The System of Rice Intensification (SRI) for super-high yields of rice in Sichuan Basin

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Abstract: The System of Rice Intensification (SRI) is a new methodology for rice culture. The main features of this system as developed in Madagascar are: transplanting of young seedlings at the 2-leaf age, singly in a square pattern, with wide spacing between plants (25x25 cm but even wider as soil quality improves), using organic rather than chemical fertilizers, hand weeding (preferably with a simple rotating hoe that aerates the soil as it removes weeds), and keeping the paddy soil moist but not flooded during the vegetative growth phase. Significant phenotypical changes occur not only in plant structure and function but also in yield and yield components under SRI cultivation. The production increases can be notable.

However, there are some constraints to adoption of the presently recommended set of practices, e.g., a small number of plants may not be suitable for the low solar radiation condition in Sichuan. Besides it is hard to transplant young seedling at 2-leaf age in multiple cropping systems. There is often shortage of organic fertilizer materials. The management requirements for weeding and keeping the soil moist but not saturated are complex and laborious. Experiments over 2 years are reported in which SRI is modified according to the agroecological conditions in Sichuan, with variations in the transplanting pattern, plant leaf-age and density, varietal response, and so on.

The following modifications were validated: transplanting 3 separated seedlings in one hill in a triangular pattern with the leaf age extended to 3-4; application of herbicide before transplanting; mulching the spaces between plants with straw; adding chemical fertilizers to promote plant growth vigorously when needed; making shallow furrows before transplanting in the zero-till fields, and applying the alternate-wetting-and-drying (AWD) method for water management with midseason drainage to inhibit tillering. With these modifications, grain yield exceeded 12 t/ha, being 46% greater than control yields using field comparison.

Media summary: The improved SRI and super-high yield (12 t/ha) of rice in Sichuan.

Keyword: Rice; SRI; super-high yield; oblong and triangular transplanting pattern

To assure food security in the rice-consuming countries of the world, farmers will have to produce 50% more rice with improved quality to meet consumers' demand in 2025. This additional rice will have to be produced on less land with less water, less labor, and fewer chemicals. The task becomes even more difficult when rice quality preferences gradually receive more attention in the region. Crop improvement and crop management have played equal roles in increasing production of major food crops in the past. There is no doubt that the task of making gains becomes even more difficult when rice yield is already at the high level.

1. The original SRI methodology and its characteristics

The System of Rice Intensification (SRI), developed in Madagascar over a 20-year period and synthesized in the early 1980s, offers opportunities to researchers and to farmers to expand their understanding of potentials already existing in the rice genome. Experience with SRI methods suggests that average rice yields can be about double the present world average without requiring a change in cultivars or the use of purchased inputs. Moreover, only about half as much water per season is required for these higher yields. Crop protection requirements are reduced because SRI plants are more resistant to damage by pests and diseases.

The SRI methodology for raising rice production makes three main changes in irrigated rice cultivation:

(a) Transplanting younger seedlings, preferably 8-15 days old, before the plants enter their fourth phyllochron of growth, which preserves inherent potential for tillering and root growth.

(b) Planting the seedlings singly, rather than in clumps of 3-6 plants (where rice roots compete with one another), and in a square pattern with wide spacing between plants, rather than in rows. This spacing permits weeding with a 'rotating hoe' in two directions. Such weeding was necessary because when the soil was not kept always flooded, weed growth becomes a problem. Use of the 'aerating hoe' has the advantage of aerating the soil.

(c) Keeping the paddy soil moist but not continuously saturated during the plants' vegetative growth phase. After panicle initiation, just a thin layer of water is maintained on the field.

2. Preliminary evaluation of SRI

2.1 *SRI is a promising way to increase rice yield* General speaking, the yield from farmers; practice is about 8.5 t/ha in Sichuan. When SRI methods were first introduced in rice production, the yield was increased 20%. But with the modified methods intended to suit Sichuan conditions better, the increase is about 50%. The triangle planting pattern increases the number of plants/m^2 compared to standard SRI methods, and also more tillers/m^2.[1]

Table 1. Comparison between triangle-planted SRI and regular SRI (2002 Guanghan, SAAS)

Transplanting pattern	Yield (T/ha)	Comparing to CK	
		+ T/ha	+ %
Tradition (CK)	8.65	--	--
SRI	10.42	1.77	20.4
Oblong and triangle	13.39	4.74	54.8

2.2 SRI promotes more vigorous growth of the rice plant

a) Leaf blades become big, especially for the functional leaves.

