REPORT ON THE WORLD-RECORD SRI YIELDS IN KHARIF SEASON 2011 IN NALANDA DISTRICT, BIHAR STATE, INDIA

M.C.Diwakar,[1] Arvind Kumar,[1] Anil Verma,[2] and Norman Uphoff[3]

A paddy yield of 22.4 tons/hectare reported at end of 2011 khariff from the SRI plot of a farmer in Darveshpura village, Bihar, Shri Sumant Kumar, has attracted considerable attention because it surpasses the previously accepted world-record yield of 19 tons/ha reported from China. This result was initially met with skepticism, but the yield was properly measured and is accepted now by the Indian Council for Agricultural Research (ICAR), confirmed by the Minister of Agriculture in Parliament March 20 (http://www.thehindubusinessline.com/industry-and-economy/agri-biz/article3016481.ece). Four other farmers in the village, also first-time SRI practitioners, achieved paddy yield levels of 19 or 20 tons/ha, so Sumant Kumar's achievement was not an isolated occurrence. Thus their accomplishment deserves national and international attention.

There is understandable interest in how these production levels were achieved; how they were measured; and what special conditions might have prevailed. This report provides data from the Bihar Department of Agriculture and from Sumant Kumar himself. More scientific evaluations remain to be done on this Darveshpura achievement. Here we present what was known at season's end about what had been done, and what resulted.

SRI stands for **System of Rice Intensification**, a set of principles and practices developed in Madagascar for raising the productivity of the seeds, water, land, labor and capital used in paddy production. SRI does this by modifying the way that rice plants, soil, water and nutrients are managed. It does not require farmers to acquire new or improved seeds or chemical fertilizer to raise their yield; although in this case, the rice varieties planted were hybrids, and there was integrated nutrient management which combined organic and inorganic inputs.

SRI has been controversial because of some very large increases in yield (>20 tons/ha) that were previously reported from Madagascar when the SRI practices were all utilized together, and were used as recommended. This report may diminish some of this controversy because the inputs and outputs of super-yield production are better documented here than before.

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[1] Directorate of Rice Development, Patna, Bihar, India (http://drdpat.bih.nic.in/); [2] PRADAN, Gaya, Bihar (http://www.pradan.net/); [3] SRI-Rice, Cornell University, Ithaca, NY, USA (http://sri.ciifad.cornell.edu/).

Data Gathering and Information on the Local Situation

During the crop-cutting of SRI demonstration plots at the end of the 2011 kharif season, Dr. Kumar, a senior agronomist with the Directorate of Rice Development (DRD) in Patna and a co-author of this report, visited farmers' fields in Darveshpura and other villages in Nalanda and other districts in Bihar state. While verifying facts about rice production on SRI demonstration plots, he collected many details and talked with officers of the state's Department of Agriculture regarding implementation of the SRI demonstrations. From what he learned, it was clear that the production context was quite favorable, not surprising for such good results.

Kumar observed that the most successful farmers involved in the trials were well-educated and have good learning ability for adopting innovative technology on their fields. As agriculture is their single source of household income, they are trying to utilize the inputs available to them in the best possible way. These farmers used green manuring, particularly *dhaincha* (sesbania), along with vermicompost and other organic sources of nutrients and a small amount of chemical fertilizer. No major insect pests or diseases were observed in these rice fields during the crop growth period, possibly reflecting the suite of crop management practices. More information on the cultivation methods used is given below.

Darveshpura village and the SRI demonstration plots are situated on the bank of the Sakri River. The water table there is high, and soil organic matter has been built up and maintained so that the soil is relatively rich in humus content, and its water-retention capacity is good. The soils are generally sandy clay and well-drained, with no waterlogging. Soil pH is in the neutral range. The climate and rainfall distribution were better in 2011 than in the previous year, when much of Bihar experienced serious drought conditions; so the weather in this season was favorable.

