System of Rice Intensification

Enhancing input use efficiency in rice

SRI

MORE CROP PER DROP

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DRR

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Preface

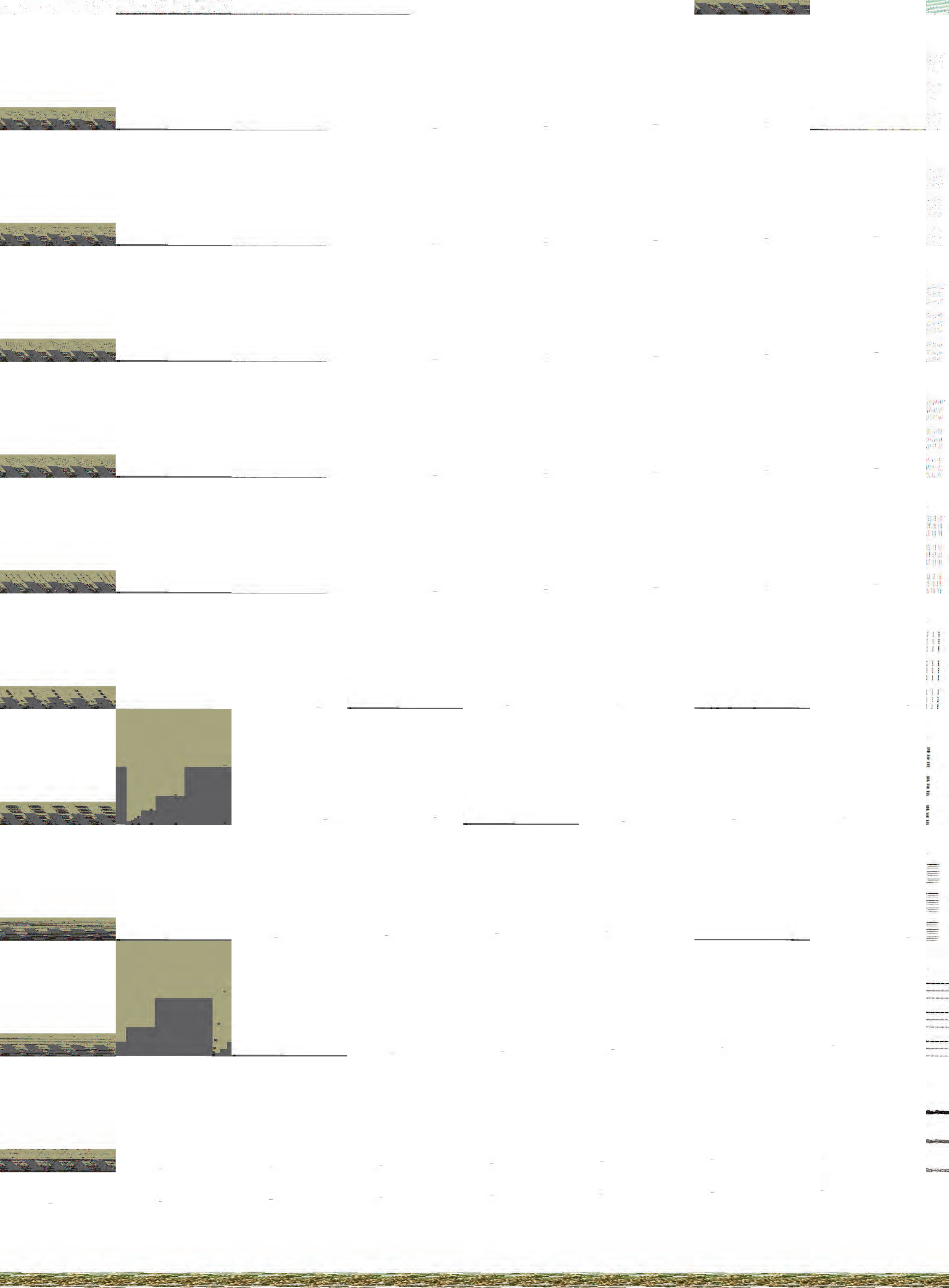
Sustainable food security in India remains an important agenda given the ever increasing population and widening gap between food availability and consumption at the house hold level. Rice being the staple food crop holds the key for food security of India. It is grown in about 44 m.ha with a production of about 99 m.t. At the current rate of population growth and per capita consumption, rice requirement by 2025 is estimated to be around 130 m.t. Keeping this in view, the Government of India has launched the National food Security Mission to achieve the production of additional 10 million tons of rice by the end of the XI plan period Production of additional 20-30 m.t. of rice by 2025 has to come in the backdrop of declining resources such as land, water, labour and the costly inputs. Area under rice is expected to be reduced to about 40 m.ha in the next 15 – 20 years and most of this reduction is attributed to water shortages and rapid urbanization. Recent estimates indicate that there would be acute water shortages in the coming decades. More than 80 per cent of fresh water is consumed for agriculture and 50% of it goes for rice cultivation. Rice consumes about 4000 – 5000 liters of water to produce 1 kg of rice. Therefore, rice cultivation could face a threat due to water shortages and hence there is an urgent need to develop and adopt water saving methods in rice cultivation so that production and productivity levels are elevated despite the looming water crisis.

