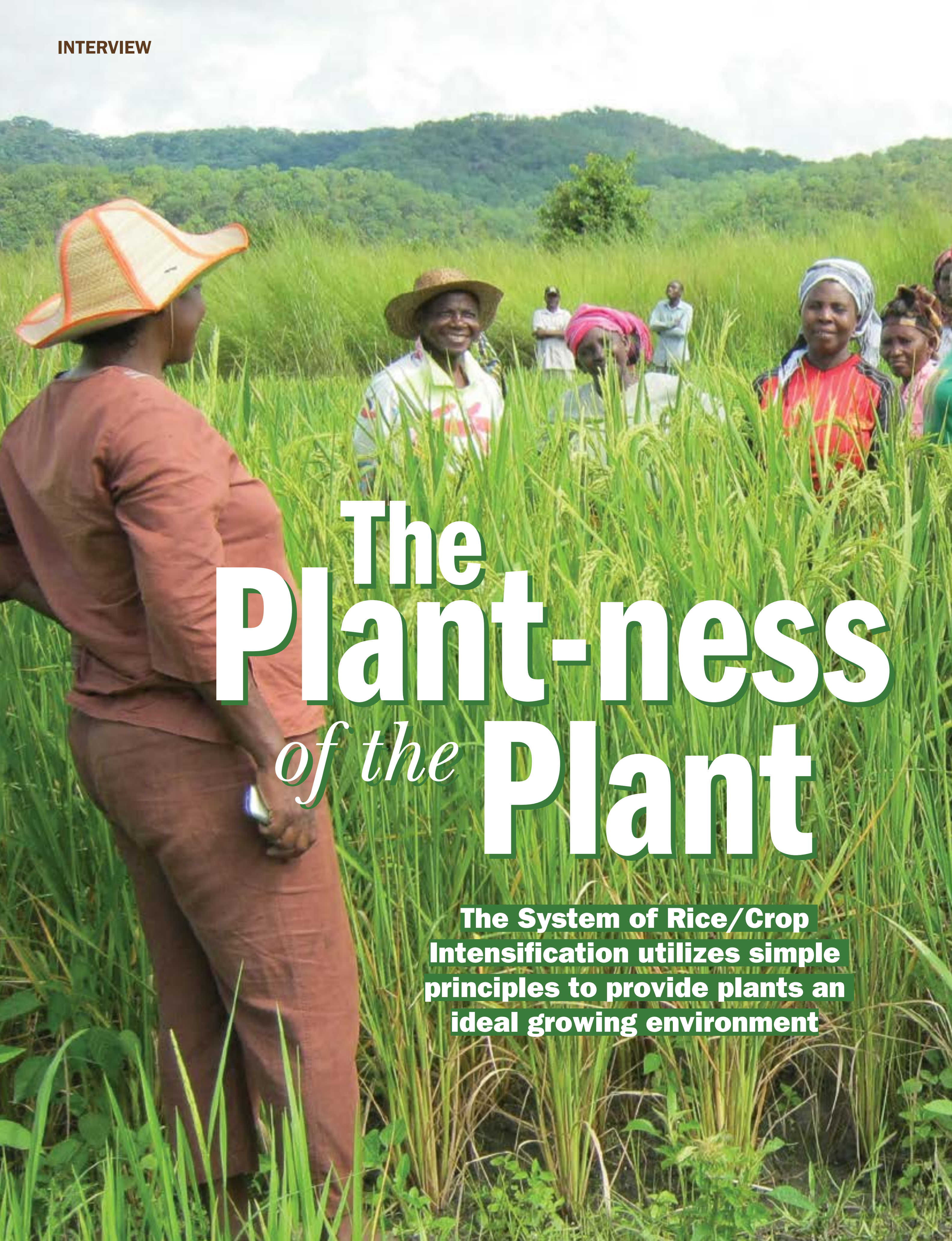

# The Plant-ness *of the* Plant

**The System of Rice/Crop Intensification utilizes simple principles to provide plants an ideal growing environment**

The System of Rice Intensification is an agronomic approach that was serendipitously discovered in Madagascar by a French priest and popularized by a university in New York, utilizing a discovery — made by Japanese scientists in the 1930s but, due to WWII, never translated into English — that follows the pattern in nature we now call the Fibonacci sequence.

This is the unlikely and fascinating story of SRI — a set of principles that has enable increased profitability and improved yields for growers of rice and other crops across the world since the 1980s. It is only now beginning to be picked up among growers in industrialized nations like the United States.

