The System of Rice Intensification (SRI)

Rethinking Agricultural Paradigms – We Are Not Alone

BSWM Public Forum

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What Is SRI Not?

1. It is NOT A THING [adj.>noun]
   a. SRI derives from a number of INSIGHTS, based on experience
   b. SRI is a SET OF PRINCIPLES that have sound scientific justifications
   c. SRI gets communicated to farmers in terms of CERTAIN PRACTICES that improve the growing environment for their rice plants - but at same time,
   d. SRI is also an alternative PARADIGM

What Is SRI Not?

2. It is NOT A TECHNOLOGY

SRI practices may look like a PACKAGE or RECIPE, but they are really a MENU

- Farmers are encouraged to use as many of the practices as possible as well as possible
- There is considerable research evidence that *each practice contributes to higher yield*
- But there is also evidence that there exists some synergy among the practices – so the best results come from *using them together*

What Is SRI Not?

3. SRI is NOT FINISHED

-- Since it was empirically developed, we are *continually improving* our scientific understanding of SRI concepts/theory

-- Being farmer-centered, SRI is always being *modified, improved, extended*

- We now have rainfed versions of SRI (7 t/ha)
- Also zero-till, direct-seed, raised-bed forms
- SRI ideas are extrapolated to other crops: wheat, sugar cane, millet, teff, beans, etc.

Liu Zhibin, Meishan, Sichuan province, China, standing in raised-bed, zero-till SRI field; measured yield 13.4 t/ha. His SRI yield in 2001 set provincial yield record: 16 t/ha

Status of SRI: As of 1999

Known and practiced only in Madagascar

Merits of SRI methods first seen outside of Madagascar in China:

1999: *Nanjing Agric. University*
2000-01: *China National Hybrid Rice R&D Center* at Sanya
2001: *China National Rice Research Institute* (CNRRI) in Hangzhou, and *Sichuan Acad.of Agricultural Sciences*

Then Indonesia (AARD-Sukamandi) & Philippines (CDSMC) in 2000-01

Prof. Yuan Long-Ping with SRI plot at Sanya station, China National Hybrid Rice R&D Center, April 2001

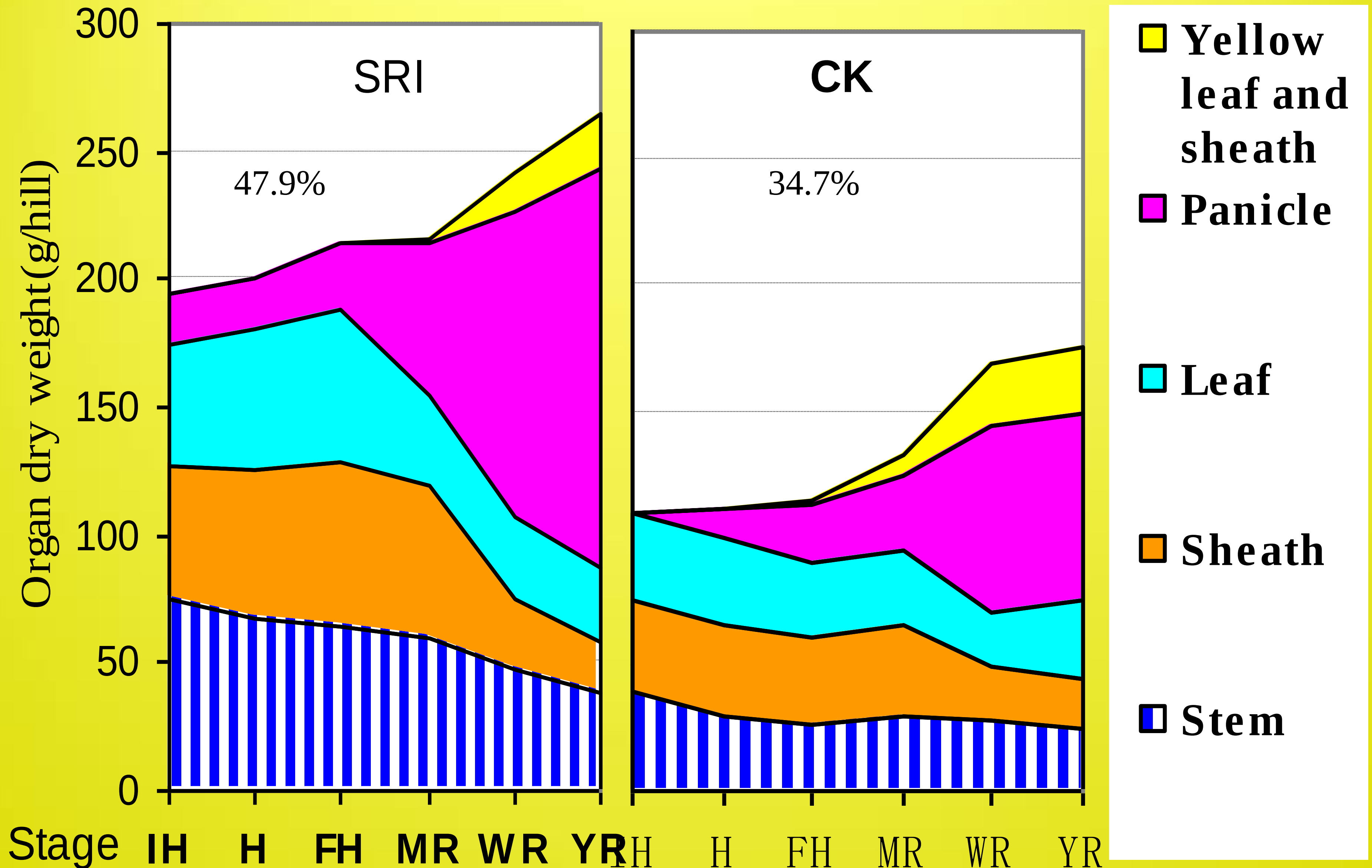
CHINA: Farmers with SRI fields in Bu Tou village,
Jie Ton township (Tien Tai city), Zhejiang province, 2004

Nie Fu-qiu, Bu Tou village

- 2004: SRI highest yield in Zhejiang province: 12 t/ha
- 2005: his SRI rice fields were hit by three typhoons – even so, he was able to harvest 11.15 tons/ha -- while other farmers' fields were badly affected by the storm damage

- 2008: Nie used chemical fertilizer, and crop lodged

CHINA: 3-S crop compared to 'normal' methods in Heilungjiong Province (Prof. Jin Xueyong, NEAU)



Non-Flooding Rice Farming Technology in Irrigated Paddy Field

Dr. Tao Longxing, China National Rice Research Institute, 2004

Factorial trials by CNRRI, 2004 and 2005 using two super-hybrid varieties -- seeking to break 'plateau' limiting yields