Table 2. Different sizes of the leaf blade (unit: cm)

Item	3rd leaf		2nd leaf		Flag leaf		Average	
	Length	Width	Length	Width	Length	Width	Length	Width
SRI	64.25	1.57	71.32	1.87	57.67	2.17	64.41	1.87
CK	56.07	1.43	62.03	1.57	48.67	2.01	55.56	1.67
+/-	8.18	0.14	9.29	0.30	9.00	0.16	8.86	0.20
%	14.59	9.79	14.97	19.11	18.49	7.96	15.95	11.98

b) The plant height and culm length becomes longer. The stem diameter of the 4th internodes (from top) is 0.49 cm by SRI, 12% more than the control (CK). So the stem is very strong.

[1] In Meishan, Liu Z.B. in 2001 achieved a yield, certified by the Provincial Department of Agriculture, with SRI methods and this triangle pattern of 16 T/ha. The highest documented yield with SRI methods in Madagascar, 21 t/ha, by Ralalason at Soatanana, was with single seedlings in a square pattern. This was on the high plateau, with temperature and sun conditions not very different from many parts of Sichuan. This was with 50x50 cm spacing, only 4 plants/m^2 (average of 70 panicles/plant and 260 grains/panicle), but in the sixth season of using SRI methods on that farm, so soil quality had been greatly improved by that time due to greater root exudation and application of compost. What constitutes the optimum spacing will depend on many factors, including soil condition, which commonly improves with SRI methods over time. So farmers and researchers should continue to experiment and evaluate when using SRI.

Table 3. Internode lengths (from top) and culm length (unit: cm)

	6th	5th	4th	3rd	2nd	1st	Panicle	Culm length
SRI	2.63	7.57	11.73	14.47	22.47	45.4	25.64	137.79
CK	1.5	4.87	8.07	12.03	21.07	41.77	25.17	118.98
%	75.33	55.44	45.35	20.28	6.64	8.69	1.86	15.81

c) Leaf area index (LAI) and dry-matter accumulation are much higher than CK.

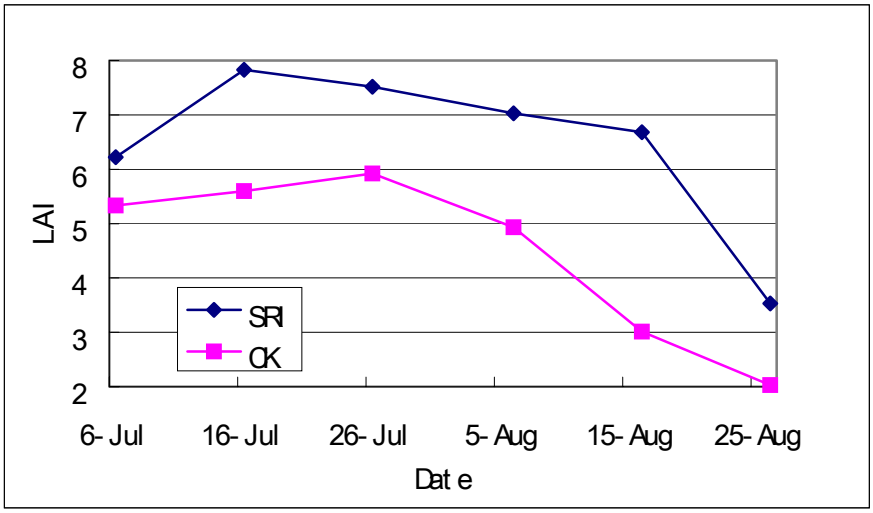


Figure 1. Change of leaf area index (LAI) during growth cycle

Table 4. Comparison of dry-matter accumulation between SRI and CK (unit: kg/ha)

Comparison	Rice stage	Stem	Sheath	Green leaf	Withered leaf	Panicle	Biomass
SRI	Full heading	6396.0	8055.0	7168.6	315.4	2361.7	24902.4
	Mature	4108.8	3265.6	3390.0	2667.3	13592.1	25407.3
CK	Full heading	3775.3	5594.5	3880.9	254.2	1204.9	14710.0
	Mature	2475.0	3064.6	1661.2	1639.6	7935.7	15832.5
SRI over CK +/-%	Full heading	1038.9	659.7	1270.6	361.0	1440.0	1039.3
	Mature	990.1	98.4	1560.9	940.0	1069.2	907.2

2.3 Response to SRI is different between varieties. The plant type is very important. If the functional leaves are too long at the late growth stage, photosynthesis will decrease. Note that 40x40 cm spacing is not usually recommended for SRI when first used, as soil quality may still be lower than necessary to get the highest yield from wider spacing (fewer plants/m^2). The standard SRI recommendation is to begin with 25x25 cm spacing and to expand this when and as the soil acquires more abundant and diverse microbial life through aeration and addition of C through root exudation and soil amendments.

