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:

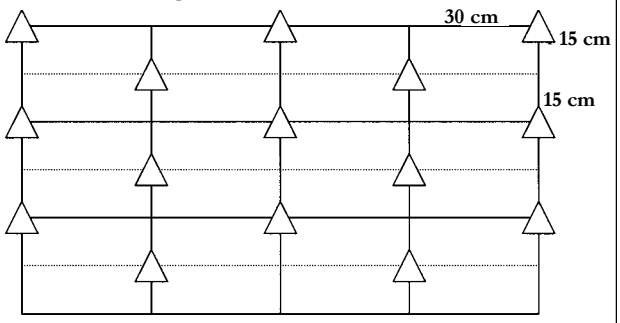
1. Use of tray nurseries to raise the young seedlings. The superiority of this method over flooded seedbeds is that there is no trauma when the young seedlings are transplanted and no shock after transplanting.
2. Application of herbicides to the field before transplanting. Weeds are a serious problem 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%.*