has prevented success so far with the NPT. The number of leaves, and thus the plant's leaf area, is necessarily related to and limited by the number of its tillers. Having fewer tillers per plant means having less leaf area and thus less photosynthetic potential.

NPT trials have been conducted, according to an article by its main proponent, Gurdev Khush, with single 14-day-old seedlings, spaced 25x25 cm. So the NPT strategy is already 'half SRI.' However, NPT plants are still grown with continuous flooding, which will impair root growth, and heavy use of chemical fertilizer, which will inhibit soil microbial activity. So the NPT strategy foregoes the two main contributors to rice yield increase that SRI mobilizes.

There was also a question raised about rice quality with SRI. I reported that in India and Sri Lanka, farmers and millers say that SRI rice has fewer unfilled grains (less chaff) and fewer broken grains during milling, because grains are more resistant to shattering. There is enough difference that a higher price is offered and received for SRI paddy in those countries. We do not have any data on chalkiness, but this is also said to be reduced in SRI rice. Farmers have reported better keeping quality in that SRI rice when cooked one day still has structure and texture the next day, not becoming mushy like HYV rice when it is cooked.

In Sri Lanka, farmers say they prefer to keep their SRI rice and sell off conventional rice, partly because they know how many chemical sprays have been used on the latter. Most SRI rice is now 'organic,' which adds to its value. Possibly there is higher nutrient content of SRI rice due to the larger root systems that can access more micronutrients from the soil. Greater nutrient uptake from the soil is indicated by SRI plants' health and vigor. However, we have no evidence on any improved nutritional quality of SRI grains. I encouraged CNRRI staff to evaluate these various parameters of quality since they have the facilities and expertise for this.

There were also questions about whether SRI is being used in the U.S. (not yet, though Ricetech has done some trials); how enough biomass could be made available for 'organic' fertilization (this needs to be investigated; so far little thought and experimentation has gone into using non-arable land for biomass production, because this has not appeared profitable; SRI can make it profitable); and genetic/cultivar differences in response to SRI methods (certainly there are differences; the top yields in Madagascar have come from an improved variety descended from a Chinese cultivar, Taichung-16). It was close to noon by the time we finished the seminar.

We had the usual splendid Chinese lunch and relaxed discussion after the seminar. In the afternoon, Zhu and I discussed plans for the national SRI meeting in August as well as how to interpret some of the SRI photographs I had showed. Zhu and colleagues are planning to prepare a book on Chinese during this year to be published early 2005. We discussed the spread of SRI in China. The three provinces I visited on this trip are the ones with most SRI activity as far as Zhu knows, but work is going on in Hunan, Anhui, Guizhou and other parts of China. He said that SRI evaluation and dissemination 'accelerated' after the Sanya conference in April 2002. At the end of the afternoon, we made the return bus ride to Hangzhou, where we had another splendid Chinese meal at dinnertime.

Visit to Sichuan Province

Thursday morning I flew to Chengdu in Western China, where I was met by **Dr. Zheng Jiaguo**, director of the Tillage and Cultivation Department of the Sichuan Academy of Agricultural Sciences. He and it have been leading the work on SRI in this huge province, where SRI is more advanced in terms of getting the methods beyond evaluation and into demonstration stage.

Zheng said that Prof. Yuan, director of the China National Hybrid Rice Center, got several institutions in Sichuan to start work on SRI in 2001, and now about 15 municipality extension services are starting to promote it. Yuan also has a hybrid seed farm at Meishan, whose manager, Liu Zhibin, has made useful innovations in SRI methods. Of most interest is the 'triangle' method for SRI planting that Liu devised. This starts with the usual SRI grid pattern of 30x30cm, but staggers the hills, planting only alternate hills with three seedlings each. This maintains wide spacing between plants but has 50% more plants per square meter, helping to achieve 'the border effect' within the whole field.

From the airport we drove an hour directly to Chongzhou township, where we met the head of its Agricultural Bureau and had a nice lunch before making field visits. The demonstration plots of SRI last season gave 9 t/ha yields compared with the usual 7 t/ha, so the Bureau head said there was much interest in spreading SRI now. Last year, there were about 100 acres of demonstration plots. This year there are about 1,000 acres. Next year it should be much more.

A Mushroom-SRI Farming System: We came to Chongzhou to see an interesting application of SRI: its rotation with mushroom production, which is spreading rapidly during the winter season in parts of Sichuan province. It turns out that SRI fits very nicely with mushroom raising, first because the input for growing mushrooms is rice straw, and SRI produces much more of this. Also, the mushrooms need to be grown on soil that has not been chemically fertilized, so this is also a plus for SRI compared to conventional rice production methods. The beds on which mushrooms are grown are made of straw with a layer of dirt spread across them.