In the sandy/sandy-clay soil of Darvesthpura, intercultivation (weeding) between rows is easier than in heavy clay soil, where also a hard pan impedes water percolation. Using a conoweeder, a simple hand implement, for weed control makes these soils more friable and provides aerobic conditions near the root zone. This can increase the extent and activity of soil microbial populations, so that soil nutrients become more easily available to the plants. This soil-aerating weeding operation is thought to increase plants' ability and efficiency for nutrient uptake.

Farmers in this area practice various rotations during their cropping year. The main rotations are: rice/wheat/*moong* (mungbean, a short-season legume)/*dhaincha* (sesbania) for green manuring; or alternatively, rice/maize/*moong*/*dhaincha*. Other rotations include: rice/potato/onion; rice/lentil/gram; rice/mustard (*toria*, a rapeseed); groundnut/red gram (*arhar*); maize/red gram inter-cropping; or some other mixed cropping rotation. In a few pocket areas, a rotation of rice/potato/muskmelon or watermelon is also practiced. Also sweet potatoes are grown in some villages.

Dr. Kumar and Anil Verma gathered information on the situation and practices of the farmers in Darveshpura village who got paddy yields in the 20-ton range by talking with Department officials who did the supervision and measurement of yield and with Sumant Kumar himself. Verma, team leader in neighboring Gaya district for the NGO that introduced SRI into Bihar (PRADAN), had helped train officials and technicians in Nalanda district who in turn trained farmers there in SRI methods. Verma was thus well-acquainted with local officials and farmers as was Dr. Kumar and Dr. Diwakar, who as DRD Director also visited the area. Having developed rapport with local persons, these co-authors could get information from local sources freely and could assess whatever they learned in light of what else they knew about the area and its agriculture from previous visits.

Department of Agriculture officials in the district prepared detailed crop reports for the five very successful farmers and also produced a summary report on results for 52 additional farmers in Nalanda district who attained very good-to-excellent SRI results in the 2011 kharif season. This information was provided by Diwakar to Prof. Uphoff as both of them have been following and conferring on the introduction and spread of SRI in India. Prof. Uphoff worked with the co-authors to analyze and present this body of data and information for a better understanding of the 2011 SRI experiences in Darveshpura village as these could have significance for other farmers in India and elsewhere in the world.

Need to Explain a Tripling of Yield due to Management Alone

The yields that these Darveshpura farmers obtained using a particular set of SRI-formulated practices were *three times higher* than the yields that they achieved from the same hybrid varieties in the 2011 kharif season on the same farms when using their usual management methods. This suggests that careful attention should be paid to the differences in crop management between SRI and normal practice. The results from five farmers in a single season in a single village do not prove anything scientifically. However, the results point to areas for systematic research that could have substantial payoff for enhancing crop production in economically and environmentally-desirable ways.

Background on the Successful Farmers

The names of these five farmers – all relatively young, between 30 and 35 years old – are Sumant Kumar, Krishna Kumar, Nitish Kumar (coincidentally the same name as Bihar's Chief Minister), Vijay Kumar, and Sanjay Kumar. Their rice crops were cultivated on well-drained upland soils with tubewell irrigation, and all worked closely with the local staff of the Agricultural Technology Management Agency (ATMA) for Nalanda district. Using tubewell irrigation gave the farmers both incentive and capability to apply water sparingly, as is recommended with SRI practice. Excess water applications from a tubewell cost the

farmers more money, and they can control water applications better than in gravity irrigation schemes.

The successful farmers have more than high school education, with 10 years of schooling plus 2 or 3 years of additional training beyond matriculation. Their landholdings are medium-sized for the region, 5 to 7 acres (2.0 to 2.8 ha). The size of Sumant's SRI test plot was 1 acre, from which an area of 50m^2 (10x5m) was demarcated in the middle of the field, then being harvested, threshed and weighed to calculate yield. This measurement was made using the Department of Agriculture's standard methods. The same methods were used for evaluating the farmers' yields with conventional agricultural practice on nearby plots. The SRI plots of each of the other four farmers were also 1 acre each. Their area of conventionally-grown paddy rice in 2011 was 5 to 7 acres. These are thus middle-sized farmers.