Table 5. Varietal differences in response to SRI practices

Variety	CXY 157	CXY 179	II you 7
Spacing(cm)	40×40	40×40	40×40
Seedlings/hill	1	1	1
Hills/m^2	6.25	6.25	6.25
Max. tillers/hill	321.3	336.7	324.6
Panicles/m^2	177.9	172.8	172.2
Yield (t/ha)	10.03	10.47	9.62

2.4 SRI gives higher output with fewer purchased input, higher output, but it requires more manual work. SRI plants have less insect and disease problems. The methodology reduces seed requirements by 50-90%. There is a saving of water, as much as 50%, with more production. However, land leveling needs to be done carefully at first to facilitate good water control and minimal application. This time requirement is less in subsequent seasons. Also, more time is needed for weeding than if fields are flooded or herbicides are used; compensating for this is higher yield from the soil aeration. Many farmers, however, may not have the additional labor available, or may not want to invest more labor in agricultural activities. So not all farmers may want to use SRI methods as recommended, and thus we have considered how to adapt the principles for use under Sichuan conditions.

3. Limit factors for adoption

3.1 *The number of foundation plants, being less, appears less suitable in a ecosystem with the low solar radiation conditions of Sichuan.* Single plants in a square pattern with wide spacing cannot produce sufficient panicles, so the yield potential is limited. [Note: The trials reported here were conducted with 40x40 cm spacing, wider than recommended for initial use of SRI methods, so the comparison should have been with 25x25 cm spacing.] What farmers want is to maximize the number of panicles/m^2, not panicles/plant. The triangular/oblong planting method development by Mr. Liu Z.B. in Meishan appears to be a valuable adaptation of SRI practice, increasing plant density by 50% while maintaining good plant exposure to the sun and air. It has long been known that rice plants on the edge of a field are more grain-bearing than plants in the interior. This is called 'the edge effect,' and it is to avoided when taking samples from which to estimate yield. What SRI practices aim to achieve is 'the edge effect' throughout the whole field.

3.2 *Many farmers find it hard to transplant young seedlings at 2-leaf age in multiple cropping systems.* Older-age seedlings (about the 7-leaf age) are transplanted into wheat fields in tradition practice. If a very young rice seedling is used, the sowing date must be postponed as the rice matures later, the yields are less, and field management is more difficult. [This question of adapting SRI methods to the requirements of other crops in a rotational of polycropped system is important. SRI does not necessarily lengthen the rice growing season. A recent report from Peru documented where SRI methods reduced the total growing cycle by 9days. Farmers in many countries use 5-10 day-old seedlings quite successfully, so 15-day seedlings should not be so difficult to use as farmers (initially) think, and may complain about.]

3.3 *Organic fertilizers are often in short supply.* Because of the popularity of reduced or zero- tillage, there are seldom many agricultural cattle in rural area. So the farmer cannot get enough organic fertilizer, which is used in SRI field. [Although SRI does not require animal manure; any decomposed biomass will serve the purpose; and even in densely populated areas, it would be possible to grow sufficient biomass on bund, along roads, on wasteland, etc. This may not be done now because there are not good returns to the labor time invested. But using wastelands to grow biomass, e.g., fast-growing leguminous plants like crotalaria or sesbania, has no economic opportunity cost because the land used has no other profitable use. When the use of decomposed biomass in conjunction with other SRI practices can add 1-2 T/ha or even more to yield, this will become a profitable use of labor even on farms that have labor shortages.]

3.4 *Management measures such as handle weeding and keeping soil moist (not saturated) are too complex, and more labor is needed with SRI.* Nowadays the farmers prefer to the simplify techniques. [But they also want to increase their returns to labor, and using the SRI practices fully and well can give them higher returns than most other opportunities. Also, after the first year or two, the labor requirements with SRI decline as farmers learn the techniques and get comfortable and skilled with them, doing everything faster and more confidently. Many farmers by the 3rd or 4th year find SRI becoming *labor-saving*. In a survey of 171 SRI farmers n Cambodia, 70% said that SRI requires less labor for them. There are always some start-up costs with new methods. Efforts are ongoing to develop labor-saving methods and equipment. Farmers in Cuba this season

have designed a simple seeder that transplants pregerminated seed onto the surface of a prepared field at 40x40cm spacing. They expect a very good harvest. The yield might not be quite as high as with hand transplanting, but saving labor time they consider worthwhile. There can also be mechanized hand weeders that do even a better (and faster) job of removing weeds and aerating the soil. SRI is not a 'fixed and final' innovation. It is being adapted and changed in various ways.]