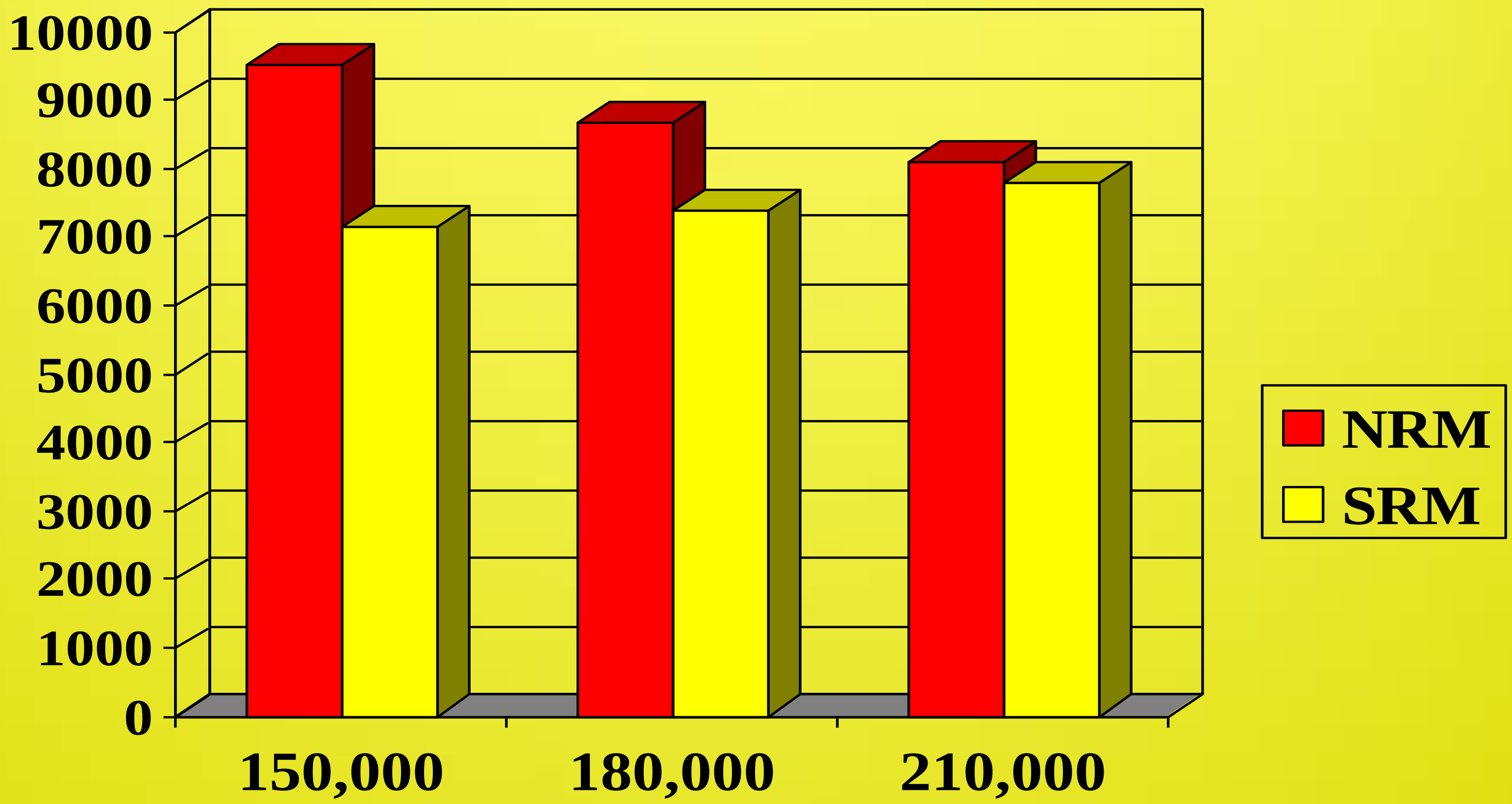
Standard Rice Mgmt

- 30-day seedlings
- 20x20 cm spacing
- Continuous flooding
- Fertilization:
  - 100% chemical

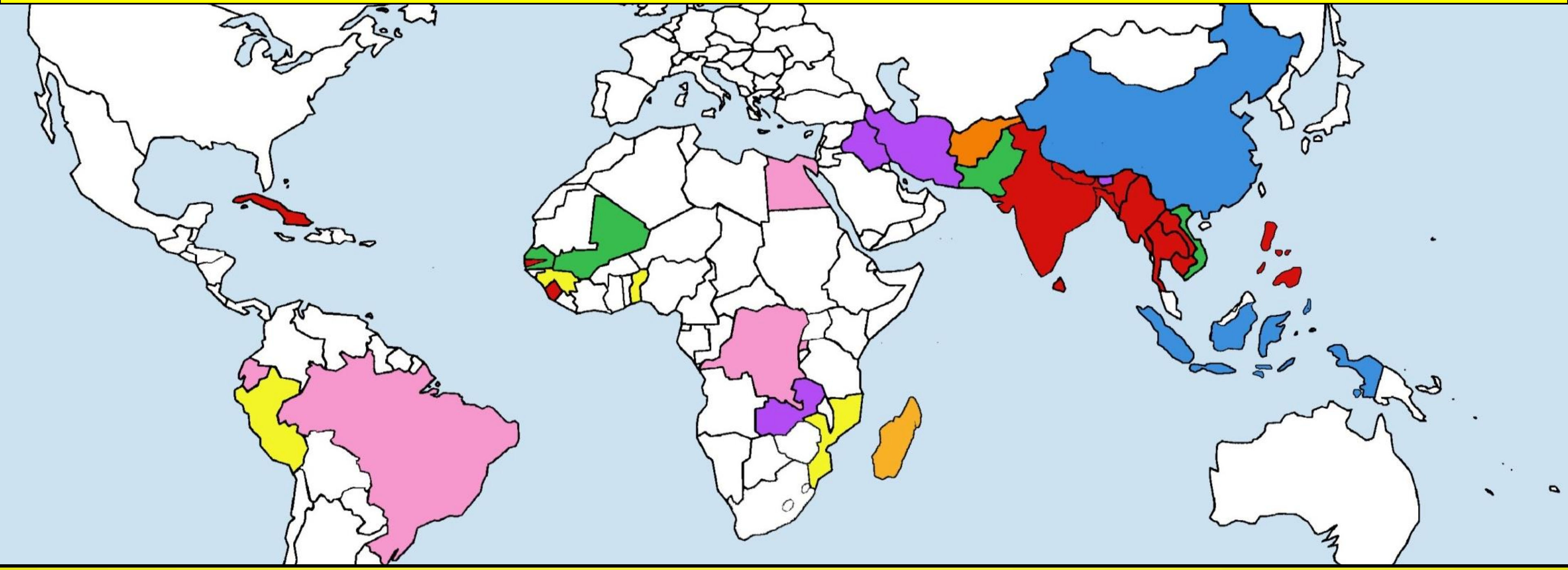
New Rice Mgmt (SRI)