Our first visit was to a large area with beds covered by black plastic 'housing' spread over bamboo frames. Farmers who can afford the cost invest about 4,500 RMB per mu, a little over $3,000 per acre, in these temporary structures which maintain higher temperatures in the winter and save labor once constructed. Mushroom growers can earn 10,000 RMB per mu with about 80 days of additional labor, so this is an attractive crop in the winter season, alternating with rice or some other summer crop.

Because it is necessary to avoid buildup of disease, the mushroom beds need to be rotated. So mushrooms are grown in a particular location only every other year. Rice, vegetables or other crops are grown in between. The plastic housing can be easily disassembled and put up in another location for the next winter. The beds are seeded in October or November, after the rice harvest, and are harvested through April, when preparation for a summer crop begins. It takes the straw from about 10 acres of rice to support 1 acre of mushroom production, so straw represents a constraint on the spread of this system. This makes SRI, with as much as 50% more straw, more attractive than just for its production of rice.

We visited also a farm where mushrooms are being grown without the plastic cover. These beds are covered with woven rice straw mats that are easily removed once a day to collect the ripe mushrooms. This method requires much less capital (no plastic or bamboo structure, much less initial labor to set up the operation) but more labor during the season (to take up and replace the mats each day). Mushroom growing is thus accessible to farmers without capital, who can move up the technological ladder with plastic covering once they have made some more money from more labor-intensive operations.

Zheng pointed out that if the beds are appropriately laid out, they can become permanent, with SRI rice planted in two or three rows on the beds in the spring, after mushroom harvesting ends in April. This is an interesting **no-till cultivation system**. Since the soil is very rich and deep, placing seedlings into the soil of mushroom beds is very easy. The recommended spacing is 40x45 cm, which I thought at first would be too wide for best yield. However, Zheng assured me that mushroom beds are so organically rich and fertile, that this wide spacing works fine. There is no lodging given the strong root systems, and irrigation is not flooding but furrow irrigation, intermittently flooding the channels between the beds. This gives the plants sufficient moisture and greatly reduces water requirements.

The mushroom business is booming in Chongzhou and other parts of Sichuan, with expanding exports to Japanese, European and U.S. markets. We visited a local processing center, operated by a large and now prosperous household, whose new concrete building had 20 rooms, and an agrochemical shop in the front in addition to the processing courtyard in back. Zheng says that he expects SRI to expand very rapidly in this area given its intrinsic benefits plus the positive 'externalities' with mushroom production.

The local governor met us on the highway and expressed his satisfaction with the way the new system is spreading, bringing in a lot of income for his area. Personally I had some misgivings about the possible boom-and-bust potential of this export operation, though it may be hard for other countries to compete with these highly efficient farms. If the mushroom opportunities change, the farmers will be left at least with a much more productive rice production system.

Back in Chengdu that evening, the president of the Sichuan Academy of Agricultural Sciences hosted a splendid dinner. Fortunately in ordering dishes, they optimized rather than maximized the use of hot spices since Sichuan cuisine can be some of the hottest in the world.

Friday morning there was a training program scheduled for extension personnel from township Agricultural Bureaus in Sichuan. About 60 persons were in attendance. The program opened with an address by Prof. Ren Guangjin, vice-president of the Sichuan Academy of Agricultural Sciences. Without intending to do so, he set the stage very well for my following presentation. To begin, he stated that the aim of current agricultural development efforts is to protect food security, raise output, and improve farmer incomes. SRI can do all three quite readily.

Ren repeated what I had learned in Hangzhou, that rice production in China peaked in 1998 and has been declining since, a total of 13% by 2003. Both area under rice and rice yields have been sliding the past five years. Part of the regression is due to the low price for rice and lack of farmer incentives, but also the technological approach has not been successful. Ren said that both new varieties and better management are needed, but the latter is probably the key approach to increasing food production currently. Another lead-in for SRI.

Ren closed by listing problems to be attended to: (1) getting higher incomes for farmers as well as more output; (2) reducing labor intensity (SRI increases labor intensity initially, but can become labor-saving once the techniques are learned); and (3) growing rice with less water and with appropriate applications of fertilizers and sprays. The latter sounded like an endorsement of current approaches to raising production through external inputs, but he elaborated that farmers

needed to pay attention to their environment and should be reducing their use of chemicals so as to support soil biodiversity. Another point for SRI. With such prefatory remarks, the participants were primed for my presentation.

Since this was mostly an extension group, I did not go into as much detail on phyllochrons, soil ecology, and so forth, but focused on the reasons why it is possible to "get more from less" with SRI, which seems illogical.

