TECHNICAL PRESENTATION OF THE SYSTEM OF RICE INTENSIFICATION, BASED ON KATAYAMA'S TILLERING MODEL

Henri de Laulanié, Association Tefy Saina[1]

This System of Rice Intensification was discovered almost by accident in 1983-84. Due to a lack of time for letting rice seedlings grow for 30 days before being transplanted, students in a farm school at Antsirabe (1,500 meters a.s.l.) were obliged to use their very small nursery twice within a month. This meant that some seedlings had to be transplanted after only 15 days. Given the very high number of tillers obtained per plant with this accidental experiment, more than 20 per plant, this age for seedlings was adopted at the school as the latest time for transplantation. Still earlier transplanting of seedlings was tried -- at only 12 days, 10 days, even 8 days after seedlings emerged in the nursery. We found that this led to a substantial increase in the number of tillers per plant, up to 60, even 80 or more. Such was the beginning of the System of Rice Intensification.

Yields rose substantially with the increase in tillering, but the exact reason for this increase could not be explained. The reason was found from reading the GRET edition of Didier Moreau's book, entitled *L'analyse de l'élaboration du rendement du riz: les outils du diagnostic.* This analysis could account for the large number of tillers produced when rice is transplanted at an early age [*before the fourth phyllochron, as explained below*]. This explanation was called by Moreau "Katayama's tillering model."

Thanks to this analysis, the System of Rice Intensification could become more than a matter of pure empiricism and could be understood in terms of rational scientific explanations. But even having reached this point in our understanding, we know that we are still far from the end of the road, if this road ever has an end.

I. ESSENTIAL PRINCIPLES OF THE SYSTEM

1. **Transplanting very young plants**

Fifteen days is apparently the limit for advantageous transplanting as far as the age of seedlings is concerned, but this still has to be determined further.[2] It is common to consider as a starting point the moment when seedlings emerge in the nursery, but this is wrong. Seeds can be sown dry or can be pregerminated, and pregermination can be more or less advanced.

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[1] *Note*: *This paper was prepared by Fr. Laulanié in January 1992, but never completed for publication. Many of these ideas here were presented in a shorter article by Laulanié published in 1993 the journal Tropicultura (Brussels). A rough translation of this paper was done by Ms. Holy Ranivohariniony, MICET, with polishing and elaboration by Norman Uphoff, CIIFAD, to make it more readable, particularly for persons not acquainted with details of rice growth and production. Father Laulanié wrote often in condensed style, so some interpolations have been made [and are noted accordingly]. This translation is fairly free in some places to make the presentation clearer, with footnotes added at various places to update what is known about SRI currently. Sebastien Rafaralahy and Justin Rabenandrasana, president and general secretary of Association Tefy Saina, the Malagasy NGO that Fr. Laulanié helped to establish in 1990, have helped to finalize this translation for a broader readership. Uphoff comments are in* ***italics****.*

By considering as a starting point the time that rice seeds come into contact with water, one has an objective base. By comparing *n*-day plants, which are raised according to different management methods but which undergo the same treatment after the transplantation stage, we will be able to determine which perform best under the same ecological conditions. If trials are done systematically, by varying *n* by one day (or half a day, why not?) each time, we will see if the best performing procedure will always be the same or will change according the age of the plants at time of transplanting. Still, we will need to explain scientifically the causes of constancy or variation. Such trials should be done with all varieties, in various types of soils and with different climatic conditions, before general rules for the system can be established.

The most difficult thing to do in agriculture is to learn how to compare things that are truly comparable. The number of factors involved is so many that the results of trials can be thoroughly confused by unknown factors -- even when using scientific equipment for measurement that is unquestionably precise. One can never be cautious enough when drawing conclusions.

2. Transplanting single plants

This principle [*of planting seedlings singly, rather than in clumps of several seedlings, 3, 4 or more*] has been applied since 1965, that is to say, already about 20 years before arriving at the System of Rice Intensification that we now call SRI. Planting seedlings singly was traditionally done in some parts of Madagascar such as in Imamo (Arivonimamo), Isandra (west of Fianarantsoa), and Tsienimparihy (south of Fianarantsoa).

Why has this transplanting method not attracted more attention? Probably because comparable rice cultivation methods were used by very few people and also because the transplantation was done too late [*to get the benefits possible when combined with other SRI practices*].

Another cause of poor yields can be transplanting seedlings too deep (more than 3 cm deep) or too densely (too many plants per m^2). This second reason limits the growth of tillers even if they do not die right away. These two practices [*transplanting young seedlings singly and widely spaced*] are the essential elements of SRI.[3]

II. GENERAL PRINCIPLES OF IMPROVED RICE CULTIVATION

1. Drainage of rice paddies

"Tambiazana," reddish [ferrous iron] flakes which are often found floating in corners of rice paddies, are indicative of soils that lack oxygen and calcium. Since rice needs only a very low rate of calcium, the significance of this condition is that it indicates a lack of oxygen. Soil that

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[2] In this text, one will find many adverbs that add nuances and affirmations that are quite relative. This is essential given our limited experience so far and the many variations of tropical climate and altitude which make it imprudent to generalize too much. [*As Tefy Saina has gained more experience in different parts of Madagascar, it appears that at higher elevations, with lower temperatures, the phyllochron (discussed below) is longer, and the latest date for optimum transplanting can under such conditions be as late as 16 or 18 days.*]

[3] *As experience has been gained and scientific explanations are established, it appears that the water management methods and weeding that aerate the soil are similarly critical for SRI.*

lacks oxygen becomes a reducer, and the iron contained in it, which is ferrous material, will become toxic. [*Such soil thus needs drainage.*] A second category of soils that imperatively require drainage is hydromorphic soils, i.e., flooded soils composed mostly of peat which can be easily recognized by their dark color.

Malagasy farmers are victims of a universal belief in the country: that ‘water is the main nutrient of rice.’ Believing this statement, they do their best to maintain a maximum amount of water in their rice paddies: farmers build high bunds around their paddies, they take more water than needed for irrigation, they retain water in their paddies during the winter. As a result, the rice paddies are permanently asphyxiated.

The fishbone pattern of drainage channels [*indentations scored on the surface of paddies to facilitate the evacuation of excess water*], generally recommended in handbooks, is not really efficacious. This method removes water only after it has crossed most of the field to reach the drain.

A better drainage system is "the peripheral belt method." This divides the different parts of the field to be drained from each other and evacuates water around the outside of the field. Also, rather than have irrigation water simply flow into the paddy, it is better supplied through a small pipe that pours the water into the paddy, thereby assuring that the water supply is aerated.

2. Irrigation with a minimum of water

There tends always to be insufficient provision for drainage, which means that irrigation tends to be excessive. The leaves of the young seedlings that grow before and after transplantation will have some of their upper parts submerged if there is standing water. If the soil is permeable, there will be percolation of water and run off. If the soil is not permeable, however, there will be standing water, which implies asphyxia. If the rainfall is no more than about 20 cm, this is likely to drain without much smothering of the roots. If rainfall is less, to assure that there is "sufficient" water in the paddy, one needs to add some water to it at favorable times.