- 20-day seedlings
- 30x30 cm spacing
- Alternate wetting and drying (AWD)
- Fertilization:
  - 50% chemical,
  - 50% organic

Average super-rice yields (kg/ha) with new rice management (SRI) vs.standard rice management at different plant densities ha^{-1}



Now in 2009, SRI benefits have been validated in 35 countries of Asia, Africa, and Latin America



Before 1999: Madagascar
1999-2000: China, Indonesia
2000-01: Bangladesh, Cuba Cambodia, Gambia, India, Laos, Myanmar, Nepal, Philippines, Sierra Leone, Sri Lanka, Thailand
2002-03: Benin, Guinea, Mozambique, Peru
2004-05: Senegal, Mali, Pakistan, Vietnam
2006: Burkina Faso, Bhutan, Iran, Iraq, Zambia
2007: Afghanistan, Brazil
2008: Egypt, Rwanda, Congo, Ecuador, Costa Rica

What Is SRI? Six Basic Ideas

1. Transplant young seedlings to preserve their growth potential -- but DIRECT SEEDING is now an option
2. Avoid trauma to the roots -- transplant quickly and shallow, *not inverting root tips which halts growth*
3. Give plants wider spacing -- *one plant per hill* and in *square pattern* to achieve "edge effect" everywhere
4. Keep paddy soil moist but unflooded -- soil should be mostly aerobic -- *not continuously saturated*
5. Actively aerate the soil as much as possible
6. Enhance soil organic matter as much as possible

First 3 practices stimulate *plant growth*, while the latter 3 practices enhance the *growth and health of plants' ROOTS and of soil BIOTA*

AFGHANISTAN: SRI field in Baghlan Province, supported by Aga Khan Foundation Natural Resource Management program

SRI field at 30 days


SRI plant with 133 tillers @ 72 days after transplanting
11.56 t/ha

IRAQ: Comparison trials at Al-Mishkhab Rice Research Station, Najaf

Two Paradigms for Agriculture:

- GREEN REVOLUTION strategy was to:
  * Change the genetic potential of plants, and
  * Increase the use of external inputs -- more water, more fertilizer and insecticides
- SRI (AGROECOLOGY) instead changes the management of plants, soil, water & nutrients:
  * To promote the growth of root systems, and
  * To increase the abundance and diversity of soil organisms to better enlist their benefits

The goal is to produce better PHENOTYPES

MADAGASCAR: Rice field grown with SRI methods


CAMBODIA:
Rice plant grown
from single seed
in Takeo province

NEPAL: Single rice plant grown with SRI methods, Morang district

IRAN:

SRI roots and normal (flooded) roots: note difference in **color** as well as **size**

INDONESIA: Rice plants of same age and same variety in Lombok province

Indonesia: Results of 9 seasons of on-farm comparative evaluations of SRI by Nippon Koei team, 2002-06

- No. of trials: **12,133**
- Total area covered: **9,429.1 hectares**
- Ave. increase in yield: **3.3 t/ha (78%)**
- Reduction in **water requirements**: **40%**
- Reduction in **fertilizer use**: **50%**
- Reduction in **costs of production**: **20%**

Note: In Bali (DS 2006) 24 farmers on 42 ha: SRI + Longping hybrids → 13.3 vs. 8.4 t/ha

INDONESIA: Rice plants in Nippon Koei office, Jakarta

SRI LANKA: same rice variety, same irrigation system & *same drought* -- left, conventional methods; right, SRI

VIETNAM:
Dông Trù village,
Hanoi province,
after typhoon

Incidence of Diseases and Pests

Vietnam National IPM Program: average of data from trials in 8 provinces, 2005-06:

	Spring season			Summer season		
	SRI Plots	Farmer Plots	Differ-ence	SRI Plots	Farmer Plots	Differ-ence
Sheath blight	6.7%	18.1%	63.0%	5.2%	19.8%	73.7%
Leaf blight	--	--	--	8.6%	36.3%	76.5%
Small leaf folder *	63.4	107.7	41.1%	61.8	122.3	49.5%
Brown plant hopper *	542	1,440	62.4%	545	3,214	83.0%
AVERAGE			55.5%			70.7%

* Insects/m^2

Measured Differences in Grain Quality

Characteristic	Conv. Methods (3 spacings)	SRI Methods (3 spacings)	Difference
Chalky kernels (%)	39.89 – 41.07	23.62 – 32.47	-30.7%
General chalkiness (%)	6.74 – 7.17	1.02 – 4.04	-65.7%
Milled rice outturn (%)	41.54 – 51.46	53.58 – 54.41	+16.1%
Head milled rice (%)	38.87 – 39.99	41.81 – 50.84	+17.5%

Paper by Prof. Ma Jun, Sichuan Agricultural University, presented at 10th conference on "Theory and Practice for High-Quality, High-Yielding Rice in China," Haerbin, 8/2004

COSTA RICA: Mechanized version of SRI -- 8 t/ha yield in first season

Fig 1 Trasplantadora motorizada
AP100 Yanmar


18.12.2008

Mechanization of weeding, i.e., **soil aeration**, is also possible

Motorized weeder developed by S. Ariyaratna, Sri Lanka

PAKISTAN: Making raised beds for rice-growing with adapted SRI methods on laser-leveled field

Mechanical transplanter for planting onto raised beds, made by machine

Mechanized/hand transplanting in Pakistan, into holes made by machine, with water sprayed into hole after 10-day seedling is dropped into it.

Mechanical weeder set for 9x9 inch (22.5x22.5 cm) spacing – can give very good soil aeration

71-day rice crop that was planted in a dry soil for the 1st time in the entire world – Average number of tillers = 90

What about 'Yield Ceiling'?

- Have we reached a biological maximum which means that we need to breed 'better' rice varieties to raise potential?
- This concept is based on modeling using *coefficients* derived from rice plants with *degraded, non-functioning* root systems (different phenotypes) and soil that is poorly endowed with diverse soil biota:
  - Anaerobic soil conditions: continuous flooding affecting mycorrhyzae and other endophytes
  - Close spacing: inadequate photosynthesis in lower leaves, reducing roots' photosynthate
  - Insufficient uptake of micronutrients

Yield x Age of Seedlings Used with SRI Methods, Morang district, Nepal, 2005 (conventional average yield: 3.1 t/ha)

Seedling age (in days)	Number of farmers	Percent of Farmers	Average yield (t/ha)	Range of yields (t/ha)
8	22	5.4	**6.94**	4.0 - 9.0
9-10	123	30.0	**6.32**	3.6 - 11.0
11-12	169	41.3	**6.41**	2.5 - 11.0
13-14	64	15.6	**5.77**	3.0 - 9.0
15 and above	32	7.8	**5.52**	3.7 - 7.0
Total	410	100.0	**6.3**	2.5 - 11.0