Agronomic Information

Soils: The soils in the area can be characterized as sandy clay, but no detailed information on soil chemistry and physical properties was generated before or during the season. Neither is information on biological parameters available, unfortunately. We are trying to get these variables assessed as they could be critical factors in explaining the high yields recorded.

Cropping System: The cropping pattern of these farmers in the preceding year was a typical rotation common in the area: rice in the previous *kharif* season (2010), followed by potatoes, and then muskmelon, with *dhaincha* (sesbania) planted as a green manure cover crop before the 2011 main-season rice crop. Interestingly, the previously reported record yield from Madagascar was also attained with a rice/potatoes/legume rotation.

Varieties: Sumant Kumar planted the Bayer hybrid variety Arize 6444, while the other four farmers used Syngenta's hybrid 6302. (Information on the varieties planted and resulting yields for another 52 farmers in Nalanda district is given below.) These are medium-duration varieties with a usual crop cycle of about 150 days, but in this season, Sumant's SRI crop reached maturity in 142 days. It is common for SRI management to reduce the length of the crop cyde.

Nursery Management and Seedling Age: Upland nurseries of 100 m^2 were established, with a seed rate of 5 kg/ha for the SRI nursery compared with a usual rate of 35-40 kg/ha. Both the SRI and regular nursery were sown on June 20, 2011, and the seeds for both nurseries were treated with Carbendazim (2 g/kg) for protection against seed-borne diseases. The SRI nursery soil was kept moist but not flooded, while the regular nursery was irrigated with a pump set. Seedlings were removed from the SRI nursery on July 3, while those planted for regular rice cropping were taken out on July 15. Respective seedling ages were thus 12 days and 24 days.

Land Preparation: Deep ploughings of the SRI field were done on May 1 and June 16, followed by shallow ploughing on June 21 and June 29, with puddling of the field on July 2 and July 3, the latter being the day for transplanting. The ploughing operation incorporated the *dhaincha* (green manure) vegetative material into the soil of both the SRI and the normal-practice fields.

Soil Amendments and Crop Fertilization: Farmyard manure (FYM), applied to the SRI field at a rate of 6 tons/ha, was incorporated during land preparation. Both the SRI and the normal-practice fields received the same amounts of inorganic fertilizer, added as basal doses the day before transplanting, i.e., July 2 for the SRI field, and July 15 for the regular field. The applications of P and K were, respectively, 80 kg/ha of diammonium phosphate (DAP) and 40 kg/ha of potash. During the season, N was applied as urea at a rate of 40 kg/ha, in split doses on July 18 and August 22, a relatively low rate of N supplementation.

For organic soil fertilization of the SRI plot, there was an application of poultry manure on July 2 at a rate of 400 kg/ha, plus 100 kg/ha of vermicompost and 40 kg/ha of a compound containing phosphorus-solubilizing bacteria (PSB) at the same time. The PSB were expected to make unavailable P residing within the soil available in the soil solution. Also, a micronutrient foliar spray of monohydrated zinc sulphate @ 25 kg/ha was applied on *both* the SRI and conventional fields on August 22.

The fertilization practices followed for SRI compared to usual production practices thus differed only in that the latter *did not receive* FYM, poultry manure, or vermicompost prior to transplanting. Also, for the conventional crop, the top dressings of urea were made later (July 18 and August 30) as was the ZnCl foliar spray (August 30).

Crop Establishment: As noted above, there was a distinct difference in **seedling age** between the two fields: 12 days vs. 24 days. SRI seedlings were transplanted at 25x25 cm distance in a grid pattern, one seedling per hill, giving a **plant density of 16/m^2**. Regular-practice seedlings were transplanted 12 days later in a random pattern in the field, with 3-5 seedlings per hill. The plant population under SRI management was thus much lower than with standard crop management practices. With SRI, the number of plants/m^2 was reduced by 75-80%.