During the whole tillering period, it is sufficient to add 1 to 2 cm of water to the rice paddy in the morning. The higher parts of the field should be at the same level as the water or slightly higher. In the afternoon, the whole rice field will be almost dried up, and adventitious roots *as well as their microbial environment* easily gain access to oxygen [*emphasis added*]. Rain can be very efficiently utilized in this case. If it has not rained during the day, water can be added by irrigation at night. One should not be afraid of having 3 or 4 days of superficial dryness, even if some cracks develop on the surface of the field.[4]

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[4] *Tefy Saina has found that for higher elevations, where soil warmth is more important for rapid growth, the recommendation now is to add water to the rice field in the late afternoon or evening, with the water providing a kind of insulation to retain the heat, and then to drain any standing water remaining in the morning, so that the field is open during the day to absorb the sun's heat and the air's oxygen and nitrogen.*

At the beginning of tillering, vegetative growth is still not very great, and only a small amount of water is needed by the plant. The rise of water in the soil by capillary action leads to drying of the soil's pores, which is important because water will then be replaced by air. Then when it rains, this air will be pushed downward, and oxygen will be more abundant below the surface of the rice paddy. This will facilitate root growth as there will be a corresponding increase in the volume of soil explored by the roots [*to seek out and acquire water*].

In the Malagasy highlands, as well as on the east coast, rice does not need much irrigation before the onset of flowering (panicle formation). The air always remains rather cool at higher altitudes. Storms cool it by mixing it with layers of air coming from the higher levels of the atmosphere and by rain evaporation. The temperature is relatively cool during nights. On the east coast, air humidity always remains high. A large amount of water is required only if the temperature is really high during the onset of flowering, but it is rarely this hot in these two areas. It was only in 1992 that some SRI trials were launched in Maintirano [*on the west coast*]. We will need to wait for 2 or 3 years before assessing the implications of the SRI system under the conditions of rice cultivation in the western areas of the country.

3. Garden-like nursery

The best seedling nursery will look like a garden and will be watered by hand when there is no rain, enough to keep the soil moist but not saturated. This method is preferable over the traditionally irrigated nursery, which has standing water. The period for seedling growth is about the same with the two methods. A garden-like nursery is better than the traditionally irrigated one provided that the pregerminated seeds are put into sticky mud and just on the surface of the mud. The nursery should not be submerged but rather is best kept moist. Plants from a garden-like nursery are stronger and keep more soil with their roots when removed for transplanting. After transplantation, the seedling becomes bigger than the others even if it was smaller at the time of transplanting. It is much easier to remove seedlings from such nurseries with a tool when their roots are covered with soil.[5]

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[5] In Fianarantsoa, some "forced" nursery trials were launched this year. Pregermination is done in 40^o-50^o water, which is heated up whenever it cools. After being soaked for 24 hours, the moist seeds to be germinated are put in a pile of manure with a similar temperature and they are sown 24 hours later. In the nursery, a layer of fermenting manure is used to raise the temperature. (According to Angladette, whose writings on rice are considered authoritative, the plant lives on the reserves of nutrition in the seed until the emergence of the third primary leaf; but this seems too long.)

This layer-nursery system provides better for the plant's growth, which can be more than 2 cm per day. A 10-day plant can be 15 cm long or even more. But it is difficult to popularize this nursery system for the moment, as it requires use of a thermometer. It is nevertheless interesting to study, because it could be useful in some limited cases, e.g., rice cultivation at 2,000 m elevation, or winter rice on the east coast which could lead to triple-cropping.

In Ambohimiadana, some people make their nursery at home on a removable pallet that is taken to the field for transplanting. Such initiatives by farmers will increase in number and lead to diverse practices of SRI in the future, each addressing particular problems that farmers encounter.

4. Preparation for transplanting

Plants should not be washed, or wrapped, or shaken. They should be handled carefully and gently. There are two important points: first, reduce as much as possible the period of time between removal of the seedlings from the nursery and their planting in the rice paddy, and second, place the plant correctly so that it can grow in the most natural position. An acceptable period of time between removal and planting can be half an hour. The maximum would be one hour. Just fifteen minutes is preferable if possible. Achieving such short times is a matter of organization that should be taught to farmers.

What makes the planting of seedlings difficult is the needs of the root system. When the seedling is planted in the soil vertically, that is, thrust straight down into the soil, the ends of its roots are turned upward. In the traditional transplantation method, one cannot see this because the roots are usually short, and the seedlings are planted deeply (from 6 to 12 cm). But in the case of SRI, the tips of any turned-up roots can be seen on the surface after transplanting because the seedlings are small and they have been planted quite shallow. [*The planter can then ensure that the root tips are covered, to minimize the trauma of transplantation.*]

The best technique will eventually be to use some kind of dibble stick (*plantoir*) for putting seedlings into the ground, but this is still difficult to realize at the moment. The only practical solution for now seems to be the "lateral placement" of the plant, placing its small roots in the soil *horizontally*, just below the surface (1 to 2 cm). If they are close to the surface they can more easily send out lateral [*adventitious*] roots. [*Seedlings transplanted thus have the profile of an L. When seedlings are thrust vertically into the soil, their profile is more like a J, which causes 'transplant shock' so that the seedling requires a week or more to resume growth.*]

5. Preparation of the rice paddy

There are two main objectives in preparing fields before planting: first, to obtain a sticky mud (at the same time, viscous but non-liquid), homogeneous and without lumps, and second, to eliminate as far as possible weeds and their roots which can be tuberous or mixed with rhizomes. To accomplish this, if there are no off-season crops, plowing should be done 3 or 4 months before transplantation, to get a friable soil which comes apart easily after being turned up, with harrowing immediately following.

In Madagascar, it is a common mistake to think that plowing should be done again several months later. This will favor the growth of winter weeds, and both microfauna and microflora will be exposed to coldness and dryness. If there is a supply of manure, it should have been put on the field before the plowing is done. To minimize nutrient loss, plowing should be done right away after application of manure, and the field should be leveled, and its soils should contain no big clods. If it rains during the winter, which may cause the growth of weeds, these have to be removed with a harrow or a hoe.[6]

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[6] *As SRI practice has evolved, with compost being used instead of or in addition to manure, and as farming systems intensify with an alternating,* contra-saison *crop such as potatoes or beans being grown between rice crops, farmers are applying their compost to their* contra-saison *crop and do not need to add anything to their field when preparing it for rice. Slow decomposition of compost appears to give best results.*

The ideal preparation of the soil after plowing, a process called puddling, must be carried out with successive applications of water, with a small amount of water applied for 24 hours, and then criss-crossing harrowings for a progressive conversion of the soil into consistent mud. The treading or trampling of the soil, usually with oxen, to break up clods and homogenize the soil, takes another day, so a cycle of puddling before the next water application takes 3 days. This cycle should be repeated three times. Every third day can be devoted to removal of non-rotting weeds. This must be real removal, not mixing them into the mud. If the mud is still too liquid after the third round of puddling, the rice paddy should be left for 1 or 2 days to dry some more before transplantation.

It is a good idea to clear weeds from at least the inner surface of the bunds around the paddy before or during the 9 to 10 days of land preparation. An *angady* (shovel) should not be used to clear the inner side of the bunds as this would make the bunds thinner and thinner each year. Practically, the preparation (puddling) of rice paddies should begin at about the same time as one starts seeding in the nursery (9 + 2 = 11 days) for transplantation which is to be done 11 or 12 days after germination, or at the same time as the rice seeds are put into water for pregermination if transplanting is to be done at 9 or 10 days.

6. Steps in transplanting

Persons doing the transplanting should be well trained every year, for several years, at the beginning of transplantation season. This training should include:

- How to place the plants in the field correctly, one by one.
- How to level the field if it is not all at the expected level, either by taking out a little mud if it is too high, or by adding some mud if it is too low.
- How to plant the seedling by holding it between the thumb and the forefinger in order to keep the roots in an horizontal position.
- How to move the transplanter's feet one by one; they have to step carefully between the lines if they are working near transplanted plants.
- How to move the ropes that guide setting out the plants in straight lines and keeping them parallel to each other by maintaining the exact spacing.
- How to make sure that the same spacing between plants is kept, even if there are no knots or any other marks on the rope to determine the exact place of each plant.
- If transplanting is done in a square or a rectangular pattern, transverse lines should be inspected regularly to keep their regularity.