Range of seedling ages: 8-21 days; average seedling age: 11.4 days

Also Reduced Time to Maturity with Younger Seedlings

51 of these Nepali SRI farmers planted the same 145-day variety, *Bansdhan*, in monsoon season 2005

Age of seedling	N of farmers	Days to harvest	Reduction (in days)
>14 d	9	138.5	6.5
10-14 d	37	130.6	14.4
8-9 d	5	123.6	21.4

With SRI doubling yield from 3.1 to 6.3 t/ha

Crop duration from seed to seed of different rice varieties using SRI vs. conventional methods, Morang district, Nepal, 2008 (in days)

Varieties	Conventional duration	SRI duration	Difference
Mansuli	155	136 (126-146)	19 (9-29)
Swarna	155	139 (126-150)	16 (5-29)
Radha 12	155	138 (125-144)	17 (11-30)
Bansdhan/Kanchhi	145	127 (117-144)	18 (11-28)
Barse 2014	135	127 (116-125)	8 (10-19)
Barse 3017	135	118	17
Sugandha	120	106 (98-112)	14 (8-22)
Hardinath 1	120	107 (98-112)	13 (8-22)

Data from Morang district, Nepal, 2008 main season

Effect of Young Seedlings Was Seen in Factorial Trials in Madagascar

Note: Each average is from 6 replicated trials

	Clay Soil	Loam Soil
SS/20/3/NPK	3.00	2.04
SS/ **8** /3/NPK	7.16	3.89
SS/ **8** /**1**/NPK	8.13	4.36
AS/ **8** /3/NPK	8.15	4.44
AS/ **8** /3/**Comp**	6.86	3.61
SS/ **8** /**1**/**Comp**	7.70	4.07
AS/ **8** /**1**/NPK	8.77	5.00
AS/ **8** /**1**/**Comp**	10.35	6.39

What Is Going On?

The 'young seedling' effect can be understood in terms of phyllochrons

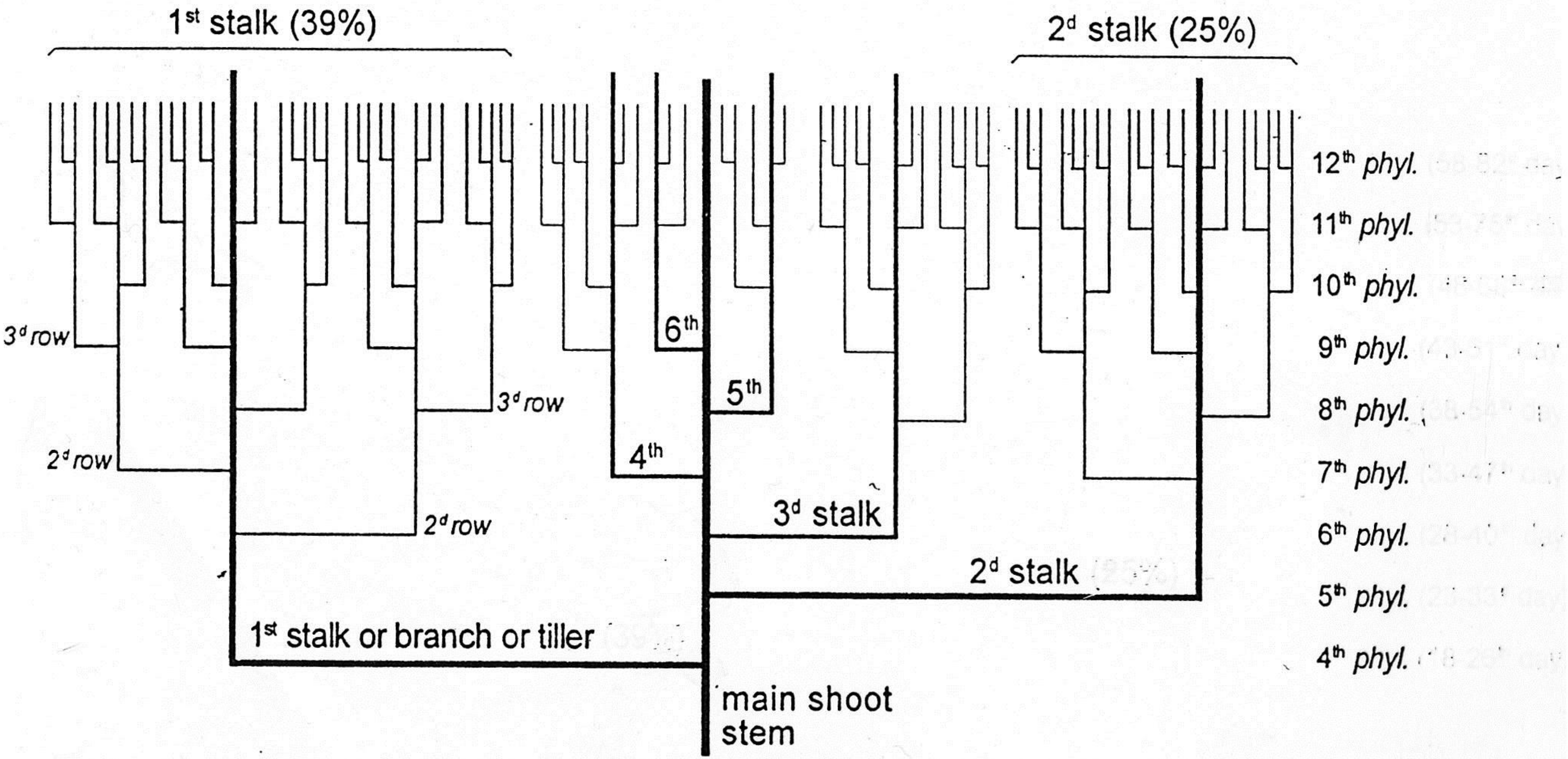
- Phyllochrons are the periods of time (4-10 days) that pattern the emergence of tillers and of roots (reflect conditions)
- These relationships can be analyzed also in terms of leaf-age or degree-days
- Phyllochrons 'discovered' by T. Katayama in 1920s-30s; published work in 1951; never translated into English language
- Analysis improved upon by de Laulaniè

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

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

DIAGRAM OF POSSIBLE STALKS OF A RICE SHOOT

stalks grow following a regular cycle (phyllochron)



Main shoot stem emerges during 1st phyllochron; no further tillering until 1st primary tiller emerges in the 4th phyllochron

How to speed up 'the biological clock' and shorten phyllochrons to have more cycles of tiller-root growth *before* PI?