Dr. Erika Styger is one of the researchers at Cornell who has been working to promote SRI for the past several decades. She is beginning to work with growers here in the states as well to implement these principles. SRI/SCI is applicable on operations of all scales and offers a framework to allow plants to best express their natural traits.

**Acres U.S.A.** How does a professor of tropical agronomy end up in New York State at Cornell?

**Erika Styger.** Good question! Cornell has a big agriculture school, with many tropical specialists. There's not much local fieldwork, but I have actually been working with some farmers in the Hudson Valley on growing SRI rice.

**Acres U.S.A.** Do you get to travel regularly to tropical places, though?

**Styger.** Oh, yes, that is where my work is. With COVID it was very difficult, but travels are picking up again.

**Acres U.S.A.** Where do you have research projects right now?

**Styger.** I work mostly in West Africa, and I have a research project in Suriname on rice diversity. I also have started to work in the south of the U.S.

**Acres U.S.A.** Great. So, for those

who've never heard of it, what is SRI, and why is it important?

**Styger.** SRI — the System of Rice Intensification — is an agronomic approach. It's a management approach to rice production, although the same approach can apply to many other crops. It's about managing plants, soil, nutrients and water: how the farmer manages the crop.

The goal of the method is for the plant to express its full genetic potential. I think that SRI shows us — it showed me, when I first learned about it — that most of the time, when implementing common agricultural practices, we don't actually listen to the plant or give it what it wants and needs.

**Acres U.S.A.** Why did SRI start with rice?

**Styger.** Rice is a very interesting crop because it has a high plasticity. It can be planted in highly unfavorable conditions — you can produce a seedling, cut its roots, cut its leaves, and stick it in the mud. Any other crop might die, but rice will recover and regrow. Sometimes growers don't pay much attention to it because rice is so robust.

But when you start using the SRI method, you realize that these rice plants have something to offer that we never realized. I've traveled to 30 countries and have met with SRI farmers in Asia, Africa and Latin America, and that's what I hear. When farmers first see an SRI plant, they're like, "Wow, I've been growing rice my whole life, but I have never seen a plant grow like that."

SRI is an agro-ecological approach because it has a lot to do with how we optimize the ecological processes, so that the plant can express its potential. But SRI is not a given, boxed-in method. It's more like a process of approaching agronomy and agriculture a little differently.

**Acres U.S.A.** In the regenerative livestock world, we talk about the "pigness of the pig" — giving the pig or the chicken or the cow the environment they want to be in. So, SRI is kind of similar, but with plants.

**Styger.** Yes, exactly.

**Acres U.S.A.** Can you talk about the history of SRI — how it was developed?

**Styger.** The SRI method was developed in Madagascar in the 1980s by a French Jesuit priest named Father Henri de Laulanié. He was working with farmers, and his goal was to help people to have a better life through improved agriculture. Together, they were experimenting with rice planting. At one point, the rainy season started early and the plants in the nursery were still too young and too small to transplant, plus they didn't have enough seedlings. They had to decide whether to plant or to wait — because if you wait, yields will most likely decline.

So, they planted, and because they had fewer seedlings, they gave each plant more space than was their usual practice. To everyone's surprise, that year the yield was higher than it had ever been. So, they continued experimenting and synthesizing different practices — although SRI is more than just the practices.

The usual practice planting rice, in many countries, is to produce seedlings in nurseries for 30-60 days. Seedlings may get even older before transplanting, if the rainy season starts late or when farmers' soil preparation is delayed. During transplanting, farmers usually take several seedlings — three to five, and I've even seen 10 to 15 — clump them together, and plant them into the mud or in standing water. Because the plants are already old and weak, growers space them close together: around 15 centimeters apart. After planting, the field is flooded from the beginning to the end of the growing season, then often drained two weeks before harvest. Growers may use a variety of fertilizers, especially urea.

With SRI, though, seedlings are transplanted much earlier. They are at the two-leaf stage: eight to 12 days old, instead of 30 to 60. Single seedlings are planted — not clumps of seedlings — and there's a wide spacing — 25 by 25 centimeters or more. That reduces seed use by 90 percent. Then, in the vegetative phase, irrigation is only done intermittently. Growers irrigate a bit, let the paddy dry, and then come back and irrigate a little more.