4. Improved SRI and its practice in Sichuan

4.1 *Use tray nursery to raise young seedlings.* The seedling nursery is operated under upland conditions, and the root system should not be traumatized during transplanting. With SRI methods, seedlings are removed carefully from the nursery, using a trowel and keeping the seed sac attached to the root, and they are gotten into the field within 15-30 minutes, allowing no time for the roots to dry out. They are placed gently into the soil, taking care not to plunge the seedling straight down into the soil, inverting the tip of the root upward. This avoids a long recovering time. Leaf age can be extended to 3 or 4. [However, we should not give up too quickly on 2-leaf seedlings. Factorial trial results reported at the Sanya conference in 2002 showed that young seedlings, other things being equal, add significantly to yield.] Raising seedlings in a nursery that can be transported to the field for transplanting can make the whole process more easier.

4.2 5-5.5 hills /㎡ is the best transplanting density.

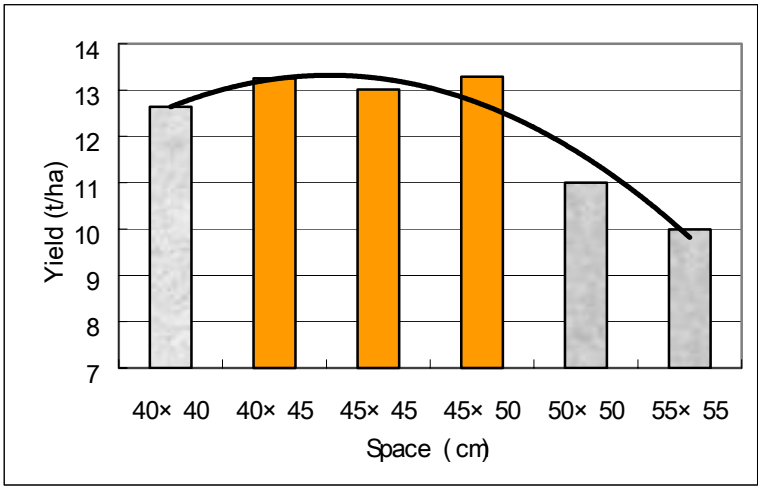


Figure 3. Relation between yield and transplanting density

[This figure starts with a spacing that is generally too sparse for a field where SRI is being used for the first time, unless the soil is for some reason already very fertile. One should not complain about a yield of 10 T/ha at 55x55 even if this is 3 T/ha less than the yield achieved at 45x50 cm.]

4.3 *Oblong with triangle transplanting pattern.* Transplanting 3 separated seedlings in one hill at triangle pattern produces more panicles/m^2, and panicle size can be even greater, as suggested above, giving more 'edge effect' throughout the whole field..

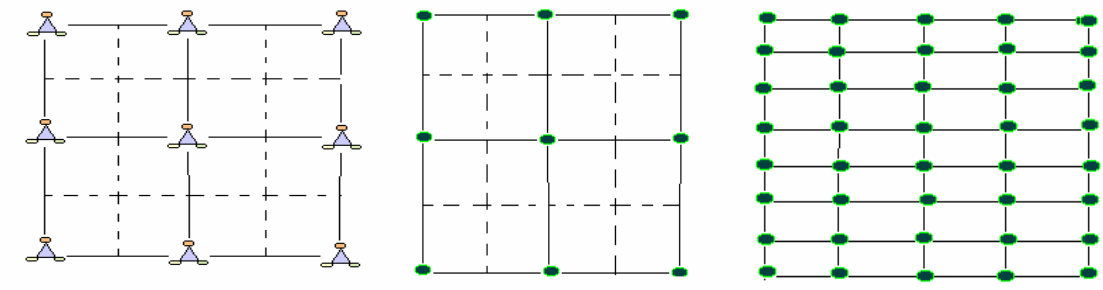
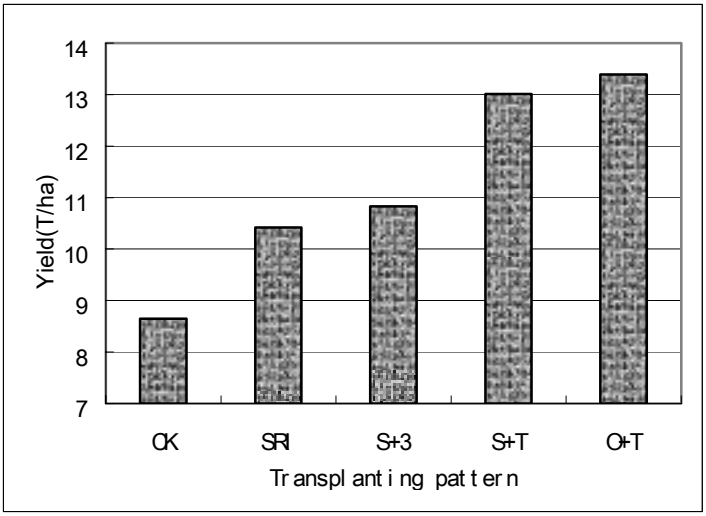