The best thing to do is to have someone check what has been done the day before. This person will systematically scrutinize everything and set right any fallen or oblique plants, replacing any missing ones or any accidentally stepped on. He should look through the rice fields to make sure that distances between each plant and the bunds are great enough for using the rotary push-hoes.[7]

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[7] *SRI spacing methods were developed using ropes tied between sticks driven into the edges of the paddy field, but farmers have developed a labor-saving method for marking (scoring) the surface of the field using a simple wooden rake (*rayonneur*) with "teeth" spaced the desired distance apart (20, 25, 50 or more centimeters). If the soil is too wet to hold the pattern, the field should be let dry a little longer.*

One might think that ideal transplanting, as we conceive it, will take a considerable, even an excessive amount of time. Clearly transplanting is a very important part of SRI. The difference between poor and perfect transplanting may affect yield by as much as 30%. This is a large difference if speaking of yields between 6 and 12 tons per hectare. In fact, if the transplanter is careful and well trained, and if the field is well prepared, the difference in time will be minor and will be easily compensated for later during the weeding, which is quicker in a well-planted field.

7. Spacing when transplanting

This depends on the farmer's choice. Every farmer should decide according to his own experience what kind of spacing suits him best considering the variety of rice grown, the soil quality, the microclimate, the transplantation density, and his own know-how in rice cultivation. [*The better the quality of soil, which can improve over time under SRI management methods, the higher yields will be possible with wider spacing, even up to 40 or 50 cm with the best soil.*]

We propose starting with 25x25 cm spacing (16 plants per m^2) up to 33x33 cm (9 plants per m^2). In these two cases, if we have an average of 100 seeds per panicle, and if transplantation has been done with the closer spacing (25 x 25), there are 25 panicles per stem, which makes 25 x 16 = 400 panicles, or 40,000 seeds per m_2. If 1,000 seeds typically weigh 25g, then 1 m^2 provides 25 x 40 = 1,000g. This would give a yield of 1 kg per m_2, which in turn makes 10 tons per hectare. For more widely spaced transplanting (33 x 33), 45 panicles per plant are required [*rather than 25*] to get the same number of panicles per 1 m^2 (45 x 9 = 405), which results in 40,000 grains. Yield is then the same as for the narrower transplantation described above. [*With good plant, soil and water management, the number of grains per panicle can average 200 or even more; I have held in my hands a SRI panicle with 930 grains in Sri Lanka.*]

8. Weeding

Whatever the crop, early weeding is always important for a good return. In rice paddies, where traditional methods are used, hand weeding is usually done one and a half months after transplanting. By this time, half of the expected harvest is replaced by weeds. The best thing to do is undertake the first weeding 8 to 10 days after transplantation. (With forced plants, grown in nursery, see footnote above in Section 3, this could be easily done after 6 or 7 days.) [*SRI experience has shown that the best results can be obtained by using the rotary push-weeder*.]

With a square or rectangular pattern of transplantation and rotary hoeing in two directions, weeds should be manageable without difficulty if the soil has been well prepared in the land preparation stage as proposed in Section 5. Most of the space between plants is cleaned by the "teeth" on the small rotating wheels of the such-weeder, and weeds germinating near plants will be covered by the churned-up mud, which will give the rice enough time to grow in advance of the weeds.

In addition, it should be strongly recommended to farmers that they clear *echinochloa* (known as *tsimparifary*) and other similar aquatic gramines by hand to ensure their removal. At the grass stage, these can be easily confused with rice. It is only at the grain-filling stage that they can be recognized easily as they are bigger than rice plants. They must be pulled out with their root, but this is difficult to do if stems are not all held together in the hand. If the stems get pulled up without the root, one has to pull it out by using the middle finger as a hook. If not, new weeds will regrow again in place of the old ones. Malagasy farmers find it hard to believe that these weeds' seeds can survive for many years without germinating and infested rice paddies need to be systematically purged of these weeds every year for 10 to 20 years before they will become free of this weed again.

9. Harvest

Most of the time, harvesting is done too late; people take more into consideration the fading color of the straw than the hardness of the seed. The later rice is harvested, the more time it will take to thresh the rice. To facilitate maturation, the rice field should be completely dried up at least fifteen days before the harvest. The plants that are going to be used to provide seeds for the next season [*because of their good quality*] should be marked beforehand, and their grains should be harvested, threshed, dried, and kept separately.

III. KATAYAMA'S TILLERING MODEL

The table presented in Didier Moreau's book is an incomplete genealogic table of rice growth. While there are preleaves, which could be indicated with "p," only regular leaves "P" are shown in the table. Other authors talk about preleaves for *gramineae* species [*grass family plants*] at the stage of seed germination; but in Moreau's table, P's represent only secondary and tertiary tillers. As we are not able to be sure about the difference between a misprint and what Moreau actually wrote, we prefer to ignore those preleaves, which are also taken as coleoptiles by other authors.

The genealogic table presented by Moreau is not operational for practitioners, so we would replace it with the following quantified growth table for rice growth, in which columns 0 to 9 are the same as Moreau's; we have added the rest.[1]

Table Showing Tillers in Order of Their Appearance for the First 12 Phyllochrons(1)

Sequence of phyllochrons(2)	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Main tiller	0	1	0	0	0	0	0	0	0	0	0	0	0	1
First row of tillers(3)	0	0	0	0	1	1	1	1	1	1	0	0	0	6
Second row(4)	0	0	0	0	0	0	1	2	3	4	5	6	5	26
Third row(5)	0	0	0	0	0	0	0	0	1	3	6	10	15	35
Fourth row(6)	0	0	0	0	0	0	0	0	0	0	1	4	10	15
Fifth row(7)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total number of tillers In each phyllochron(8)	0	1	0	0	1	1	2	3	5	8	12	20	31	84
Total number of tillers produced in 3 phyllochrons(9)			1 ($1 = 4^0$)			4 ($4 = 4^1$)			16 ($16 = 4^2$)			63 ($63 = 4^3-1$)		
Total number of tillers produced in 4 phyllochrons(10)			2				11					71		
Cumulative total of tillers for each phyllochron(11)	0	1	1	1	2	3	5	8	13	21	33	53	84	

[1]*The table shows only the first 12 phyllochrons of growth. Most rice plants never complete this many phyllochrons (periods) of growth before they start their reproductive phase, with the onset of panicle initiation. Under ideal conditions is if possible for more phyllochrons of growth to be achieved. Because rice plants seldom have such conditions, they usually do not complete more than 6 or 7 phyllochrons. In October 2009, Indonesian SRI farmers presented me with an SRI plant having 223 fertile tillers, which means that it had tillered into its 14th phyllochron.*

Notes for the table:

[(1)] The phyllochron is the *time interval*, or period of time, separating the onset of two successive leaves on the same tiller. It is a variable characteristic, which is especially related to temperature, expressed in degrees (the sum of the average daily temperatures for successive days). Phyllochron successions make up the rice's calendar of growth. Buds developing from the main tiller nodes begin growing 3 phyllochrons after the emergence of the leaves, whose bases are attached to these nodes (primary tillers). For the other categories of tillers, the interval is only two phyllochrons. These dates of onset are very important. A tiller which does not appear at the expected date will never develop. For the rice variety 1632, the phyllochron length is generally 5 days on the east coast, near sea level with higher temperatures; 6 days in Lac Alaotra (600 m); and 7 days on the high plateau (1,000-1,500 m). These durations are for the warm season. The amount of variation from these figures for the cold season on the east coast needs to be determined.