(adapted from Nemoto et al., *Crop Science*, 1995)

Shorter phyllochrons		Longer phyllochrons
Higher temperatures	>	cold temperatures
Wider spacing	>	crowding of roots/canopy
More illumination	>	shading of plants
Ample nutrients in soil	>	nutrient deficits
Soil penetrability	>	compaction of soil
Sufficient moisture	>	drought conditions
Sufficient oxygen	>	hypoxic soil conditions

Effect of Weeding (Soil Aeration)

412 farmers in Morang district, Nepal, using SRI in monsoon season, 2005

SRI yield = 6.3 t/ha vs. control = 3.1 t/ha

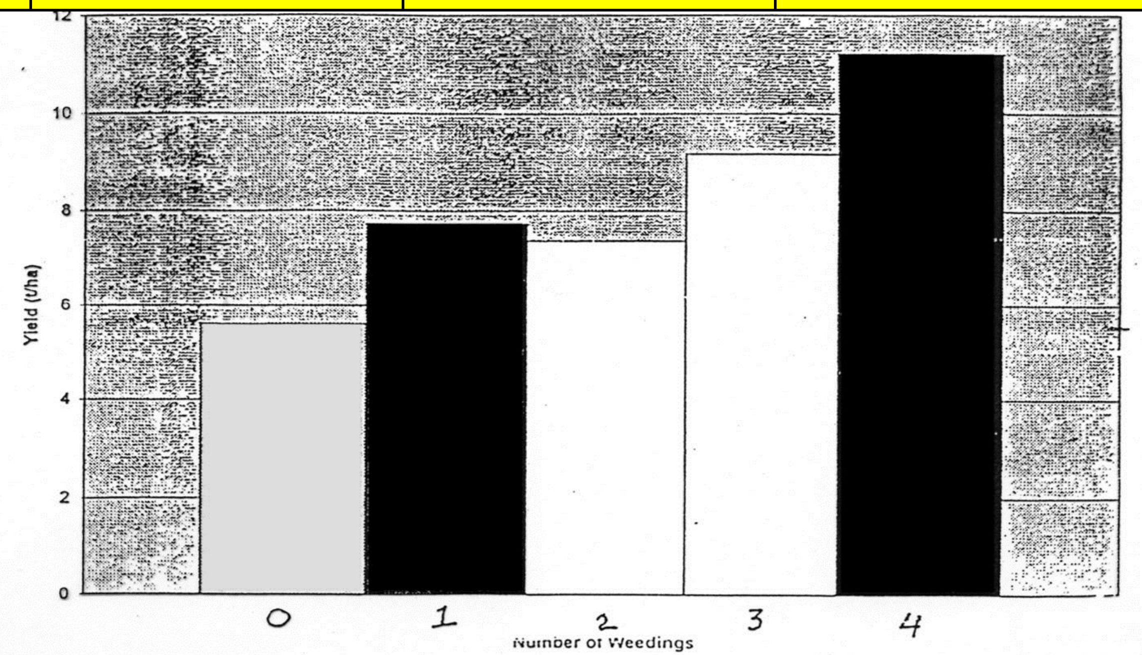
- Data show how WEEDINGS can raise yield

No. of weedings	No. of farmers	Average yield	Range of yields
1	32	5.16	(3.6-7.6)
2	366	5.87	(3.5-11.0)
3	14	7.87	(5.85-10.4)

Impact of Weedings on Yield with SRI Methods

Ambatovaky, Madagascar, 1997-98

Mechanical Weedings	Farmers (N)	Area (ha)	Harvest (kg)	Yield (t/ha)
None	2	0.11	657	5.973
One	8	0.62	3,741	7.723
Two	27	3.54	26,102	7.373
Three	24	5.21	47,516	9.120
Four	15	5.92	69,693	11.772



Lessons & Recommendations for SRI Paddy for Mountainous Regions (PSI)

Transplanting Time (days)

(i) 10-15 days:	7.0-7.5 t/ha
(ii) 16-23 days:	5.5-6.0 t/ha
(iii) > 23 days:	4.0-4.5 t/ha

Weeding (no. of times)

(i) 3 times:	7.0-7.5 t/ha
(ii) 2 times:	6.0-6.5 t/ha
(iii) 1 time:	5.0-5.5 t/ha

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Microbial populations in rice rhizosphere
Tamil Nadu Agricultural University research

Microorganisms	Conventional	SRI
Total bacteria	88×10^6	105×10^6
Azospirillum	8×10^5	31×10^5
Azotobacter	39×10^3	66×10^3
Phosphobacteria	33×10^3	59×10^3

T. M. Thiyagarajan, WRRC presentation, Tsukuba, Japan, 11/04

ENDOPHYTIC *AZOSPIRILLUM*, TILLERING, AND RICE YIELDS WITH CULTIVATION PRACTICES AND NUTRIENT AMENDMENTS

Results of replicated trials at Anjomakely, Madagascar, 2001 (Andriankaja, 2002)

CLAY SOIL	*Azospirillum* in Roots (10^3/mg)	No. of Tillers/ plant	Yield (t/ha)
Traditional cultivation, no amendments	65	17	1.8
SRI cultivation, with no amendments	1,100	45	6.1
SRI cultivation, with NPK amendments	450	68	9.0
SRI cultivation, with compost	1,400	78	10.5
LOAM SOIL			
SRI cultivation with no amendments	75	32	2.1
SRI cultivation, with compost	2,000	47	6.6

'Ascending Migration of Endophytic Rhizobia, from Roots and Leaves, inside Rice Plants and Assessment of Benefits to Rice Growth Physiology'

Rhizobium test strain	Total plant root volume/ pot (cm^3)	Shoot dry weight/ pot (g)	Net photosynthetic rate (μmol^{-2} s^{-1})	Water utilization efficiency	Area (cm^2) of flag leaf	Grain yield/ pot (g)
Ac-ORS571	210 ± 36^{A}	63 ± 2^{A}	16.42 ± 1.39^{A}	3.62 ± 0.17^{BC}	17.64 ± 4.94^{ABC}	86 ± 5^{A}
SM-1021	180 ± 26^{A}	67 ± 5^{A}	14.99 ± 1.64^{B}	4.02 ± 0.19^{AB}	20.03 ± 3.92^{A}	86 ± 4^{A}
SM-1002	168 ± 8^{AB}	52 ± 4^{BC}	13.70 ± 0.73^{B}	4.15 ± 0.32^{A}	19.58 ± 4.47^{AB}	61 ± 4^{B}
R1-2370	175 ± 23^{A}	61 ± 8^{AB}	13.85 ± 0.38^{B}	3.36 ± 0.41^{C}	18.98 ± 4.49^{AB}	64 ± 9^{B}
Mh-93	193 ± 16^{A}	67 ± 4^{A}	13.86 ± 0.76^{B}	3.18 ± 0.25^{CD}	16.79 ± 3.43^{BC}	77 ± 5^{A}
Control	130 ± 10^{B}	47 ± 6^{C}	10.23 ± 1.03^{C}	2.77 ± 0.69^{D}	15.24 ± 4.0^{C}	51 ± 4^{C}