Basically, rice is not an aquatic plant. However, its ability to withstand water stagnation has made it as a water loving plant. The main purpose of inundating rice fields is to control the weeds very easily. There is enormous scope for reducing the water usage in rice cultivation and making rice cultivation more water use efficient. Some of the farm level interventions are i) alternate wetting and drying, ii) raised bed cultivation, iii) direct seeding, iv) aerobic rice and v) system of rice intensification. Among these options, System of Rice Intensification (SRI) has an edge over others as this method offers not only water saving but also enhances the yields and helps in environmental protection. Under the circumstances, innovative farmer –friendly strategies that can meet the lively hood and food security of millions of small and marginal farmers are essential. System of Rice Intensification (SRI) that has evolved during the early 1980's and adopted by millions of the farmers in nearly 40 countries is one of the viable options for improving productivity and farm incomes while conserving precious natural resources.

To get insight in to the SRI method and to optimize it for realizing full benefits, agronomic trials were conducted at DRR and several AICRIP centers spread across the country. The results obtained from these trials on various aspects of SRI are summarized in this bulletin. This publication contains comprehensive information on all aspects of SRI, package of practices and it is hoped that this will be of immense use to the researchers, extension workers, students working on rice especially on SRI and farmers in different regions of the country.

08.04.2011
Hyderabad

(B.C. Viraktamath)
Project Director



Contents

RICE PRODUCTION SCENARIO IN INDIA

Rice is the staple food for more than half of the world's population and plays a pivotal role in food security of many countries. More than 90% of the global production and consumption of rice is in Asia. As for India, rice is not only a food commodity but also a source of livelihood for millions and foreign exchange earnings of about 12,000 crores annually. Since attaining independence in 1947, India has witnessed a remarkable progress in rice production. Though there has been only one and half times increase in the area from 30 to 44 m.ha, the productivity increased three times from 700 kg ha^{-1} to 2000 kg ha^{-1} and the annual rice production has increased more than four times from 21 m.tons to 99 m.tons in 2008-09 (Table 1). India ranks first in area in the world (44.0 m ha). Growth trends in rice area, production and productivity during the last five and half decades are given in (Table 2) indicating progressive decline in recent years.

Table 1 : Rice area (m. ha), Production (m. t) and Productivity (kg/ha) from 1950-51 to 2008-2009 in India

Year	Area (m. ha)	Production (m. t)	Productivity (kg/ha)
1950-51	30.8	20.6	668
2006-07	43.8	93.3	2191
2007-08	43.9	96.6	2202
2008-09	45.5	99.2	2178

Table 2 : Growth trends (compound growth rate, %) of rice area, production productivity and area under irrigation during the period 1950-51 to 2005-06

	During the decade ending					2000-01	Overall
	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	to 2005-06	
Area	1.26	0.83	0.88	0.41	0.67	-0.45	0.68
Production	4.46	1.19	1.90	3.62	2.02	0.46	2.63
Productivity	3.15	0.36	1.02	3.19	1.34	0.91	1.94
Irrigated area	2.90	1.04	2.08	1.65	2.33	-	-

Currently, mainstream technological options to improve rice production focus mainly on

1. Adoption of high yielding varieties/hybrids
2. Adoption of improved crop production (nutrients, water and other inputs) and protection (pests, disease and weeds) technologies

Based on the current rate of population growth (1.4%) and per capita consumption (215 - 230 g/day), the projected demand for rice by 2025 would be around 130 m tonnes. The rice production has to be invariably enhanced by more than 2 m. tonnes annually to meet the future requirements. The projected demand has to be met in the background of declining land and water resources, scarcity of labour and costly inputs which are making rice cultivation too expensive. Reducing the cost of cultivation and making rice cultivation more profitable to the farmers is the need of the hour. Among these constraints, water scarcity will pose a major threat to rice cultivation and all our efforts are needed to enhance water productivity and to ensure production of more rice crop from every drop of water.

