Nalanda District, Bihar: World-Record Sri Yields

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Experimenting with SRI cultivation, five farmers of Darveshpura village in Bihar attract considerable attention with their bumper yield; the results indicate a viable alternative to the conventional methods of growing rice and other crops

Initially, Sumant Kumar's bumper yield with SRI—quite an achievement—was met with skepticism; but the yield was properly measured and has now been accepted by the Indian Council for Agricultural Research (ICAR) and was acknowledged and confirmed by the Minister of Agriculture in Parliament on 20 March 2012 (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 18 or 19 tonnes per ha. Sumant Kumar's achievement was not an isolated occurrence; the accomplishment, therefore, deserves attention.

There is an 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 conducted on the Darveshpura achievement. We present here what was known at the end of the season about the process and the result.

SRI stands for System of Rice Intensification, a set of principles and practices developed in Madagascar for raising the productivity of the seeds, land, labour, capital and water used in paddy production. SRI does this by altering the way that rice plants, soil, water and nutrients are managed. It does not require farmers to acquire new or improved seeds or chemical fertilizers to raise their yield, although in this case, the rice varieties planted were hybrids and there was an integrated nutrient management, which combined organic and inorganic inputs. SRI has been controversial because of some very large increases in yield (more than 20 tonnes per hectare) that were previously reported from Madagascar when all the recommended practices were used simultaneously as prescribed. This report may reduce some of this controversy because the inputs and the outputs of super-yield production are better documented here than before.

DATA GATHERING AND INFORMATION ON THE LOCAL SITUATION

Dr. Kumar, a senior agronomist with the government's Directorate of Rice Development (DRD) in Patna and a co-author of this report, visited the farmers' fields in Darveshpura and other villages in Nalanda and other districts of Bihar when the crops were being cut in the SRI demonstration plots at the end of the 2011 *kharif* season. When verifying facts about rice production in the high-yield SRI demonstration plots, he collected many details; he also talked with the officers of the state Department of Agriculture, regarding the implementation of the SRI demonstrations.

Dr. Kumar observed that, being well-educated, most successful farmers had a good ability for learning and adopting the innovative technology in their fields. Agriculture is their single source of household income; they, therefore, try to utilize the inputs available to them in the best possible way. These farmers used green manuring, particularly *dhaincha* (sesbania), along with vermi-compost and other organic sources of nutrients, and a small amount of chemical fertilizer. No major insect pests or diseases attacked or afflicted these rice fields when the crop grew, possibly a reflection on the suite of crop management practices. More information on the cultivation methods used is discussed here.

Darveshpura village and the SRI demonstration plots are situated on the banks of the Sakri river. The water table in the village 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 soil is largely sandy clay and well-drained, with no water-logging. Soil pH is in the neutral range. Climate and rainfall distribution were better in 2011 than the previous year when much of Bihar experienced serious drought conditions. So, certainly, conditions were favourable.

In the sandy/sandy clay soil of Darveshpura, inter-cultivation (weeding) between rows is easier than in the heavy clay soil where a hard plain impedes water percolation. Using a cono-weeder, 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 the ability and efficiency in nutrient uptake of plants.

The farmers in this area practise various rotations during a cropping year. The main rotations are: rice/wheat/*moong* (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 pockets, a rotation of rice/potato/muskmelon or watermelon is also practised. Sweet potatoes are grown in some villages.

Dr. Kumar and by Anil Verma gathered information on how Sumant Kumar and the other farmers in his village got paddy yields of 18 or 19 tonnes per ha from the department officials, who supervised and measured the yield. Sumant Kumar himself volunteered much of the information. Verma, as team leader of PRADAN, the NGO that introduced SRI in Bihar in the neighbouring Gaya district, helped train officials and technicians in Nalanda district, who in turn trained the farmers there in SRI methods. Like Dr. Kumar and Dr. Diwakar, who as DRD Director had visited the area, Verma

was well-acquainted with local officials and farmers. Having developed a rapport with the locals, they got information from local sources freely and could assess whatever they learned in the light of what else they knew about the area and its agriculture from previous visits.