Figure 2. Alternative transplantıng patterns



Note: S+3= Square with 3 seedlings; S+T=Square with triangle; O+T=Oblong with triangle

Figure 3. Yield differences between transplanting patterns

4.4 *Application of herbicide before transplanting, and mulching the spaces between plants with straw after recovery stage.* Because of the wide spaces and more fertilizer, there are more weeds than with conventional cultivation, especial in the zero-till field. Combining herbicides and mulching measures, the weed problem can be solved easily. [However, herbicide use does not aerate the soil, and it can have some inhibiting effect on tillering, farmers tell us, so it probably also has some adverse effect on soil biota,. We should keep on evaluating evaluation of different options for weed control. The use of mulch is a very promising innovation.]

4.5 *Adding chemical fertilizers to promote plant growth vigorously when needed.* The effect of organic fertilizer is slower than chemical fertilizer. We do better to use some to promoting tillering during productive tillering stage. [However, the value of organic fertilizer material is not its content of N, P and K compared to that in chemical fertilizer. Rather, the value of organic sources of nutrients is what they do to stimulate biotic growth and activity in the soil, things that chemical fertilizers inhibit. There is a convenience factor with using nutrients in a bag, but if these work less well, i.e., if they have adverse effects on soil quality and even on water quality (which is an increasing problem in China and the US if not yet in poorer countries), and if better returns to land, labor, water and capital can be obtained by using organic nutrients in conjunction with changes in plant, soil and water management recommended with SRI, there will be changes in farmer practice.. A lot of farmers in India and Sri Lanka are switching to 'organic' agriculture because they dislike the effects on the food, on themselves and on the environment from their agrochemical addiction.]

4.6 *Inhibiting tillering after productive tillering stage.* In fact, the tillering ability of rice plants is very strong, and the ratio of panicle/tillers is often less than 50% by SRI technique. So midseason drainage is introduced in the SRI field to inhibit excessive tillering. [However, these results may be an artifact of the use of agrochemicals. Effective tillering is often 80-90% with SRI methods, even higher than with conventional methods when the soil has been improved by SRI practices used as recommended, with of course appropriate local adaptations and variations. The 50% rate of tillering reported here may be a result of too much fertilizer still being used, or too many agrochemicals accumulated in the soil and inhibiting the growth and functioning of bacteria and fungi and other organisms which make the soil fertile and productive. Draining midseason may be a desirable practice, but the problem of late tillers being unproductive has not been often observed with SRI.]

4.7 *Making shallow furrows before transplanting in the zero-till fields.* The alternative wetting and drying method is a good way for water management. The irrigation is easy, and the surface soil is kept in aerated condition when some water remains in the furrows. [This modified 'raised bed' technique has a lot of merit. The method for land-forming of rice paddies that Association Tefy Saina recommends in Madagascar is a 'drain' around the outside of the paddy, not the usual 'fishbone' furrowing within the field that is very superficial and does affect soil saturation levels. This innovation could be very beneficial, especially when combined with mulching (which might best be done after one weeding 'pass' over the field 10 DAT before putting the mulch on). We should be encouraging the dramatic growth of earthworms as these can do the necessary soil aeration for plants (requiring a lot less labor from farmers than weeding several times with the rotating hoe). Keeping soil water levels low is another way of getting soil aeration.]

5. The practice of super-high yields with SRI in Sichuan

Leshan City is a typical place where the rice-wheat cropping system is practiced. The irrigation system is well developed. But in conjunction with SRI cultivation, early-maturing crops such as mushrooms and vegetables are much better than wheat. Improved SRI has been applied for 2 years in Leshan city from 2002-2003. The grain yield surpasses 12 t/ha continuously, which has been certified by the Provincial Department of Agriculture in 2002 and by national experts in 2003. This is the new record of super-high yield in this ecotope, being 46% greater than control yields using field comparison.

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