[(2)] Each column marks the transition from one phyllochron to another. Numbers in each column indicate the number of new tillers that emerge at the beginning of a phyllochron. It is not likely that their onset will correspond exactly to each change in phyllochron. A plant is not a machine. There is a certain dispersal of biological events that it would be interesting to evaluate. The 0 phyllochron at the beginning of the series (a non-phyllochron) refers to the time preceding the appearance of the first leaf (from the beginning of the germination). If the temperature is favorable, it appears that the duration of the 0 phyllochron will be 5 days or maybe even less.

[(3)] The primary first tiller appears three phyllochrons after the onset of the first leaf, whose lower part is attached to the inferior node of the main tiller which gave rise to this tiller. According to Moreau, Murayama has developed an idea of Ishizuka and Tamaka by suggesting that the set of a leaf and a node develops in three different stages: the lamina first, then the stalk and the whole internode, and finally tillers and roots. But one cannot say that those three stages correspond to three phyllochrons. In fact, from the secondary tillers, the interval between associated leaf and tiller will only be two phyllochrons. If 6 nodes develop from the lower part of the main tiller, there will be 6 tillers. This number seems to admit of some exceptions to this growth pattern, with longer (rare) or shorter intervals.

[(4)] This row forms the basis for all of the secondary tillers that appear in each successive phyllochron, starting from the sixth. One can easily trace the descendents of each primary tiller along six lines that are identical to the one of the primary tillers.

[(5)] The set of tillers in this third row can be traced along five lines, each of which gives details on the descendents of the five primary tillers. Each line would be similar to line 4 concerning the distance between phyllochrons. This category of tillers becomes the most numerous one by the twelfth phyllochron, and this would be true also if there were a 13th or 14th phyllochron.

[(6)] Tillers in this fourth row start only at the tenth phyllochron but increase rapidly, with 20 new tillers in the thirteenth phyllochron.

[(7)] Tillers in the fifth row appear only in the twelfth phyllochron [*if the plant's cycle of growth has gotten this far*]. Their number increases much more quickly than the former ones (1, 5, 15…). We end the table with 12 phyllochrons as plants with more than 84 panicles [*fertile tillers*] have not been reported in the literature [*but see footnote above*]. To exceed this, one would have to resort to successive divisions of the clumps. This technique can allow us to go further in terms of tillering, but this is rarely done in practice. If tillering reaches or surpasses 100, the thirteenth phyllochron will have been reached, and the total number of new tillers may increase by 50. Only the future can tell us if it is effective to seek such a large number of tillers, or if it is better to aim for less than biologically maximum levels. Note that we are not talking here about a resumption of tillering, which can happen when submersion has destroyed inflorescences after harvest, or about ratooning, which occurs when some varieties are harvested and resume growth and production without replanting. It is possible that studying this process may produce new knowledge on the tillering phenomenon that is not well known so far.[8]

(8) This row shows the total number of possible new tillers for each phyllochron. Either Katayama was wrong (but our experience since 1983 supports this table), or the greatest part of what was said in the past about rice tillering is outdated. Then, many results which are "scientifically proved" are brought into question and should be systematically reconsidered on rather new bases.

(9) Grouping the 12 phyllochrons this way 3 by 3 gives prominence to the exponential character of dynamic of tillering, in a way that it can be easily understood by all those who can count.

(10) Grouping all 12 phyllochrons into groups of 4 has special educational and psychological value for the spread of SRI. It can be presented like this: "During the first month of the tillering process, an SRI rice paddy seems empty. The tillers are preparing themselves for growth. During the second month, the SRI rice paddy is making further preparations, and the tillering is slowly expanding. During the third month, when the SRI rice paddy is filling itself with grain, the tillering "explodes."

(11) This row with all the totals enables us to draw the tillering curve for rice grown under optimal conditions. This will be the basis for the following section.

IV. MAIN CONSEQUENCES OF KATAYAMA'S MODEL

1. *Exponential growth:* This has already been confirmed by some farmers [*with plants exceeding 100 tillers*]. Clear evidence of this is given here, as elaborated on in the notes for the above table.

2. The rate of production of new tillers and the implied solidarity of all tillers. One can think of the rice plant as producing new tillers in a fairly constant proportion to the number of tillers that already exist. To see this, one should compare the number of tillers existing at the end of the previous phyllochron (row 11) with the number of new tillers emerging within the next phyllochron (row 8), for each phyllochron starting from the fifth. This gives the following set of fractions, which have an average ratio of approximately 1.66 (1⅔):

3/2 = 1.5
5/3 = 1.66
8/5 = 1.6
12/8 = 1.625
21/12 = 1.615
33/20 = 1.65
53/31 = 1.7

These figures indicate a fairly constant rate at which new tillers are produced. Each phyllochron produces approximately two-thirds as many tillers as already exist. These ratios start somewhat lower (1.5) and become higher (1.7 and 1.75), but represent quite a narrow range.

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[8] *Tefy Saina has found that plants grown with SRI methods when harvested and cut back near the ground will regrow and produce a second crop, as much as 75-100% of the original harvest. This is obtained with little investment of labor, so* ratooning *should be evaluated.*

It appears that all existing tillers contribute to the production of new ones from the beginning until the end of tillering. This outdates the theory of the primacy to the main stem. It is the first in terms of time, but it works equally together with the others until the end of the tillering process. This solidarity is more like that of a family than of a collectivity. It has nothing to do with the solidarity of seeds sown in packets as proposed by Lysenko. Its logic validates the practice of transplanting seedlings separately, whereas transplanting two (or more) plants together replaces solidarity with competition.[9]

Does this solidarity continue even after tillering? This is a question of tillering regression, which is related to the onset of flowering (panicle initiation). These questions are still very controversial. Instead of being a matter of regression, we understand it as "regulation." Rice maintains a balance between its nutrient availability and the number of panicles produced to be ripened, before producing more tillers. Food supplies, stored in tillers which do not produce panicles (infertile tillers), are used [*during maturation*] for grain filling.

Consider the following case: One rice paddy we observed had produced plants with 25 to 30 panicles per plant. The homogeneity of the panicles was excellent, and the number of spikelets (epillets) per panicle was more than one hundred. But they did not ripen. Even a month later, the stems, leaves and panicles remained as green as they had been until the end of the flowering season. When looking carefully, one could find only one formed and matured grain per panicle. When searching for the cause of this grain failure, we related it to the passage of a weather depression (low pressure front) at the beginning of the flowering season. A decrease in temperature, accompanied by rains, had inhibited the formation of pollen, and there was thus no pollination of the panicle, with just a few exceptions. As these rice plants did not have grains to fill, there was no more migration of the nutritive elements from the plants' vegetative to reproductive organs.

This suggests that there are still some unknown mechanisms -- organizers and regulators – that govern the functioning of plant organs and the sequence of development steps of plants. We know that there are precise relationships between tillering and the onset of flowering, for example. But we are so far dealing only with the external phenomena generated by these organizing "centers" or "mechanisms," which are not precisely known. People conducting research on plant physiology and agronomy still have many years of work ahead of them.

3. *A rationalized calculation of transplantation dates:* The analysis that we undertook based on Katayama's model of tillering allowed us to explain why it was necessary to transplant single plants to get increased tillering. It did not, however, justify the need to transplant very young plants. For that, it was necessary to transform the table in a way that clearly showed the dependence relationships between tillers from different categories.