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The Department of Agriculture officials in the district prepared detailed crop reports of the five very successful farmers and also produced a summary report on the 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 to Prof. Uphoff by Dr. Diwakar. Both had been following and conferring with each other on the introduction and spread of the SRI in Bihar as well as elsewhere in India. Prof. Uphoff worked with the co-authors to analyze and present this body of data and information to have a better understanding of the 2011 SRI experiences in Darveshpura village because these would be significant for other farmers in India and elsewhere in the world.

TRIPLING OF THE YIELD

The yields that the Darveshpura farmers obtained, using a particular set of SRI-formulated practices, were three times higher than the yields that they achieved using their usual management methods from the same hybrid varieties in the 2011 *kharif* season. 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 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.

THE SUCCESSFUL FARMERS

The five farmers—all relatively young, between 30 and 35 years old—are Sumant Kumar, Krishna Kumar, Nitish Kumar, Vijay Kumar and Sanjay Kumar. Their rice crops were cultivated on well-drained upland soils with tube-well irrigation, and all worked closely with the local staff of the Agricultural Technology Management Agency (ATMA) of Nalanda district. Using tube-well irrigation gave the farmers both the incentive and the capability to apply water sparingly, as is recommended with the SRI practice. Excess water applications cost the farmers more money, and with tube-wells they can control water applications better than in gravity irrigation schemes.

These five farmers have had 10 years of schooling plus two or three years of additional training beyond matriculation. Their landholdings are medium-sized for the region, five to seven acres (2.0 to 2.8 ha). The size of Sumant's SRI test plot was one acre, from which an area of 50 sq m (10 x 5 m) was demarcated in the middle of the field, then being harvested, threshed and weighed, to calculate the yield. The crop was measured, using the Department of Agriculture's standard methods. The same methods were used for evaluating the yields through conventional agricultural practices on nearby plots. SRI plots of each of the other four farmers also measured one acre each. Their area of conventionally-grown paddy rice in 2011 was five to seven acres. These are thus farmers with moderate landholdings.

AGRONOMIC INFORMATION

Soils: The soils in the area can be characterized as sandy clay, but no detailed information on the soil chemistry and its physical properties was

generated before or during the season. Neither is information on the biological parameters available, unfortunately. We are trying to get these variables assessed because they could be critical factors in explaining the high yields.

The fertilization practices followed for SRI differed from the usual production practices only in that the latter did not receive the FYM, poultry manure, or vermi-compost, prior to transplanting

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 whereas the other four farmers used Syngenta's hybrid 6302. (Information on the varieties planted and resulting yields for another 52 farmers in Nalanda district follows). 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. This is not unusual for the crop cycle to get reduced in SRI.

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

Land preparation: On May 1 and June 16 the SRI fields were ploughed deep, followed by shallow ploughing on June 21 and June 29, with the puddling of the fields 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 conventional fields.

Soil amendments and crop fertilization: Farmyard manure (FYM) was applied to the SRI fields at the rate of 6 tonnes per ha at the stage of land preparation. Both SRI and the conventional fields received the same amount of inorganic fertilizers, added as basal doses the day before transplanting, that is, on July 2 for the SRI field, and on July 15 for the regular fields. The applications of P and K were, respectively, 80 kg per ha of diammonium phosphate (DAP) and 40 kg per ha of potash. During the season, some N was applied as urea, at a rate of just 40 kg per 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, poultry manure was applied on July 2 at a rate of 400 kg per ha, plus 100 kg of vermi-compost and 40 kg per ha of a compound containing phosphorus-solubilizing bacteria (PSB) at the same time. The PSB were expected to make unavailable the P residing within the soil. Also, a micro-nutrient foliar spray of monohydrated zinc sulphate was applied at the rate of 25 kg per ha on *both* SRI and conventional fields on August 22.