Feng Chi et al., *Applied and Envir. Microbiology* 71 (2005), 7271-7278

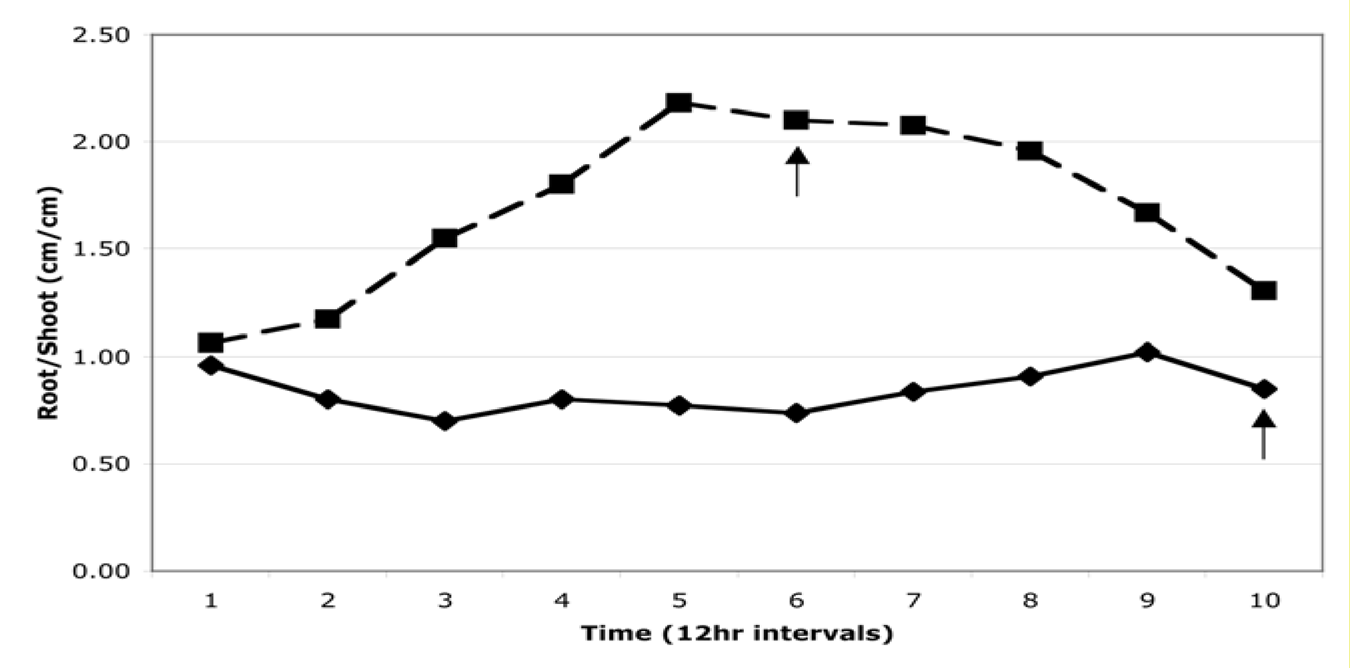
'Ascending Migration of Endophytic Rhizobia, from Roots and Leaves, inside Rice Plants and Assessment of Benefits to Rice Growth Physiology'

"Rice-adapted isolates of rhizobia have previously been shown to produce the growth-regulating phyto-hormones IAA and GA in pure culture and to increase IAA levels accumulated externally in root exudates of gnotobiotically-cultured rice plants...

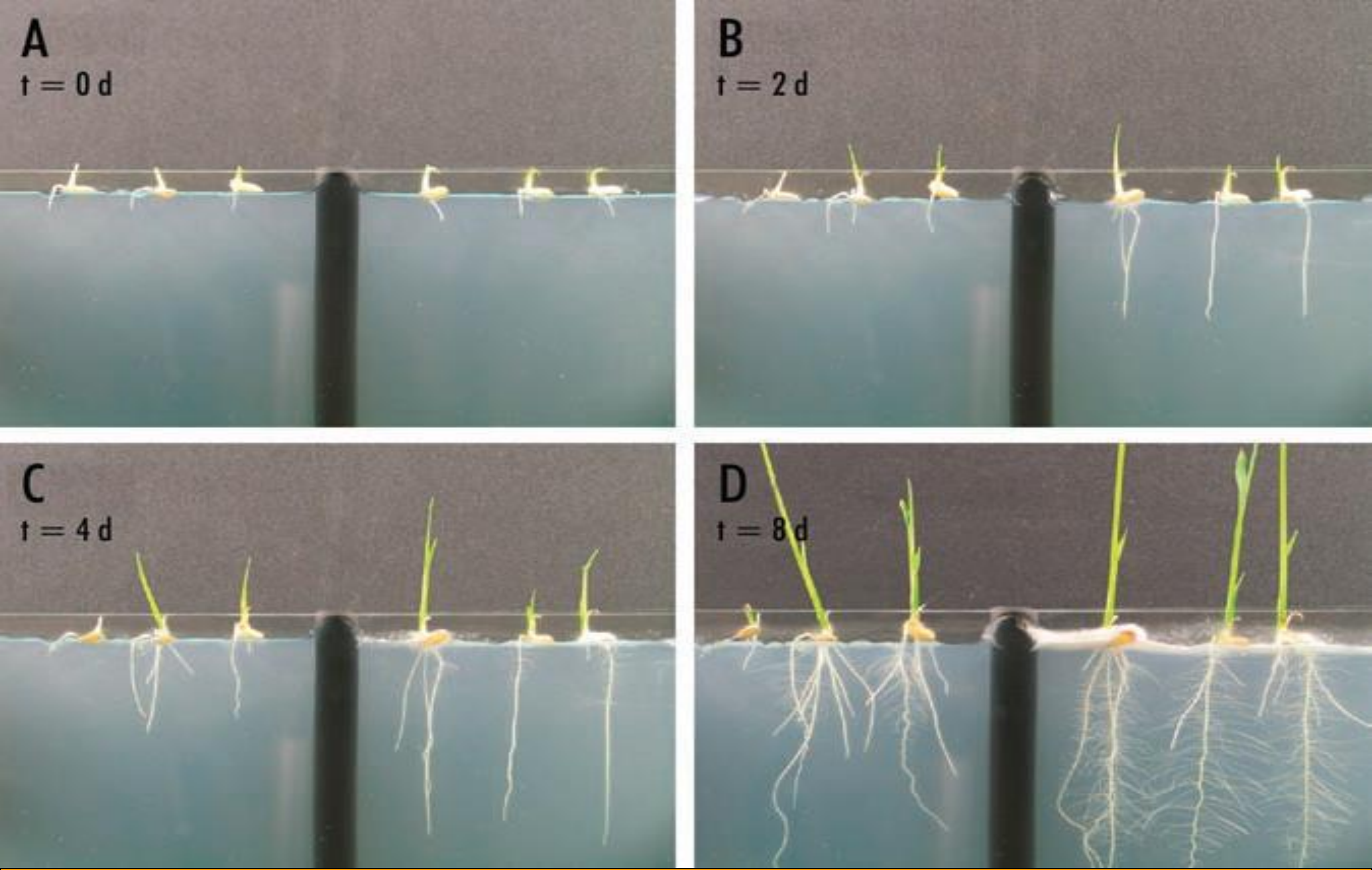
We predict that this rhizobium-induced elevation of the levels of these growth-stimulating phytohormones within above-ground rice tissues contributes to the underlying mechanism(s) allowing ***certain strains of these bacteria to enhance vegetative and reproductive growth of cereals in general..."*** *(Feng et al., 2005)*

Ratio of root and shoot growth in symbiotic and nonsymbiotic rice plants (symbiotic plants inoculated with *Fusarium culmorum*)

Russell J. Rodriguez et al., 'Symbiotic regulation of plant growth, development and reproduction,' ***Communicative and Integrative Biology***, 2:3 (2009).