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[9] This suggests that all the points of contact which link adjoining tillers are points of transition in two senses, first, for the elaborated sap and probably for the rough sap, and for all the tiller, root and leaf components working together. Is there any "regulator agent" at work, or is there a general balance in the repartition of tiller production that favors those parts having the highest needs? This problem reminds us of the one concerning the dominance and non-dominance of dicotyledon buds and could become the focus of research.

Actually, tillers belonging to the fourth row depend on those of the third row, and many tillers of the fourth row depend on the same tiller of the third row, but each is related to different nodes of this tiller. This is also the case concerning the relationship between tillers in the second row and those in the first row. We are not trying to make a comprehensive table on descendence as that would be too complicated. We only need to make one for the descendents of the six primary tillers:

Table of descent	(1st)	(2nd)	(3rd)	(4th)	(5th)	(6th)	Total
Tillers of the 1st row	1	1	1	1	1	1	6
2nd row	6	6	5	4	3	2	26
3rd row	15	10	6	3	1	0	35
4th row	10	4	1	0	0	0	15
5th row	1	0	0	0	0	0	1
Total	33	21	13	8	5	3	83
Descendents as % of total	39.7%	25.3%	15.6%	9.6%	6.0%	3.6%	100%

The main stem is not presented in this table because everything depends on it, i.e., no main stem, no rice plant. But once it has produced six primary tillers which depend on it, the original tiller can disappear, by accident or by another way; there will only be one less panicle among the 84 that can be produced within twelve phyllochrons of growth.

It is important to compare the respective importance of the six primary tillers and their descendents. Out of the 83 possible tillers from the first 12 phyllochrons, two-fifths (33) result from the first primary tiller and its descendents. One-quarter (21) of the tillers derive from the second primary tiller. (Note that each successive primary tiller accounts for about two-thirds as many total tillers as the preceding one, the same proportion as was reported in the previous section on rate of production of new tillers.)

One can say that the first primary tiller contributes as greatly as the second and third primary tillers together, and it contributes more than twice as many subsequent tillers as the last three primary tillers taken together. If the first primary tiller does not emerge at the beginning of the fourth phyllochron, total tillering cannot amount to more than 50. If the second primary tiller does not appear either, at the beginning of the fifth phyllochron, the total is reduced to 30. [*This analysis assumes that the plant is in a soil/water/nutrient environment favorable enough so it can go through all 12 phyllochrons and reach its maximum potential for the period of growth.*]

If the third primary tiller does not appear at the beginning of the sixth phyllochron, the maximum achieved will go down to 16. If transplantation is done a month after the seedling's emergence in the nursery, the plant is already well into its fourth phyllochron. If transplantation is done poorly, the plant will not be able to catch up before the end of the fifth phyllochron, and one cannot expect more than 16 tillers. If two or three plants were transplanted together in a clump (*touffe*), solidarity is replaced by competition, and the tillering of individual plants will be limited at five in maximum. This is what happens in traditional rice cultivation, which could be called anti-tillering rice cultivation.

Let us come back to our rice cultivation method, which consists of planting seedlings one by one with early transplantation. What are the obstacles that may prevent the first primary tiller from growing in rice cultivation? Various traumas (called "stress" in plant breeding terms). The rice plant has a certain ability to produce living material.

The relationship we have seen between the number of existing tillers and the number of new ones suggests that the rice plant's production effort is completely oriented to producing new tillers during tillering. If the rice plant is obliged to devote available energy and nutrients for cell growth to compensate for some trauma, there will be no new tiller. It seems obvious that this is what happens when one transplants plants from the nursery [*after the start of the fourth phyllochron*] when they are about to produce [*more than two*] tillers. After transplantation, there will be no more tillering during at least two weeks or sometimes even more. Afterwards, competition among plants close together will inhibit tillering.

Apart from physiologic or climatic stresses, and pest and disease attacks, there are only two traumas which may affect our System of Rice Intensification: they are transplanting and weeding. Where and when has rice cultivation research addressed this question? How many days are required for a rice plant to recover from the trauma of transplanting caused by the different ways in which this operation may be performed? Probably nowhere and never, because researchers would ask the question this way: When varying transplantation practices as a factor, what will be the subsequent variations in terms of yield?

Our present experience allows us to say that the younger the plant is, the shorter will be the period for catch-up after the trauma of transplanting. The older the plant is, the longer the catch-up will take. This applies to living beings in general. A 10-day or 12-day plant, if transplanted carefully, does not need a whole day before it resumes functioning. This does not mean that the plant was able to recover fully in one day. It has to reestablish its connection with the soil, replace the missing radicle left in the nursery, probably reorient its channels of circulation for this or that soil element, renew the stock of its nutrient reserves which have been used up during transplanting, and then resume the functioning of the whole root system.

As for weeding, trauma is certainly less important, because this does not affect the whole plant. Only superficial long roots stretching between the lines of plants may get damaged and will need to catch up. Two or three days are enough for this, and plants will need less time if the weeding is done earlier.

These considerations lead me to the following conclusions about variety 1632 (Chainan 8), when grown at an altitude of 1,500m, near Antsirabe. Phyllochron 0 lasts 5 days, from germination to the onset of the first leaf, and it is followed by three seven-day phyllochrons. This makes 26 days for the onset of the first tiller. (People often talk about this period as three weeks, but there is not enough precision about either the starting point or maybe the end.) One should allow three days for the plant to catch up from the trauma of weeding, seven for transplantation, and an extra day as our data are not certain, which adds up to 11 days. Transplantation, then, for this variety and at this altitude should take place at 15 days (26 days minus 11 days) after germination.

We can see that this kind of recommendation is still only approximate, especially as there are still many variables which are difficult to assess: the quality of germination (it is not the germinative power in the seed, but the actual conditions surrounding germination compared to the best possible ones that shape growth), nursery conditions, transplantation, weeding, rice field conditions, the length of the phyllochron, etc.

Note that the 15 days after germination (according to the above calculation) is 12 or 13 days after seeding in nursery. To go further, systematic trials should be done to see the reaction of the rice plant. We have asked all those who can do so to do systematic trials on small plots of land (to reduce heterogeneity of soil conditions) and to compare the results from transplanting after 8, 10, 12 and 15 days. These lengths of time become 6, 7, 8 and 10 days [*at low altitudes and higher temperatures*] on the coast during summer.

At present, it is impossible to recommend generally the most suitable date for transplanting, as there have been so few valid trials done so far. When research departments become interested in SRI and will conduct statistical trials in a rigorous and systematic way, we will progress much more quickly. This would build upon the fundamental research which was fortunately launched by Katayama.

V. QUESTIONS ASKED ABOUT S.R.I.

1. *Does the proposed statistical table correspond exactly to Katayama's tillering model?*
Only specialists can answer this question with certainty. We expect to have one in Madagascar some day, but it is only a wish.

2. *Do all rice varieties in the world correspond to this model?*
We think that the behavior reported here is characteristic of the *Oriza sativa* species. But as there are more than 20,000 varieties in the world, it is practically impossible to show this directly from varietal trials. One has to find the suitable gene for tillering and must be able to test its stability or movability. We understand that this will take lots of time. In Madagascar, we need to consider the Indica rice family in contrast to Japonica varieties. At the moment, we are comparing in Fianarantsoa, variety 1285 which is Indica, and variety 2067 which is Japonica. The results of 1285 have been the best, but the trials have been disturbed by drought first and then by flood.[10]

If differences between varieties occur, it is possible that these come from photoperiodism. A trial has been made with a local variety of rice. Sown in October, it started by following the classical model, and then when there were about 25 tillers, it stopped growing and resumed growth again for grain filling only during the equinox period. This would be a typical result of photoperiodism. Still, one should know if the cessation of tillering was due to photoperiodism (too short nights and too long days) or to something else. Besides, photoperiodism is a very complicated phenomenon. Depending on the varieties, both photoperiodical phases and aperiodical phases may occur. We can understand all the problems that can be posed when we study the growth and development of different varieties of rice.