The fertilization practices followed for SRI differed from the usual production practices only in that the latter did not receive the FYM, poultry manure, or vermi-compost, 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: There was a distinct difference in the age of the seedlings at the time of transplantation in the two fields: 12 days vs 24 days. SRI seedlings were transplanted at 25 x 25 cm distance in a grid pattern, one seedling per hill, giving a plant density of 16 per sq m. Regular-practice seedlings were transplanted 12 days later in a random pattern in the field, with three to five seedlings per hill. The plant population under SRI management was thus much lower than standard crop management practices. With SRI, there was a 75–80 per cent reduction in the number of plants per sq m.

Weed and pest management: Broad-leaf weeds were the main problem of the farmers in this area. In regular fields, a herbicide (2, 4-D), was sprayed to control these, applied at a rate of 1.5 litres per ha. In Sumant Kumar's SRI field, on the other hand, there was no chemical weed control, only soil-aerating cono-weeding done 13 days and 26 days after transplantation. No chemical crop protection measures were taken because there were no insects, pests, diseases or rodents observed in either the SRI or the regular fields.

The regular field was managed with flood irrigation whereas the SRI field was served by sprinkler irrigation. No volumetric measurement was made of the total amount of water used; however, an estimate is that the SRI crop received about one-third as much water during the crop-growing season compared to the flood irrigation for the conventional fields

Water management: This revealed a major difference between the two cropping strategies. The regular field was managed with flood irrigation whereas the SRI field was served by sprinkler irrigation. No volumetric measurement was made of the total amount of water used; however, an estimate is that the SRI crop received about one-third as much water during the crop-growing season compared to the flood irrigation for the conventional fields.

Harvesting: Sumant Kumar's SRI and regular fields were harvested, respectively, on November 10 and November 20, so his SRI crop matured 10 days sooner and in addition had 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 that was harvested from the 50 sq m crop-cut on the SRI plot weighed 112 kg, representing a wet-rice yield of 22.4 tonnes per ha. The dried weight of the paddy from the harvested area was 100.8 kg, which represents a dried-weight yield of 20.16 tonnes per ha, well above the previously reported world-record yield from China of 19 tonnes per ha.

Other high yields in the village: Four of Sumant's neighbours 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 the crop cycle.

	Yield from 10 x 5 sq m 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

To assess yield stability, 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. All agronomic yield-contributing factors will be recorded with the soil testing of nutrients.

DIFFERENTIAL IN YIELD BETWEEN SRI AND REGULAR METHODS

The Department of Agriculture measured the yields attained with the conventional methods for only three of the five farmers. But the differentials are so great, that it is highly unlikely that the differences in the yield can be attributed to measurement errors, and three out of five is a reasonable sample. Further, the same in-field sampling and harvesting methods were used by the same technical personnel for both SRI and the regular crop measurements. So relative (ratio) differences should be reliable, even if any questions are raised about the absolute figures.

The data for Sumant Kumar's farm showed a dry-weight yield of 6.5 tonnes per ha from his regular field with the hybrid variety 6444. For Nitish Kumar, his hybrid yield, using the regular method, was 5.9 tonnes per ha; and for Sanjay Kumar, it was 6.0 tonnes per ha. These yields are only about one-third of the yield measured from the SRI fields of the same farmers. Moreover, they are in line with the hybrid yields achieved by other farmers in the area, which ranged from 5.0 to 6.5 tonnes per ha.

This differential could be attributed in part to the differences in the 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 skills were not different in these comparisons. The main influence on the differential yield would be attributable to agronomic practices, which is of significant interest.

DIFFERENCES IN CROP MANAGEMENT

The following are the differences in the practices.

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

Practices	SRI Management	Conventional Management
Transplanting	Single seedlings in grid	Random transplanting
Planting density	16/sq m	~60-70/sq m
Soil-water management	Sprinkler irrigation	Flooding
Weed management	Soil-aerating weeding	Herbicides
Nutrient management*	More organic soil amendments: farmyard manure and vermi-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 a shorter time, gave a significantly higher yield. This was associated not just with the reduction in seeds, but also reduced water applications (by as much as two-thirds), and with little reliance on organic nutrient amendments, instead emphasizing organic soil amendments. Two other differences that stand out were the age of the seedlings (for the SRI these were considerably younger) and the method of weed control (the SRI involved active soil 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 labour-intensive. It is true that when the farmers first begin to use these new methods, when they are just starting on their learning curve, the work does progress slowly. But the data available from the Department of Agriculture indicate, as seen in other evaluations as well, that when SRI methods, as listed above, are practised over a period of time, there is labour-saving in most of the cultivation operations.