**Acres U.S.A.** And compost is typically used as fertilizer, correct?

**Styger.** Yes. Compost and organic matter are added ahead of the growing season. SRI doesn't have to be organic, but it emphasizes building up soils, which will allow growers to reduce their chemical inputs. I've seen farmers who no longer need to apply any fertilizers, but in many instances, farmers may still add a little urea later in the growing process. Father Laulanié didn't say much about organic fertilization because growers



ALL PHOTOS COURTESY OF DR. ERIKA STYGER

in Madagascar were already doing that. He did recommend to continue using organic manure, so that there wouldn't be any need to move toward chemical fertilizers.

Cornell University had a project in Madagascar in the mid-1990s. The project team worked to prevent deforestation by introducing improved agricultural practices as an alternative to the traditional slash-and-burn farming. They heard about SRI, and although surprised and a bit skeptical about claims that it increases yields by 50 or 100 percent, the Cornell team, led by Dr. Norman Uphoff, began testing the SRI method. After three consecutive years of confirmed improved rice productivity, they decided to make the method known beyond Madagascar. Dr. Uphoff, who had previously worked on rice production, had a large international network and traveled a lot, so he began to give talks about the method. People started to test SRI in different countries. I think the first reports came out in the year 2000. Today SRI has been validated and adopted, at different levels, in more than 60 countries.

**Acres U.S.A.** We've touched on some of the key principles — transplanting an eight- to 15-day-old seedling at wider spacings, less irrigation than normal, the addition of organic matter. Can you talk about cultivation as well — aeration with a tool as opposed to simple hand weeding? That's a key aspect, too, isn't it?

**Styger.** It is. We are making a distinction between principles of SRI and the associated practices. It's important to anchor the method in principles, because when SRI started to spread around the world, everybody began doing a slightly different version of it. People would adapt SRI to their own environments, whether a desert or a rainforest, the uplands or the lowlands. Some would irrigate and some could not, and some would use 12-day-old seedlings and others 15. The variety of practices started a great debate among researchers (not among farmers), which unfortunately cast doubt upon the method and for a time distracted from the task of developing innovations that work for farmers. It is therefore important to step back, look at the bigger picture, and think about the principles that guide the practices.

So, we came up with four SRI principles that are practical to apply. Principle one is to encourage early and healthy plant establishment. The second is to minimize competition among plants. The third is to build up soils so that they become richer in organic matter and beneficial soil biota. And one aspect of beneficial soil biota is that it needs aerated soil, which gets back to your question about cultivation. We can call it regenerating soils, because we know how essential it is to build back the soils that we have been degrading for so long. Finally, the fourth principle is to manage water in a way that reduces flooding and does not induce water stress.

You can apply these four principles in any environment and adapt the practices to your farming conditions. Take, for example, early healthy plant establishment — one farmer would say, "I'm going to direct-seed my rice, and I inoculate it with beneficial microorganisms so that it gets a healthy start." Another farmer uses seedlings. Careful seed selection supports this principle. So, there are many different practices that can go with it. If you follow the principle of enriching your soil — we're talking about 60 countries — most everyone will take a different approach. Some farmers have cattle manure, some do compost, some plant green manure. The practices can vary, and if they follow the four guiding principles, the plants can express themselves much better, become healthier and more productive, and therefore follow the SRI method.

**Acres U.S.A.** Can we go back to the second principle? How do you distinguish between trying to reduce competition with all that we know from ecology about the symbiotic benefits of growing different species together?

**Styger.** The SRI principle refers to minimizing competition among plants. The conventional paradigm is to use more seed to produce more crop; with SRI, we use fewer seeds to produce more crop.

This goes back to letting the plant express itself — to give it the room it needs to fully grow. SRI plants change in their appearance, they develop thicker tillers, their leaves get wider and thicker and the panicles become longer — these plants are completely different beasts!

**Acres U.S.A.** And they're tillering more, correct? You're getting higher yields by planting fewer seeds because each plant is tillering more; can you talk about how that works? And what's a phyllochron?

**Styger.** That is correct, when planted young, in a rich and aerated soil and given enough space, rice plants produce many more tillers. Conventionally grown rice plants grow from five to a maximum of 20 tillers, while with SRI, some varieties can get to 60 or 80 tillers, and sometimes even more.

A phyllochron is basically a growth period occurring every four to eight days, during which the plant produces a shoot and a root. Each shoot produces another shoot two phyllochrons later; therefore this becomes exponential. Young transplants will go through more of these growing periods than will older transplants. Wide spacing allows the tillers to emerge and thrive.

**Acres U.S.A.** It's fascinating that there's this built-in mechanism within the plant to keep tillering — it's like each step begets more success. And it's incredible that it follows a Fibonacci sequence.