[10] *Variety 2067 has also performed excellently in the Ambatovaky area east of Fianarantsoa, yielding 12.1 tons per hectare on 0.9 hectares in the 1997-98 season. One farmer in Soatanana the next season reached 21 tons per hectare on his 13 ares of land with variety 2067.*

3. *Is the tillering model invariable, or can it undergo accidental modifications under some actions of climatic or toxic factors?*
This question is certainly important, but for the moment, all that we can do with these phenomena is to observe and note them. Finding the answer will take a lot of time. The more SRI spreads, the more will rice planters become careful observers as they make progress in their fields.

4. *If the extraordinary yields obtained from SRI are generalized, won't this system exhaust soils rapidly, and isn't it necessary to use a considerable amount of fertilizer?*
This question is certainly important, but nobody yet knows the answer. Only the future can tell us. Note that fertilizer use was promoted during a government campaign, but the resulting yield increases were less than from SRI methods. One may think that when SRI proponents use fertilizers, there will be even more benefits from this system than now. But nobody knows for sure what will be the benefit if fertilizers are used with SRI in a reasonable way.

In Japan, some of the best farmers in the country (there is an annual contest) use only manure on their fields. Near Sahambavy, in Fianarantsoa region, a drained swamp has yielded 8 to 9 tons of rice per hectare [without any use of fertilizers] for more than ten years without any decreasing trend. It should not be forgotten that rice is one the less demanding crops in terms of nutrients. (Cassava requires less work to grow than does rice, but without manure, cassava destroys the soil.)

Rice paddies, moreover, get nutrient benefits from the water runoff from hills. While this is a catastrophe for the national heritage, it nevertheless maintains fertility in the valleys. What is important now is to feed Malagasy people. If SRI can do this, after some years we can look forward to some break with traditional systems and thinking, with some changes resulting in mentality that will facilitate the development of the rural environment in general. We can also reply that very high yields show that the rice plant is more effectively using its natural possibilities and operating then with maximum efficiency to meet a minimum of needs.

VI. SEVERAL QUESTIONS

1. *If SRI is so beneficial, why has it appeared all of the sudden, only now, when there have been so many researchers who have worked on rice for so many years?*
The answer seems to be, as Christopher Columbus said when asked why the New World had not been discovered before: "It was necessary to have thought about it." The obstacles were people's attachment to routine, their conformism, habits, etc. There are many examples in the history of science of important things having been overlooked, for instance, Mendel's work that led to the laws on heredity.

As for rice cultivation in Madagascar, there is a document written by J. Velly and J. Celton entitled: "Techniques culturales du riz repiqué à Madagascar," which was published by IRAT (#298) in October 1971. It focused on the "age of plants" on pages 15 to 30 and reports on the following experiments:

- In Ambohibary-Sambaina (at an altitude of 1,640m), there were four management practices evaluated: transplanting at 35, 50, 65, and 85 days. Transplanting was done with spacing of

20 x 20 cm, with 4 plants per clump (100 plants for 1 m2). Three years later, it was concluded that: "the oldest plants gave the best yields every time... The average increase in yields for variety 1285, which underwent 35 to 80 day transplantation, was 1,123 kg/ha."

- In Mahitsy, three varieties with "seedlings of three different ages were studied: 30, 40 and 60 days at transplantation. For the Japonica rice, one has to plant young plants (30 days). As for local varieties of Indica rice, the age of the plants seems to make no difference."

- In Belanitra on the Antananarivo plains, comparisons were made for variety 1285 with seedlings of three different ages: 104, 54 and 44 days, and for variety 1572, at four ages: 104, 73, 54 and 44 days. In Laniera, also on the Antananarivo plains, "similar experiments with 107, 77 and 47-day plants" were made for the local variety *Vary aloha.* In both Belanitra and Laniera, during the second season, rice plants of variety 28-1 and 25-1 were transplanted at 75, 60, 45 and 30 days. "For Indica rice, it is often profitable to use older plants... [while] for Japonica varieties, one should use younger plants, ones with less than 45 days in the nursery."

- In Vohipeno and Manakara on the east coast, after some experiments hindered by a cyclone, it was concluded that: "We will make an effort to transplant young Japonica rice during the hot season (at about 25 days); as for Indica, more days in the nursery are required if possible. During the dry season, Japonica can be left in the nursery for a longer time, for 30 to 35 days approximately. It is good to transplant them at that time."

Starting from page 38, this IRAT document deals with "the influence of transplantation density on yield." The general conclusion was: "We were surprised by the fact that fertilization and variety were secondary [*factors affecting yield*]. We can recommend 200 plants per 1 m^2 at an altitude of more than 1,200m, 100 plants per 1 m^2 for an altitude ranging from 1,200 to 750m, and 785 plants per 1 m^2 for less than 750m."

In these experiments, the lowest densities evaluated were 25 plants per 1 m^2 on the coast and sometimes 22 per 1 m^2 in the highland, but transplanted two to a hill with a spacing of 30 cm, and very rarely, 25 cm spacing and one plant each: "The unusual choice of one plant per clump is explained by the wish to favor the suggested tillering faculties..."

Given IRAT's research orientation for rice cultivation, it is not evident how its researchers could ever have thought of transplanting 15-day plants one by one. We should not forget that apart from this, the depth of transplantation was not controlled. FoFiFa has taken over from IRAT in this field of research. The SRI way of thinking has not been pursued before.

2. *Is not SRI just a kind of "dapog" nursery technique?*
The "dapog" system practiced in the northeast part of Luzon Island in Philippines was experimented with by J. P. Dobelmann in Marovoay in 1964. With this method, one transplants seedlings 8 to 10 days old. It is now being used by the *Centre Semencier de Lac Alaotra*.
One or two materials that can store moisture (powdered manure, compost, wood peat, etc.) are set on banana leaves or on horizontal plastic sheets, and the materials are then covered with

pregerminated seeds (20,000 or more per 1 m^2). The layer will be kept always moist, and after 8 to 10 days, they will be laid in groups of 3 or 4 in the muddied rice paddy.

During the experiment in Marovoay, 10-day plants grown in an accelerated dapog nursery with spacing of 30 x 20 cm for each group of 3 or 4 plants, which equals 45 or more plants per 1 m^2, were compared to 36-day plants, sown at 27 days or earlier and with 30 x 20 cm spacing (16 per 1 m^2). Another dapog trial was made with transplantation of 20-day plants, which were not grown according to the SRI method. The variety used was Ali-Combo rice. The dapog plants reached a yield of about 5.9 t/ha and that with normal plants was 5.1 t/ha. The average tillering of the latter was more than 20. Those results were interesting, but this research was not carried out either by planting 10-day normal plants or by planting dapog plants one by one. (Their clumps gave only 24.5 panicles, which amount to 6 to 8 per plant). Dobelmann was certainly in a better position to arrive at SRI techniques. But probably what prevented him from achieving this was water control.

3. *Instead of transplanting such young plants, wouldn't it be easier to plant seeds directly in rice paddies?*
This is the most common question and the answer is simple. Agronomically speaking, there is no difficulty in putting pregerminated seeds in the rice paddy at the same intervals as transplanted seedlings. It has never been proved that transplantation itself increases yields; indeed, the opposite is logical. The problem is technical and practical. If the germination rate of the seeds used is 98 to 99%, there is no problem. If it is between 97 and 92%, it is better to sort out and discard nongerminated seeds. If it is only 91% or less, seeds must be sorted. If 4 kg of pregerminated seed are sown per hectare, 133,000 to 160,000 seeds will need to be carefully sorted.