Weed and Pest Management: The main weed problem for these farmers was broad-leafed weeds, and in the regular field a herbicide (2,4-D) was sprayed to control these, applied at a rate of 1.5 liters/ha. In Sumant Kumar's SRI field, on the other hand, there was **no chemical weed control, only soil-aerating cono-weeding** done at 13 days and 26 days after transplanting. No chemical crop protection measures were taken as no insect pests or diseases or rodents were observed in either the SRI or regular fields.

Water Management: This presented a major difference between the two cropping strategies. The regular field was managed with flood irrigation, while the SRI field was served by sprinkler

irrigation.No volumetric measurements were made of the total amounts of water used. However, an estimate is that the SRI crop received about **one-third as much water** during the crop-growing seasoncompared with the amount applied in flood irrigation.

Harvesting: Sumant Kumar'sSRI and regular fields were harvested, respectively,on November 10 and November 20, so his SRI crop matured 10 days sooner from the date of sowing in the nursery, while giving a much higher yield. The SRI crop cycle was 142 days, compared to the usual time to maturity of 150 days (in this case, 152 days for the regular-practice field).

The paddy rice harvested from the 50 m^2crop-cuttingon the SRI plot weighed 112 kg. This represented a wet-rice yield of 22.4 tons/ha. The dried weight of the paddy from the harvested area of 50 m^2 was 100.8 kg, which represents a dried-weight yield of 20.16 tons/ha, well above the previously reported world-record yield from China of 19 tons/ha.

Other High Yields in Village: As noted above, four of Sumant's neighbors also got remarkably high yields using the same methods, although with a different hybrid variety(Syngenta 6302). Their dates for maturity and harvesting were 12 days later than that of Sumant, November 22, reflecting a varietal difference in crop cyde.

	Yieldfrom 10x5 m^2 area (kg)		Yield (t/ha)	
Name	Wet	Dry	Wet	Dry
Krishna Kumar	101	90.9	20.2	18.18
Nitish Kumar	98	88.2	19.6	17.64
Vijay Kumar	96	86.4	19.2	17.28
Sanjay Kumar	95	85.5	19.0	17.10

These farmers along with Sumant Kumar have been advised to use a similar package of practices with the same hybrids on the same plots in the next *kharif* season to assess yield stability. All agronomic yield-contributing factors will be recorded with soil testing of nutrients.

Differential in Yield between SRI and Regular Methods

The Department of Agriculture measured comparison yields attained withconventional methods on the same farms, with the same variety,for only three of the five farmers. But the differentials are great enough that it is highly unlikely that the differences in yield are attributable to measurement errors, and 3 out of 5 is a reasonable sample. Since the same in-field sampling and harvesting methods were used by the same technical personnel for both the SRI and the regular crop measurements, the relative differences (ratios) should be reliable even if any questions areraised about the absolute figures.

The data for Sumant Kumar's farm showed a dried-weight yield of 6.5 tons/ha from his regular field using the hybrid variety 6444.Nitish Kumar's hybrid yield with usual methods was5.9 tons/ha; and for Sanjay Kumar, it was 6.0 tons/ha.These yields are only *about one-third* of the yield measured from these same farmers' SRI fields. Moreover, they are in line with the hybrid yields achieved by other farmers in the area, which were from 5.0 to 6.5 tons/ha.

This differential could possibly be attributedin part to differences in field conditions and field management. However, the varieties, the farms, and the farmers were all the same. Thus, the soils and genotypes as well as farmer skill were not different for these comparisons. The main influence would have beenattributable to agronomic practices, which is of significantinterest.

Differences in Crop Management

The differences in practices were the following:

Practices	**SRI management**	**Conventional management**
Nursery management	Moist but well-drained soil	Flooded soil
Nursery seed rate	5 kg/ha	35-40 kg/ha
Plant management:		
Age of seedlings	12 days	24 days
Transplanting	Single seedlings in grid	Random transplanting
Planting density	16/m^2	~60-70/m^2
Soil-water management	Sprinkler irrigation	Flooding
Weed management	Soil-aerating weeding	Herbicides
Nutrient management*	More organic soil amendments: farmyard manureandvermi-compost with green manure	Recommended NPK applications, with green manure
*Both fields got PSB applications and micronutrient foliar sprays		

A much smaller plant population, which matured in 10days' less time, gave significantly higher yield. This was associated not just with reduction in seeds, but also with reduced water applications (by as much as two-thirds), and with little reliance on inorganic fertilizer, instead emphasizing organicsoil amendments.