**Styger.** Some breeders don't want too many tillers — they breed for fewer but more productive tillers. But then you need to buy more seed — an added expense.

The other aspect is that SRI plants have much deeper roots. As the tillers develop, the roots develop. The roots support the tillering and can extract more nutrients and support better grain filling, resulting in bigger grains and fewer empty ones. When rice paddies are flooded and when you plant older seedlings, the roots cannot grow as well and remain superficial. The roots still need to breathe, so when they're submerged in water, the plant has to pump oxygen into the roots, which uses a lot of energy. These submerged roots also die back much more quickly, which results in a small, inefficient root system. Then the grain-filling period is shortened, which produces smaller and fewer grains. When there are high winds, these plants will fall over much more quickly; when there's an insect attack, the weaker plants will succumb to it faster. And when the plants are spaced very closely, disease can spread much faster, especially under the high humidity in the tropics, and when fields are flooded.

**Acres U.S.A.** What is the bottom line in terms of yield improvement with SRI?

**Styger.** In many traditional smallholder rice systems of the tropics, rice yields average from two to four tons per hectare. With SRI, rice yields can go up to five to seven tons — a 50 percent increase or more. In higher-yielding systems, the increases are relatively smaller — 20-30 percent — and yields might improve from seven to nine tons per hectare.

**Acres U.S.A.** Can you talk about how rice is conventionally grown on a large scale here in the states, or in other countries, and what kind of SRI principles could be adapted by a large-scale grower here?

**Styger.** Sure. I primarily work with smallholder farmers because 80 percent of the world's rice farmers are smallholders. But rice in the U.S. is usually direct-seeded, either with a drill or by a plane. No one is transplanting single seedlings.

All principles should be used for a productive SRI system. One farmer who implements SRI at a large scale is Adam Chappell in Arkansas. He uses a precision seeder, planting one seed with wide spacing (SRI Principle 2). He adds molasses to the seed to feed the soil microbes and to speed up germination and early growth (SRI Principle 1). For SRI Principle 3, he keeps his soils always covered by using cover crops in the winter, only tilling minimally during the growing season. He saw the soil biology coming back almost instantly. He irrigates only lightly (SRI Principle 4), and his rice plants are really big and bushy. He uses much less fertilizer, and the plants show much less disease. Although his yields are comparable to the highly intensive conventional rice production systems, his costs for seed, agrochemicals and water have gone down significantly; thus he obtains a much better profitability.

A small number of farmers in the U.S. have gotten into specialty rice farming on smaller acreage. Working with the organization Jubilee Justice in Louisiana, I am involved with developing a fully organic, regenerative SRI rice farming system, where we transplant small rice seedlings with a vegetable transplanter. This works very well for a rice-growing area of two acres or less, but seedling production might be the limiting factor for scaling.

**Acres U.S.A.** SRI is specifically for rice, but SCI — System of Crop Intensification — would be for any other crop. Can you talk about doing this with other crops?

**Styger.** Yeah, I think that's important to mention. When I helped to introduce SRI to Mali, working in Timbuktu, some rice farmers approached me and said, "We plant wheat in the winter — can we use the SRI method for wheat?" I said, "I don't know, but let's try it." And that's how the System of Crop Intensification started in the mid-2000s, with SRI farmers in India, Ethiopia and Mali, who had successfully used SRI and innovated to use it for other crops.

SCI innovation started with wheat, but the principles were quickly applied to other grain crops, such as barley and finger millet, as well as for sugar cane. All crops show increased tillering and often the doubling of yields. In India, farmers use SCI for their vegetables, including eggplants and tomatoes.

SCI is a farmer-led innovation. It follows the same SRI principles — farmers adapt them to optimize the resources available to the plant and to minimize stress — to give each individual plant the room it needs and the environment it wants to thrive in. The principles for SRI and SCI are the same.

SRI is open-source. Nobody owns it. It provides some new guidelines on improving our agriculture and is open for continuous innovation so we can grow better and healthier crops.

# The Role *of* Phyllochrons *in* SRI Performance

*EDITOR'S NOTE: the following is an excerpt from Dr. Norman Uphoff's* System of Rice Intensification FAQ Guide*, used by permission of the author and available online at http://sri.cals.cornell.edu/aboutsri/SRI_FAQs_Uphoff_2016.pdf.*

**THE PROFUSE TILLERING OF** SRI plants can be better understood by considering the effects of *phyllochrons*, a little-known periodicity in rice plants' growth that regulates and determines their ultimate number of tillers and roots. When Fr. Laulanié learned practically by accident in the 1983-84 season that transplanting very young seedlings can lead to more robust and productive rice plants, this was hard to explain; it was just an empirical observation (Laulanié 1993).