This can be done, but it requires very close attention, and not anybody can sustain this effort. It is much more difficult to hold a pack of seeds in one's hand and prevent them from falling while bending over than holding a pack of plants which are more or less stuck together by the soil hanging on their roots. It is easier to notice a plant falling on the ground than a seed. If the farmer is distracted while working, he can easily locate the last seedling transplanted, which is not the case for seeds, where the farmer can easily make errors, sowing too thickly or too thinly. Also, cleaning up the rice paddy soil before planting must have been done with extreme care, because otherwise by the time new rice plants are sprouted, weeds would already be growing. It is apparently not possible to use a forcing technique as described in footnote 3. Further, if anyone planting rice would like to apply SRI principles in direct sowing, they can perfectly well do it, but in general, we think it not wise to recommend this practice nowadays.

4. *Can SRI be used in rain-fed rice cultivation in the uplands?*
In the midwest of Madagascar, it is common to sow 40 kg of seed per hectare for growing rainfed rice, which equals 48 to 50 seeds per 1 m^2. When sowing with 40 x 15 cm spacing, 16 to 17 seeds per 1 m^2 are required. To make sure that one has successful sowing, one has to pregerminate seed and sort it, because of the problem described above under 3. Afterwards, one has to make sure that seeds are put one by one in the right place. This is very hard work if done by hand. There is no monograin sower available, though one could be manufactured. One would have to set the manufacturing specifications and find purchasers. This is a very difficult technological problem given present circumstances.

The main problem comes from lack of reliable meteorological forecasts. Rice paddy soil keeps humidity for a longer time than hill soils. Drought is a more acute risk in the uplands. A rice farmer can use SRI principles in the uplands, but he has to do this on his own responsibility. The situation is less acute on the east coast, but rainfed rice is much less common there. There one finds mostly upland rice grown on cleared and burned forest land (*tavy*). It is far from probable that this technique can get adopted and expanded there, unless it is already used in rice paddies. The spread of SRI is closely related to water control in this region, which has problems of drainage in low-laying, often swampy areas. The advantages of drainage have been known for a long time, but its application has not been well-recognized so far.[11]

5. *Isn't SRI much more vulnerable to pest or disease attacks?*
We have not seen this so far. The reason appears to be: the more vigorous a plant is, the more it can resist pests and diseases. But it is obvious that it would be unwise to cultivate varieties which can be easily afflicted by any disease that is common in a given region. SRI is practiced with the minimum quantity of water. It seems that many pests like rice lice, piriculariose, etc. prefer to feed on rice that is flooded. Also, certain diseases flourish more in a humid environment. So it is possible that SRI methods are somewhat protective against at least some pests and diseases. Only the future can give the right and full answer.

6. *What are the different possible levels of SRI yield?*
I deliberately chose to address this question at the end because it is the most difficult to answer in a precise way. I do not know what is the world record in rice yields for a single crop. The world record for corn yield is now 24 tons. This was possible thanks to the creation of hybrid varieties whose heterosis effect is good for heterogamous plants. Rice is an autogamous cereal which cannot benefit from heterosis (according to what we have heard so far).[12] But it is more robust and less demanding than corn; it has particular properties that it does not share with corn.

One such characteristic is its exceptional tillering ability. This is why, in my opinion, if one can thoroughly exploit tillering, it may be possible to reach some production level around 30 tons, which equals 3 kg/m^2. For that, 100,000 seeds are required, weighing 30 grams per 1,000 seeds. The 100,000 seeds can be obtained from 10 plants with 100 panicles each with an average of 100 seeds per panicle, or from 12 plants each with 80 panicles having 105 seeds. Researchers can choose which combination seems easier to achieve.

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[11] *A Malagasy extension worker in the Zahamena area has experimented with an adaptation of SRI principles to upland rice production. Clearing the land without burning, applying compost, spacing rice plants about 25 x 25 cm, and doing manual weeding, the yield obtained was double that of usual upland (tavy) cultivation, using only one-eighth as much seed. This makes the efficiency of seed multiplication with adapted SRI methods was 16 times greater. With upland production, where land area is not a constraint, this is a relevant measure of productivity (personal communication, Joseph Schaeffer, U.S. Peace Corps, January 1998).*

[12] *Prof. L. P. Yuan, director of the Chinese National Hybrid Rice Research and Development Center, has solved the problem of hybridization of rice and holds the world record for highest yield, over 17 tons per hectare. He has begun experimenting with SRI methods to further increase the yields achieved with hybrid varieties, understanding and accepting the principles of optimum rice management developed by Father de Laulanié.*

The essential conditions, difficult to carry out, are: everything must be done perfectly from the beginning until the end, including the farmer's practices, the climate, and the soil environment. All this is what makes world records. I hope that a Malagasy rice planter will be the first to reach this record. For the moment, the yield increase possible for a rice cultivator who switches from traditional methods to SRI ranges between 3 and 4 tons, but it can reach 5 or 6 tons and even more. The lower the starting level is, the easier it is to increase the level of production.

It is worth pointing out that the first 15-day transplantation (17 days after germination) was done in November 1983. Much increased tillering started to appear only in 1986 and 1987. Katayama's model became known in Madagascar only in early 1988, and it was translated into the table presented above in 1990. SRI was actually launched in 1992. Is it too late if one waits for the 1994-95 season before trying to draw up a conclusive evaluation of SRI potential?

VII. CONCLUSION

There is an agronomic philosophy which supports SRI: Agronomy is the science of life, and life is autonomous. In rice cultivation, rice is the true master of the game, and the rice planter is its knight, or in other words, its disciple. The environment is of course important, but soil, fertilization, nutrition, treatments, all are secondary. What is essential is the rice itself: it is the supreme judge and master. The most important thing in agronomy is plant physiology. Rice itself is the only source for learning about actual and efficient rice cultivation. The first lesson learned from rice is: It has to tiller. A rice plant which grows by chance outside of rice paddies, as shown by J. P. Dobelmann, confirms this statement. Powerful tillering can be at least 10 times greater than for wheat. This is why one has to transplant rice only one plant at a time.

The plants have to be young to achieve their potential. Twenty years ago, we began transplanting rice seedlings when they were only 25 days old [at that time considered "young"]. After a fortuitous accident led to our discovering the beneficial results of transplanting at 15 days, others should have been willing to take advantage of this discovery and welcome the insights into rice growth gained from Katayama's model, which gives us scientific tillering theory. To close this presentation, remember: Observe and listen to your rice. It is the only one who can really tell you what should be done.

APPENDIX: SOCIO-ECONOMIC ASPECTS OF S.R.I.

1. *There are four types of inputs for rice crops: seeds, irrigation water, fertilizer, and agrochemicals.*

Economizing on seeds and nursery work is considerable with SRI: a farmer needs only 5 kg of seeds per hectare compared with 40 or 50 kg (and even more most of the time) in traditional rice cultivation. As in the case of water, this economy is not immediately implemented, even during experiments undertaken on small plots, because the farmer is always suspicious. However, the saving can be considerable right from the beginning and is entirely achieved by the fourth year.

In principle, we recommend that those who are ready to try the system carry out their production activities as they have done before as regards seed varieties and manure. We recommend to them not to use fertilizer so that they can see themselves the average yield increases that SRI methods alone enable them to get. In 98% of the cases in Madagascar, either rice farmers or their advisers do not know how to use inorganic nutrients properly anyway. Later on, if farmers are willing to use fertilizers, they can decide this by themselves. Let us hope that this will be done properly, suitable for whatever varieties that they would use.