Data are based on the average linear root and shoot growth of three symbiotic (dashed line) and three nonsymbiotic (solid line) plants. Arrows indicate the times when root hair development started.



Growth of nonsymbiotic (on left) and symbiotic (on right) rice seedlings. On growth of endophyte (F. culmorum) and plant inoculation procedures, see Rodriguez et al., ***Communicative and Integrative Biology***, 2:3 (2009).

What is going on to produce better phenotypes?

SRI plants have profuse ROOT GROWTH with *little or late senescence*

- Continue taking up N until end of cycle
- Roots are reaching lower horizons
  - More uptake of micronutrients (Cu, Zn …)
  - Also more uptake of silicon (Si)?
- Interaction and interface with SOIL MICROORGANISMS – phytohormones?

Cuban farmer with two plants of same variety (VN 2084) and same age (52 DAP)

ROOT GROWTH: Research findings from on-farm studies in 2005 by Dr. O.P. Rupela, ICRISAT/WWF

Average yield:

- SRI: 7.68 t/ha vs. FP: 6.15 t/ha

Length of roots in *top 15 cm of soil*

- SRI: 19.8 km/m³ vs. FP: 2.4 km/m³

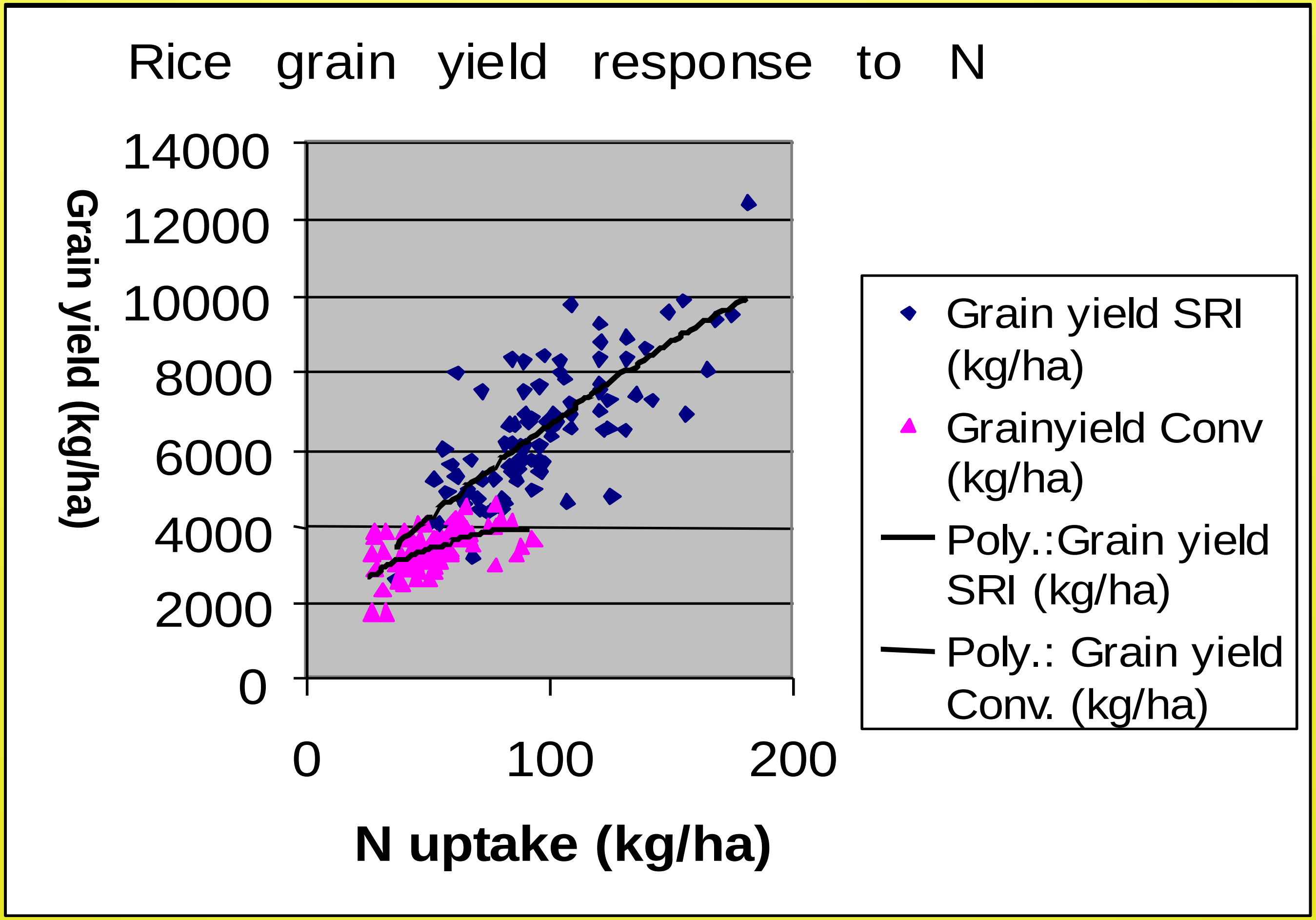
We should not consider roots separately from soil biota – instead, roots and biota are best regarded as a single system

Root length density ($cm\ cm^{-3}$) under SRI, SRA and conventional systems (Barison, 2003)

	Soil layers (cm)					
Treatments	*0-5*	*5-10*	*10-20*	*20-30*	*30-40*	*40-50*
SRI with compost	3.65	0.75	0.61	0.33	0.30	0.23
SRI without compost	3.33	0.71	0.57	0.32	0.25	0.20
SRA with NPK and urea	3.73	0.99	0.65	0.34	0.18	0.09
SRA without fertilization	3.24	0.85	0.55	0.31	0.15	0.07
Conventional system	4.11	1.28	1.19	0.36	0.13	0.06

Comparison of root pulling resistance (RPR), in kg, different stages of plant growth (Barison, 2003)