However, four years later, Laulanié learned about phyllochrons from reading a book on rice science that presented this concept (Moreau 1986). It derived from research that was done during the 1920s and 1930s by a crop scientist in Japan, T. Katayama. Unfortunately, his research findings were not published until after World War II (Katayama 1951), and they have never been translated into English, so they are not widely known outside Japan….

From his studies of rice, wheat and barley, Katayama discovered a regularity in the way tillers (and roots) emerge from the meristematic tissue at the plant base of these cereal crops. He documented a remarkable *patterning* in the way that grass-family species (*gramineae/poaceae*) grow, described below.

Understanding phyllochrons helps explain why transplanting rice seedlings *before they are about 15 days old* can give a different and greater growth response to all the other practices of crop management than seen with seedlings that are transplanted at an older age, i.e., after the start of the 4th phyllochron. The timing and length of phyllochrons is determined by multiple factors, as discussed below.

The term itself combines two Greek words *phyllo* + *chron*, which respectively mean leaf + time. Phyllochron refers to *an interval of time* during which a plant leaf, together with an associated root and tiller, emerges from the plant's meristematic tissue, which produces new cells that create plant organs. This generative tissue derived from the rice plant's seed is located at the base of the plant, at or near the soil surface, between the plant's root system and its above-ground canopy.

Beyond the 4th phyllochron, multiple units of leaf and associated root and tiller will emerge at the same time, i.e., within a *period of time* that is designated as a phyllochron.

A synchronously emergent unit of a leaf, together with a tiller and a root, referred to collectively as a *phytomer*, grows both upward and downward from the plant's meristem at the base of the visible plant. At the same time that a plant's leaves and tillers grow upward into the air, its roots grow downward into the soil. Roots emanate from the same cell-division processes as do the leaves and the tillers.

The length of a phyllochron for rice can vary considerably, from:

- *Perhaps 4 days* if the conditions for growth are ideal, i.e., if the plant is encountering no stresses that will slow or impede its growth, to
- *8 to 10 days* if growing conditions for the plant are unfavorable because the plant is subject to many stresses (temperature, water, compacted soil, etc.).

When growing conditions are good, with favorable temperatures, enough water and sunlight, adequate availability of nutrients in the soil, lots of space all around the roots and canopy, and friable soil for root growth, a phyllochron can be 5 or 6 days in length, and the plant can complete 10, 11 or 12 phyllochron periods of growth before it (a) comes to the end of its initial phase of *vegetative growth* and (b) switches into its *reproductive phase*, from panicle initiation to flowering and heading, and then (c) proceeds with grain forming and filling, ripening, and maturation, when the grains have become ready for harvesting….