Concerning the application of chemicals, the only suitable solution for the struggle against rice lice is systemic nursery treatment. If a limited quantity of water and humid mud are used, the damage is very much restricted. In areas where *fusariose* is abundant, these plants have to be pulled out during the third weeding or a bit later.

It is worth pointing out that the saving of irrigation water -- which is recommended with SRI for agronomic reasons, to oxygenate the soil and prevent the asphyxia of roots and aerobic micro-organisms -- will be good for rice cultivation in general, both to permit transplanting when the rain is late and for drought during the vegetative growth period. If only a small quantity of water need be applied in the rice paddy, the remaining amount of water can be used to irrigate much larger areas than with the present system of water application.

2. *SRI and labor needs*
These needs cover the preparation of the rice paddy and the nursery, transplanting, weeding, irrigation, and harvesting.

a. *Preparation of the rice field*: This should be the same, whatever system of cultivation is used. Even if SRI requires a more careful preparation, it presents some unquestionable advantages. If there is no off-season crop planted in the paddy, initial land preparation should be done after harvest, as soon as the soil structure allows plowing under the most favorable conditions, and plowing should be done immediately. If an off-season crop has been grown, the farmer will have enough time for plowing when that crop is harvested. If some weeds appear after the winter rain, harrowing should be done quickly to remove them. There may be some equipment needs: rakes for manual work, harrows for oxen. Puddling the fields with a minimum of water will be much easier to do than in 30 or 40 cm of liquid mud, where there are still some remaining lumps, which were not churned up by the implements.

b. *Nursery*: This will require less time as the size is reduced to about a quarter compared to what has been done before: 2/3 of an are (less than .01 hectare) instead of 3 ares (.03 hectare) for each hectare of rice field to be planted. Even if an SRI nursery is managed with more care, it will require less total work.

c. *Transplantation*: It is true that this requires more attention, but still it involves less work. Instead of 50 to 200 and even 400 plants or more put in per square meter, only 10 to 20 seedlings need to be transplanted. At first, transplanters who are not yet used to the method will work with some hesitation and spend more time, which makes one believe initially that more laborers are needed. But once they get acquainted with the method of handling small seedlings, it saves time according to our calculations.

Transplanters who have switched back from SRI to the traditional method of transplanting say that the latter is more tiring, given the depth of the mud they work in and the weight and number of plants. SRI is complicated only because the square or rectangular transplanting requires use of two-directional lines. Some specific materials are needed for this (already available in some countries): non-elastic small ropes with knots or permanent marks every 25 cm or 33 cm; these allow three different combinations for transplanting 16, 12 or 9 plants per 1 m^2. A small rope tied in a circle with three knots at 3, 4 and 5 interval spacing can be put across the main ropes perpendicularly to mark where seedlings should be plants. It should be easy to make these planting materials at a modest price. [*The use of wooden 'rakes' (rayonneur) to mark lines on the field is now reducing labor time required to transplant rice with precise rectangular spacing.*]

d. *Weeding*: SRI users have complained about their traditional hand weeders (*sarcleuses*) that these are too narrow for the new interline spacings. One can tell them that this is an advantage because it allows them to work the interlines quickly (7 to 8 days after transplanting) without harming the frail and hard-to-see plants. Weeders can be used in pairs (in tandem) as well, so two rows can be weeded at the same time. The farmer's balance will be better as well this way, and the work will be done more quickly (in half the time). Investment will be higher this way but it is very modest compared to the tripled or doubled yields. [*The price of rotary hand weeders around Lac Alaotra is about 90,000-100,000 (US $ 12-15), but the price has been less than half this much in Fianarantsoa when buying directly from producers.*]

We should also point out that nowadays, weeders are most of the time narrower than the first models imported 25 years ago. If users require it, weeders can be widened. For hand- weeding, 15 or 20 cm-wide rakes can be made and rented at a very low price to rice farmers who cannot afford to buy weeders until harvest time. SRI weeding presents no inherent constraints in itself, but early weeding does so long as rice farmers do not understand the importance of using suitable implements and have no access to them.

e. *Irrigation*: There is no hard work required for this, but it requires monitoring. A good rice farmer will spend time (day and night) controlling water in and out of his rice paddy. Within a population of 100 rice planters, only 10 or at most 20 will do this, however. This is one of the psychological revolutions required for the success of SRI, which should lead to the rehabilitation of most rice valleys. [*Water management with SRI often depends more critically on drainage of rice fields than on water application.*]

f. *Harvest*: Have you ever heard a farmer complaining about the fact that his harvest is too good and that this makes too much work for him? But most of the time, harvest is done too late and this leads to a loss of grains.

3. *SRI and its economic impact*

It is too soon to make an evaluation of this impact, which is always difficult to do and requires extreme caution. We can try to make a first attempt in autumn 1992. For the moment, with the available information, we estimate the average coefficient of multiplication to be about 3. It is not enough to evaluate what are said to be SRI yields; one needs to make sure that it is really from SRI and not just any method.

The farmer is the only person who can assure one whether he has used the SRI methodology or not. Sometimes a farmer supervised by the government program just says that he used an improved practice when its agents are there, but in fact he is doing something else at night; e.g., he puts additional seeds in the nurseries that he prepared with the monitor during the day.

The main challenge with SRI management is water control and weeding. Only a few SRI users are willing to destroy a nursery full of plants when these have become too old before the rice paddy is ready, in order to make another one to ensure that the seedlings transplanted are 15 days or less. In fact, Malagasy rice farmers' behavior provides us with the only criteria to assess SRI.

4. *SRI and the Malagasy peasant community*

a. There is an invariable factor: the first farmers who have adopted new techniques did this secretly, as much as possible and especially without any advertisement. This has been the case with SRI too. However, some have asked for technical support and are trying it on a rice paddy which is not far from the main road so as to discredit the one who promotes the technique in case it fails.

b. What we noticed secondly is: village community members think that they have the right to laugh at innovators among them. It happened to the first Malagasy farmers who planted coffee, and who transplanted rice in rows, and who now use SRI.

c. There is another element whose impact is difficult to assess. A crop that is too successful is dangerous; villagers are afraid of the ancestors' and spirits' jealousy. When yield is good, it has been noticed that portions of the rice field are not harvested in some regions, even if they were already ripe. It was said that this is given as a sacrifice to the ancestors and spirits who might take revenge.

This way of thinking Malagasy farmers have in common with other farmers in the world. This can explain the fact that some farmers who have already used SRI once or twice have given it up and switched back to the traditional method. It is not the shortcomings of SRI itself that caused the reversion, but the good harvest that SRI provided. The farmers' apprehension made them switch back to the traditional method, which is safer for them as this precludes any revenge from the ancestors or bad spirits.

d. The incidents mentioned above can explain some of the disappointing use of SRI. These did not come from the system itself but from a misinterpretation of its results. Still, SRI seems to arouse a certain interest wherever it has been tried out, and it has gained an extraordinary attachment from its proponents.

Nowadays, there are at least three or four people on the high plateau who devote half or more of their time to promoting SRI. The spreading of this method is done spontaneously for the most part without any charge. To avoid any misinterpretation and wrong recommendations from any ill-informed persons, simple and easy-to-understand dialogues on SRI and its different steps should take place. It will also be good to have many colored pictures that will briefly present the main steps of this new rice cultivation method so that farmers can use it correctly.

We think that a change in farmers' mentality will occur after some years, and that they will understand the whole mechanism of SRI and will be able to use it correctly, understanding the plant life cycle and all that is happening underground.