Two other differences that stand out were the**age of seedlings** (for SRI, this was considerably younger) and the **method of weed control** (SRI involved activesoil aeration). Also differences in nursery management need to be considered, as assessed previously by Mishra and Salokhe (*Experimental Agriculture*, 2008, 44:1, 1-19).

Economic Evaluation

A common perception of SRI management has been that it is more labor-intensive. When farmers first begin to use the new methods, when they are just starting up their learning curve, the field work does go more slowly. But the data available from the Department of Agriculture indicate, as seen in other evaluations, that when the SRI methods listed above are practiced, there is labor-saving in most of the cultivation operations.

Nursery: A DRR assessment in Bihar has shown that with SRI, there is a saving of 40 man-hours per hectare for nursery management, given its radical reduction in nursery area and its much lower seed rate. Another 50 man-hours per hectare are saved when pulling out and transporting seedling bundles from the nursery area to the main field because they are fewer and smaller.

Transplanting: Due to more widely spaced transplanting and much lower numbers of plants, fewer labourers were required with SRI management. Farmers report that 50-60 women labourers were needed with conventional transplanting methods, whereas only 25–30 labourers were needed with SRI.

Weeding: Once skill is acquired in using the conoweeder, weed control operations can also require less labour compared with the usual hand weeding. Moreover, this work becomes a less laborious process than for the manual removal of weeds.

Reduced costs of labour with SRI as compared to conventional method of rice-growing are:

	SRI (Rs /ha)	Conventional (Rs/ha)	Savings (Rs./ha)	Reduction (%)
Nursery	1,200	1,800	600	33
Transplanting	2,390	2,895	505	17
Weeding	2,600	4,405	1,805	41
Total	6,190	9,100	2,910	32

The DRD data showed SRI reducing labour for these major operations by 32% in the sampled farms.

On the other hand, more labor is needed to manage the water applications according to the SRI principle of keeping the paddy soil moist but not continuously saturated. Still, the higher cost of labor for irrigation is offset by reduced payments for the water itself, since less is required.

There is of course more cost for harvesting because the yield is much higher, but this added cost is compensated for several times over by the higher production and by the resulting

greater income. Cost per kilogram of paddy produced is much lower with SRI management, giving farmers more income.

Varietal Differences

From Agriculture Department data for 57 farmers in Nalanda district where crop-cut estimates of yield were made for farmers using SRI methods, we can report differences in average yields for a number of different varieties, as show below. Average SRI yield for the whole set of farmers was 9.34 tons/ha. These results are very encouraging for adoption of SRI production methods, and also for hybrid varieties. Note that with a larger numbers of farmers, the average yield for Arize 6444 was less than with Syngenta 6032. This underscores that the growing environment, which includes the soil biota, has as much or more of an impact on results than simply the genotype involved. This also suggests that farmer differences are important in accounting for yield outcomes.

Variety	No. of farmers	Average SRI yield (t/ha)
Syngenta 6032	4	17.85
Arise 6444	8	12.82
Loknath 505	1	12.75
Pusa 44	39	7.90
Dhaniya 775	3	7.66
VNR	1	7.62
Basmati Kohinoor	1	6.75
All varieties	57	9.34

Observations

The experiences of Sumant Kumar and his neighboring farmers give strong support to the recommendations that derive from the work with rice and with farmers in Madagascar by Fr. Henri de Laulanié:

- Manage a smaller nursery carefully with lower seed density and with aerobic soil conditions
- Transplant young seedlings singly, carefully, and with wide spacing, in a square pattern
- Apply only as much water as the plants need for their growth
- Control weeds with several soil-aerating weedings, and
- Enhance organic matter in the soil as much as possible.