(1) Smaller, young seedlings (<15 days) produce larger, more productive mature plants. This can be explained in terms of the physiology of phyllochrons, transplanting during the 2nd or 3rd phyllochron so as to disturb the plant minimally and preserve maximally its potential for tillering and root growth. I suggested that in their own gardening experience, they may have found, e.g., with tomatoes, that setting out smaller seedlings ultimately produced bigger and better plants; it is tempting to transplant larger, more mature seedlings, but this is not the best practice.

(2) Fewer plants per hill and per square meter give higher yields, in conjunction with other SRI practices. Close spacing reduces the amount of light that can reach lower levels of the canopy. An evaluation of canopy illumination by Dr. Anischan Gani in Indonesia found that with standard close spacing, there was not enough light reaching the lower leaves to support photo-synthesis, so they were being 'subsidized' by the photosynthesis of leaves higher in the canopy. They were a drain on plant resources rather than augmenting these.

So fewer plants, all entirely active photosynthetically, will be more productive than a larger number of crowded plants. I reminded them of what is known as 'the edge effect,' also known as 'the border effect,' which is to be avoided when measuring crop yield. Samples should be taken from the middle of fields because plants on the edge are known to be more productive, being exposed as they are to more sunlight and also circulating air. SRI aims to achieve 'the edge effect' for the whole field, with fewer but better spaced plants.

(3) Less water gives higher yields because the roots of rice plants under continuous flooding degenerate, due to hypoxia. Rice plants can survive in standing water but they do not thrive, because their roots are 'suffocating.' In well-drained soil, roots stay alive and effective right through maturation. I had shown pictures of tremendously large rice root systems from Cambodia, Cuba and India, so this point was very clear. Applying more water impairs roots' growth and functioning.

(4) Using fewer external inputs of fertilizer and chemical sprays contributes to more production because soil microbes and other organisms are not suppressed or inhibited. They can provide the rice plants many services and benefits if numerous and diverse: N fixation, P solubilization, root growth stimulation (many bacteria and fungi produce plant growth regulators such as auxins and cytokinins to promote root growth). In flooded soils, neither fungi nor aerobic bacteria can survive. In any case, inorganic nutrient amendments unbalance and commonly reduce soil biotic populations.

So there are four quite different sets of reasons why SRI practices can increase production by reducing inputs: smaller and fewer plants growing in less water with little or no chemical use

should be able to outproduce more, larger plants that are continuously submerged and chemically fertilized and sprayed. There is no magic to SRI. Its practices are supported by well-established biological knowledge.

Zheng then reported on SRI experience in Sichuan province specifically. In his introduction it was wonderful to see the name of Henri de Laulanie sticking out among a whole slide of Chinese characters. In 2001, they had four SRI plots, 6.5 mu (almost half an acre), with a yield of 12.2 t/ha. In 2002, they had four larger plots in different parts of the province, and the average was 13 t/ha. In their analysis of components of yield, it was seen that leave area was 16% greater in SRI plants, and leaf area index at maturity was almost double, 3.5 vs. 2. Dry matter was 60% more, and panicles 71% more. He showed impressive pictures of standing SRI crops.

Some problems he noted were: (1) because of cloudiness, sunlight is often poor in Sichuan, which makes using very young seedlings less successful; they need to figure out how to resolve this, probably by planting seedlings older than 15 days in some or many cases; (2) farming systems in Sichuan are very intense, with 2 or 3 seasons per year; they need to work out timing for setting up nurseries to be able to fit SRI most efficiently into rotational systems; (3) SRI should have a lot of organic matter, but this is often in limited supply; they need to find ways to increase this supply if SRI is to spread more widely; and (4) there may have to be some adjustments in plowing and irrigation schedules to accommodate SRI within existing farming systems.

On the positive side, Zheng noted that it may be fairly easy to get hybrid rice plants in Sichuan through 12 phyllochrons (periods) of growth before panicle initiation, or maybe even more, so that getting 100 tillers per plant should be possible; and using the 'triangular methods' of spacing that Z. B. Liu in Meishan devised in 2001 when he first started practicing SRI should help get higher yields in this province Zheng showed yields of 10 t/ha with standard methods and 12 t/ha with SRI (using the recommended square grid pattern), alongside a yield of 13.65 t/ha with the 'triangular' planting method complementing other SRI practices. (I asked him afterwards whether he could provide an English translation of his powerpoint presentation that we can put up on the SRI home page.)

One conclusion they have reached is that varieties that produce the largest panicles do not necessarily give the highest yields with SRI because they do not always produce the most panicles. Current thinking is to work with varieties having middle-sized panicles as they seem to respond best to SRI practices in terms of number of fertile tillers. Also, Zheng said that they are quite confident that they can reduce chemical use with SRI, as the plants are better able to withstand diseases and pests.