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

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

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

Reduced costs of labour with SRI as compared to the 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 results showed that SRI reduces labour for these major operations by 32 per cent in the sampled farms.

On the other hand, more labour is needed to manage the water applications, according to the SRI principle of keeping the paddy soil moist but not continuously saturated. But the higher cost of labour for irrigation is offset by the reduced cost for the water itself. The harvesting is also more expensive because the yield is much higher, but this added cost is compensated for, several times over, by a higher production and the resulting greater income. **The cost per kilogramme of paddy produced is much lower with the SRI management, giving the farmers more income.**

VARIETAL DIFFERENCES

From the Agriculture Department data for 57 farmers in Nalanda district, where crop-cut estimates of yield were made for farmers using the SRI methods, we can report on the differences in average yields for a number of different varieties, as shown in the following table. The average SRI yield for the whole set of farmers was 9.34 tonnes per ha. These results are very encouraging for SRI production methods and also for hybrid varieties. With a larger number of farmers, the average yield of Arize 6444 is less than that of Syngenta 6032, which underscores that the growing environment, including the soil biota, has as much or more impact on results than simply the genotype involved. This also suggests that farmer differences are important in accounting for the 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 neighbouring 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 a lower seed density and with aerobic soil conditions.
- Transplant young seedlings singly, carefully and with wide spacing.
- Apply only as much water as the plant needs for its growth.
- Control weeds with soil-aerating weeding.
- 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, which has favourable 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.

In this situation, therefore, the soil biota possibly played some role, perhaps an intermediary one, in producing healthy and more productive rice plants. That as many as five farmers in fairly close proximity achieved such super-yields 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 potato crop last year (see box).

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The results from the past *kharif* season in Nalanda district show that improvements in the genotype can make a significant contribution to raising the paddy yield, but that changes in management practices, providing plants with optimum growing conditions, can have an even greater impact. What is little understood is what impact the altered practices have upon organisms in the soil, which can provide a multiplicity of services and benefits, including nutrient cycling, nitrogen fixation, phosphorus solubilization, phytohormone production especially to promote root growth, 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 life in the soil rather than the inorganic amendments now favoured, often to the detriment of the soil biota.

We have encouraged Indian colleagues with expertise in soil microbiology to conduct 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.

WORLD-RECORD YIELDS IN DARVESHPURA FOR POTATO PRODUCTION

There are reports from Darveshpura that some potato farmers were able, this past year, to produce potatoes weighing as much as 800–1,000 gm, that is, up to 1 kg each (http://www.indianexpress.com/news/After-paddy-feat--a-Nalanda-village-looks-at-potato/904362/).

One farmer—also called Nitish Kumar—in the village 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).

From Verma's discussions with the farmer we know that the potato production methods featured were:

- Extracting the eyes, treating them with a chemical solution and sprouting them before planting them.
- Wider spacing between plants than normal.
- Good pulverization of the soil, so that the roots could grow easily.
- Use of both organic and inorganic fertilizers (vermi-compost, poultry compost, NPK).
- Inter-cultivating between rows and plants two times, thereby helping to loosen the surface soil.

These practices contributed to having a well-aerated, organically-rich environment around the 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 new knowledge coming in from the SRI training, and his practices represent an adaptation of the agro-ecological principles.

In many villages in Bihar, farmers have begun adapting these principles, to improve the production of crops such as mustard, tomatoes, chillies and brinjals. The Bihar Rural Livelihoods Promotion Society (BRLPS), working with NGOs such as PRADAN, supports such innovations under the rubric of the System of Crop Intensification (SCI) or the System of Root Intensification, a new kind of 'SRI'.