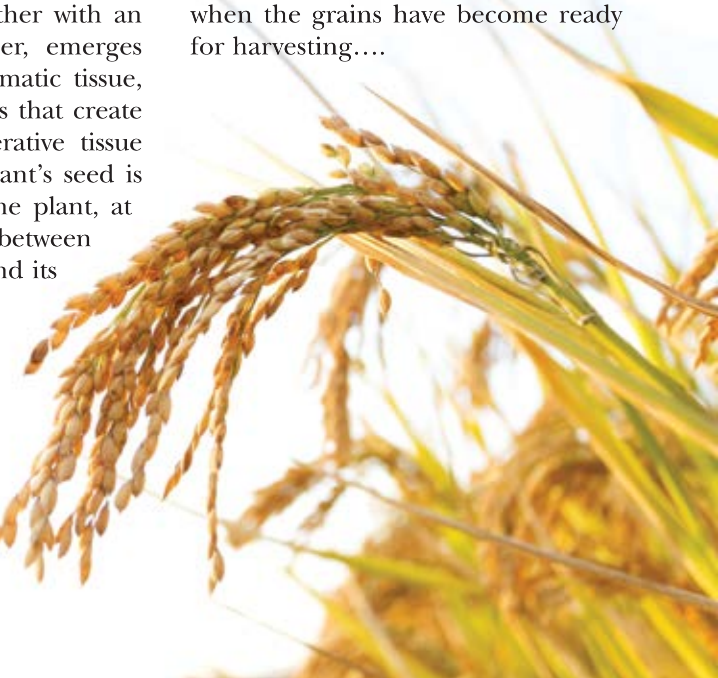

PHOTO FROM CANVA

**Pattern of Rice Tillers' Emergence over a 12-Phyllochron Sequence**

Sequence of Phyllochrons

| Tillers | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main tiller | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1st row of tillers | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 7 |
| 2nd row of tillers | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 5 | 26 |
| 3rd row of tillers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 6 | 10 | 15 | 36 |
| 4th row of tillers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 10 | 15 |
| 5th row of tillers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| No. of tillers produced in each period | 1 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 8 | 12 | 20 | 31 | 84 |
| No. tillers in 3 phyllochrons | 1 ($1 = 4^0$) | | | 4 ($4 = 4^1$) | | | 16 ($16 = 4^2$) | | | 63 ($63 = 4^3-1$) | | | |
| Cumulative no. of tillers | 1 | 1 | 1 | 2 | 3 | 5 | 8 | 13 | 21 | 33 | 53 | 84 | |

Source: Laulanié (1993).

PHOTO COURTESY DR. NORMAN UPHOFF

This rice plant with 98 fertile tillers, grown in the Nepal terai, was able to go through more than 12 phyllochrons of growth before its panicle initiation started.

Readers may have noticed that the pattern of tillering indicated in the table corresponds to what is known in mathematics and biology as a *Fibonacci series*. In such a series, *the number that emerges in each period is the sum of the previous two periods*: 1+1=2, 1+2=3, 2+3=5, 3+5=8 ... The number of tillers produced in each period is approximately 2/3 more than emerged in the preceding period. Such mathematical regularity in nature is noteworthy.

A rice plant that can complete 12 phyllochrons of growth before the end of its vegetative phase and moves into its reproductive phase, starting with panicle initiation, can have as many as 84 tillers…. Such a plant would have *a similarly profuse root system* because its roots emanate from the same meristem cells that go through cell division and differentiation to create tillers and leaves, forming the plant's canopy above-ground.

If rice plants are transplanted during the 4th phyllochron or during even later phyllochrons, it is seen that their subsequent production of phytomers is both decelerated and diminished. Accordingly, such rice plants, when they begin their reproductive phase, have fewer tillers and fewer leaves, and also fewer roots.

What is described here is a mechanistic presentation of a biological process. Specific plants do not necessarily grow as mathematically as the model above indicates. For one thing, the length of their phyllochrons is not always so uniform. Also, in practice, rice tillers increase according to *a modified Fibonacci series*, not a perfect one; 12 periods should hypothetically produce 89 tillers, rather than 84. This discrepancy is apparently due to physical congestion in the base of the rice plant, which keeps the emergence of tillers (and roots) from the meristematic tissue from reaching its hypothetical maximum.

Transplanting rice seedlings during their 2nd or 3rd phyllochron of growth – roughly between the 5th and 15th days – represents a *window of opportunity* for the best management of rice plants. Their roots will be less traumatized if they are transplanted during this relatively dormant period, and these plants, when they resume their growth after transplanting, will produce more phytomers (units of tiller, leave and root) in an accelerated way….

The concept underlying this presentation is that the rice plants' growth proceeds according to some kind of *"biological clock."* This runs faster or more slowly depending on *the totality of favorable and/or unfavorable growth conditions*. It is regulated operationally by the speed with which the plant's cells are growing, elongating and dividing, in turn growing, elongating and dividing….

More research remains to be done on phyllochrons and on their implications for rice crop growth. There has been considerable research on phyllochrons in wheat (see, e.g., a special issue of *Crop Science,* 35:1, 1995), and on phyllochrons in forage grasses, especially in Australia. However, there has been little consideration of rice phyllochrons except by rice scientists in Japan and China, where they are well known. In the English-reading world, phyllochrons do not figure much in plant science considerations, presumably because the original research on phyllochrons has not been translated into English.

Considerable research has been done along similar lines in terms of *degree-days*, but these are not linked to an understanding of plant physiology and morphology as closely as analysis done in terms of phyllochrons. For SRI, an understanding of phyllochrons helps to explain why the use of young seedlings has such a strong positive effect, validated empirically (Uphoff and Randriamiharisoa 2002). The rapid tillering and root growth which is possible when the full set of SRI practices are used together is not seen when older seedlings are used or when rice plants are grown under continuously flooded conditions with degenerating plant roots, which lengthens their phyllochrons. We hope that this area will become the focus of extensive research, such as that reported by Veeramani et al. (2012).