The three research focuses that Zheng closed with were: (1) evaluations need to be made of how amounts of fertilizer can be optimized and also reduced; (2) transplanting patterns may be further improved beyond the 'triangular' pattern; and (3) how can SRI be used to raised yields on soils with presently low fertility. He said in conclusion that he thinks SRI is very extendable in Sichuan.

After a short tea break, there was another presentation on SRI, starting with pictures of Prof. Yuan Longping and of me on a visit to Sichuan in September 2002. "What Is SRI?" the speaker asked. It is ideas more than a technology. It was good to hear that introduction. This researcher has been experimenting with plastic mulch, which controls weeds and also raises soil temperature. It also conserves water by reducing evaporation. The cost of this may make this technology unavailable to the poorest farmers, and there is need to avoid plastic pollution. But the researcher reported at 12.6 t/ha yield with SRI methods (triangular planting) and mulch, which could justify the added expense. It was reported that plastic can be collected and recycled. Large sheets are easier to control than plastic shopping bags, which have been a real pollution problem.

A plant protection presentation, without powerpoint, focused on how to reduce chemical use on rice fields. Planting strategies that increased the diversity of varieties and also dates of maturity were recommended, along with combining duck production or fish production with rice growing. During this presentation, a student who is doing her PhD thesis on SRI asked what I thought of an argument made in the literature (by Achim Dobermann in his recent article in *Agricultural Systems*) that SRI is productively mostly in certain kinds of ecosystems, particularly on Fe-rich acid soils.

I said that this argument was not based on any empirical evidence. In Madagascar we have seen SRI doubling or tripling yields from poor soils in tropical climate at sea level to better soils in temperate climates at 1200 m. In India, 300 trials distributed across all 22 districts of Andhra Pradesh state with diverse soil conditions were all positive except on saline soil. Here in China, SRI methods are producing favorable results from the tropical south (Hainan) to the cold north (Heilongjiong), from the low-lying east (Zhejiang) to the upland west (Sichuan). So the idea that SRI is a 'niche' innovation appears to have no real foundation.

When we broke for lunch, Li Chongde from Leshan (which means 'beautiful mountain') came over to tell me about his success with SRI. He got 12.2 t/ha last season and is very happy with SRI methods. He didn't know how to answer directly my question about whether his costs of production were reduced, but they obviously had gone down since he said that his costs with SRI had gone up 40% but his production by 60%. During lunch we spoke further. Last year there were 10 mu (.67 ha) under SRI in his village. This year there are 100 mu (6.7 ha). Next year, he says there could be 1,000 mu (67 ha), or even more

I asked him what had surprised him in my presentation during the morning. First, he said, was the importance of soil life, and how organisms provide nutrition and other benefits to the plant. Second, the importance of soil organic matter. He had seen how adding farmyard manure benefited the crop. He was concerned there where would be shortages if they expand SRI very much. I said that one doesn't need manure for SRI, only decomposed biomass of any kind. With some thought and effort, they should be able to find and utilize many kinds of biomass, starting with rice straw. If they grow mushrooms in this village, this would be a competing use for the rice straw rather than put it into compost for the field. However, if they are combining mushroom growing and SRI, they can benefit from the straw if used in mushroom beds as these make find soil for growing rice. The top SRI yields have been in fields with alternating mushroom production.

From his alertness and mannerisms, it was clear that Li is a 'can-do' farmer, like W. M. Premaratna, Ariyaratna Subasinghe, Gopal Swaminathan, Ramasamy Selvam, Mey Som, Luis Romero and Nico Espinoso whom I have met in Sri Lanka, Andhra Pradesh, Cambodia and Cuba -- and many other farmers whom I have not met. They are problem-solvers who will adapt and adjust the ideas and practices of SRI to make it more productive with their resource inputs.

Fortunately, in China, there are also researchers like Dr. Jin, Dr. Zhu and Dr. Zheng who are thinking flexibly and creatively about SRI, taking initiative rather than sitting back to watch it progress. Surely there are still other scientists like them whom I could not meet on this short trip. Whenever I get a chance (or remember to do so), I try to remind people that 'SRI is not finished.' It is 'a work in progress' and will presumably be more diversified and better within a few years. This trip confirmed that there is a solid base of experience, excellent results and a network of fine professionals and farmers in China who will adapt the ideas developed in Madagascar 20 years ago to meet the needs and conditions of this huge country, where the 'profile' of this innovation matches quite closely the agricultural sector aims being articulated by policy-makers.