Treatments (plants per hill)	RPR at panicle initiation	RPR at anthesis	RPR at maturity	Decrease from anthesis to maturity
SRI with compost (1)	53.00	77.67	55.19	28.7%
SRI without compost (1)	61.67	68.67	49.67	28.3%
SRA with NPK + urea (2)	44.00 (22.00)	55.33 (27.66)	34.11 (17.06)	38.3%
SRA without fertilization (2)	36.33 (18.16)	49.67 (24.88)	30.00 (15.00)	39.4%
Conventional system (3)	22.00 (7.33)	35.00 (11.67)	20.67 (6.89)	41.0%



Regression relationship between nitrogen uptake and grain yield for SRI and conventional methods (Barison, 2003) – same relationship for P and K

System of Finger Millet Intensification on left; regular management of improved variety and of traditional variety on right

Sugar cane grown with SRI methods (left) in Andhra Pradesh

Reported yields of **125-235 t/ha** compared with usual 65 t/ha

Extensions of SRI to Other Crops: Uttarakhand / Himachal Pradesh, India

Crop	No. of Farmers	Area (ha)	Grain Yield (t/ha)		% Incr.
2006			Conv.	SRI	
Rajma	5	0.4	1.4	2.0	43
Manduwa	5	0.4	1.8	2.4	33
Wheat	Research Farm	5.0	1.6	2.2	38
2007					
Rajma	113	2.26	1.8	3.0	67
Manduwa	43	0.8	1.5	2.4	60
Wheat (Irrig.)	25	0.23	2.2	4.3	95
Wheat (Unirrig.)	25	0.09	1.6	2.6	63

Rajma (kidney beans)

Manduwa (millet)

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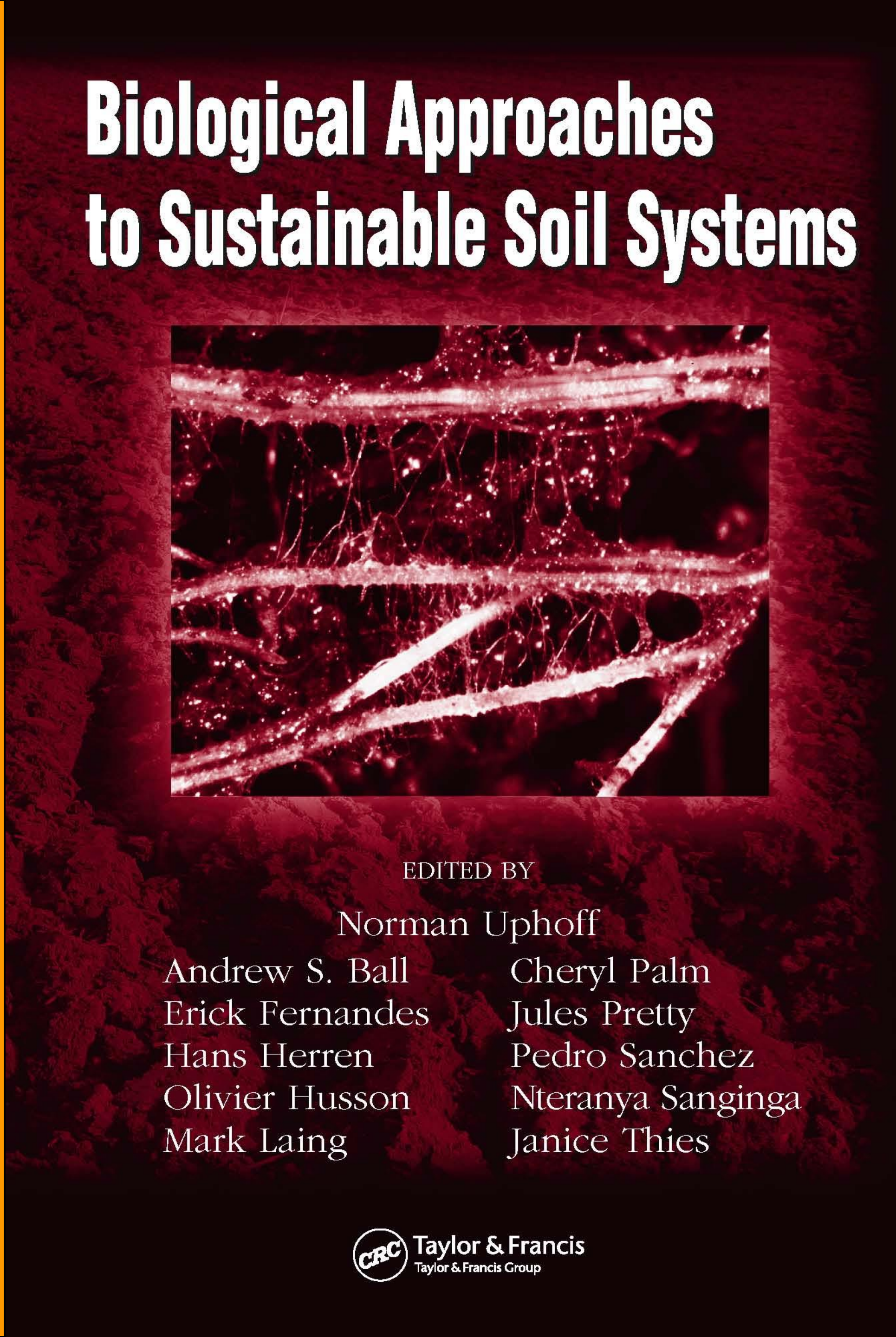
Contributions of Larger Root Systems and Soil Organisms?

- Uptake of N until end of growth cycle
  - Higher protein → less breakage in milling?
  - Higher nutritional value of grains?
- Uptake of more micronutrients
  - Heavier grains are denser → less breakage?
  - Greater conversion of macronutrients taken up into grain output?
  - Higher nutrient value of grains?
- Many research Qs – SRI is not finished

SRI is pointing the way toward a **possible paradigm shift** in our agricultural sciences:

- Less '**genocentric**' and more profoundly '**biocentric**'?
- Re-focus biotechnology and bioengineering to capitalize on **biodiversity** and **ecological dynamics**?
- Less **chemical-dependent**?
- More **energy-efficient**?
- More **oriented to health** of humans and the environment?
- **Intensification** of production > continued extensification?
- Focus on **factor productivity** and **sustainability**?



Theory of Trophobiosis

- (F. Chaboussou, *Healthy Crops*, 2004) deserves more attention and empirical evaluation than it has received to date
- Its propositions are well supported by published literature over last 50 years -- and by long-standing observations about adverse effects of nitrogenous fertilizers and chlorinated pesticides
- Theory does not support strictly 'organic' approach because nutrient amendments are recommended if soil deficits exist

Theory of 'Trophobiosis'

Explains incidence of pest and disease in terms of plants' nutrition:

Nutrient imbalances and deficiencies lead to excesses of free amino acids in the plants' sap and cells, not yet synthesized into *proteins* – and more simple sugars in sap and cytoplasm not incorporated into *polysaccharides*

This condition attracts and nourishes insects, bacteria, fungi, even viruses

THANK YOU

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