What has not been assessed in Darveshpura is what effect, if any, these practices may have had on the **soil biota**: the massive and complex populations of bacteria, fungi, protozoa, and other larger organisms like mites and earthworms that inhabit the soil under favorable conditions. These diverse organisms are known to have many beneficial effects on plant growth and to be promoted in aerobic soil with abundant organic matter.

It can be hypothesized that in this situation the soil biota played some role, perhaps an intermediary role, in producing healthy and more productive rice plants. That as many as five farmers in fairly close proximity achieved such super-yields of paddy rice lends some weight to this hypothesis and raises the possibility that soils in Darveshpura have some particularly beneficial species or associations of soil organisms. This seems to be supported by experience in this village with the ensuing potato crop (see box).

The results from the past kharif season in Nalanda district show that improvements in genotype can make a significant contribution to raising paddy yield, but that changes in management practices, providing plants with optimum growing conditions, can have even greater impact. What is little understood is what impact the altered practices are having upon organisms in the soil which can provide a multiplicity of services and benefits, including nutrient cycling, nitrogen fixation, phosophorus solubilization, phytohormone production especially to promote root growth which is beneficial to the soil biota as well as to the plant, protection against various pathogens, and induced systemic resistance to support plant health.

Much research and evaluation remains to be done, but the Darveshpura results may support a paradigm shift for agriculture that focuses upon the life in the soil rather than so much on inorganic amendments as now favored and promoted, often to the detriment of the soil biota.

We have encouraged Indian colleagues with expertise in soil microbiology to do some studies of the soils in this village, but that work remains to be done. Already the paddy results from the 2011 *kharif* season in Bihar should remove any remaining reservations about utilizing SRI ideas and methods on a broader scale, making appropriate adaptations to local conditions which is in fact part of the SRI methodology.

BOX: WORLD-RECORD YIELDS IN DARVESHPURA FOR POTATO PRODUCTION

There are reports from Darveshpura that some potato farmers there were able this past year to produce potatoes weighing much as 800-1,000 grams, i.e., up to 1 kilogram each. One farmer in the village, Nitish Kumar (with the same name as one of the farmers there who achieved a paddy super-yield and also as Bihar's Chief Minister), produced a world-record yield of almost 73 tons/ha, far surpassing the previous record yield of 45 tons/ha reported from the Netherlands (http://www.dailypioneer.com/home/online-channel/dont-miss-it/49620-Bihar-farmer-sets-world-record-in-potato-production.html; http://www.indianexpress.com/news/After-paddy-feat--a-Nalanda-village-looks-at-potato/904362/; http://www.patnadaily.com/index.php/news/7060-world-record-in-potato-production-for-bihar-farmer.html).

From Verma's discussion with this Nitish Kumar, we know that his potato production methods featured:

- Extracting the eyes, treating them with a chemical solution, and sprouting them before planting
- Wider spacing between plants than normal
- Good pulverisation of the soil, so that roots could grow easily

- Use of both organic and inorganic fertilisers (vermicompost, poultry compost, NPK)
- Intercultivating between rows and plants two times, which loosened the surface soil

These practices contributed to having a well-aerated, organically-rich environment around the potato plant roots, with room for both roots and canopies to grow. The soil is also relatively rich in silicon, which is an element often neglected. Like other farmers in the village, Kumar has been influenced by the new knowledge coming in from SRI training, and his practices represent an adaptation of agroecological principles.

In many villages in Bihar, farmers have begun adapting them to improve production of crops like mustard, tomatoes, chillies and brinjal. The Bihar Rural Livelihoods Promotion Society (BRLPS) working with NGOs like PRADAN is supporting such innovation under the rubric of System of Crop Intensification (SCI) or called the System of Root Intensification as an expanded version of SRI: http://www.brlp.in/admin/Files/Concept%20Note%20on%20National%20Colloquium%20on%20SCI.pdf.