Water and irrigated rice

Irrigated rice occupies about 50% total rice area and contributes nearly 70% to total rice production of the country with an average yield of 3.1 t/ha. India's food security largely depends on irrigated rice which consumes nearly 50- 60% of our finite fresh water resources. Flooded rice cultivation requires 900-2200 mm of water (average 1500 mm) depending on the water management, soil and climatic factors. It is estimated that rice needs about 3000-5000 liters of water to produce one kg of grain which is three to five times more than the other cereals like wheat, corn etc. The expenditure towards water alone is 20-30% of the total variable cost of rice production (Table 3).

Table 3 : Average water requirement of irrigated rice

Farm operation/process	Consumptive use of water (mm)
Land preparation	150 – 200
Evapo-transpiration	500 – 1200
Seepage and percolation	200 – 700
Mid season drainage	50 – 100
Total	**900 - 2200**

There is growing awareness about the need to optimize water use in rice production which will have far reaching effects. At constant level of fresh water availability, per capita supply of water is decreasing progressively with time. Besides, competing demands for water from industrial and urban sectors, and the predicted climate changes are likely to further accentuate the impending water crisis, more so, for rice production which warrant change in the practices adopted for rice cultivation. Water is going to be most critical input in the future for agriculture in general and rice cultivation in particular. Per capita water availability has dwindled from 5.3 x10^3m^3/year in 1955 to 2.5 x10^3m^3/year in 1990 and is expected to further decrease to 1.5 x10^3m^3/year by 2025 (Fig1). Availability of water for agriculture may drastically go down from the present 90 to 60 % by the year 2025 thus putting enormous pressure on rice cultivation.

Share of water for agriculture is likely to drastically go down from 90 to less than 60% by the year 2025.

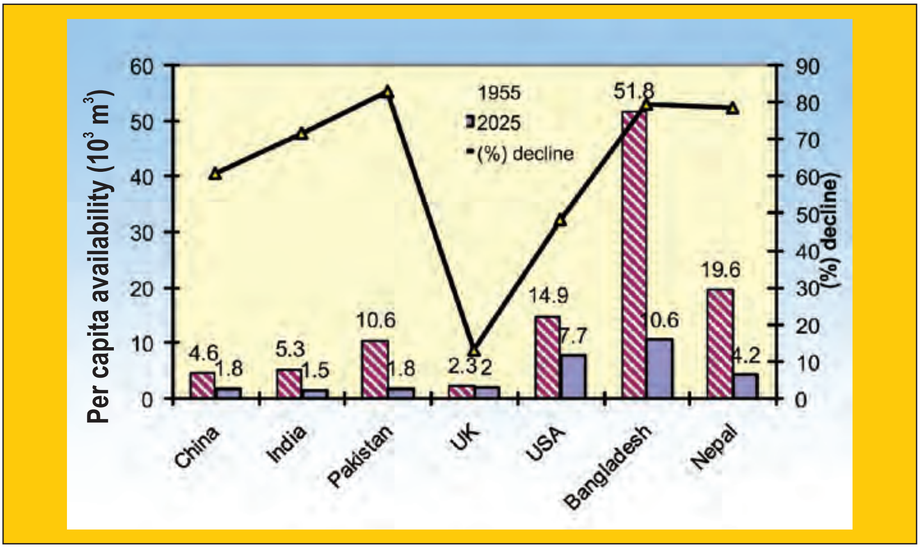


Fig.1. Per capita water availability in selected countries (10^3 m^3/ year)

Rice cultivation has been traditionally under flooded and impounded conditions and hence it has come to be known as water loving crop. The ability of rice to survive and grow under water submerged soil and effective weed management through standing water have further given credence to this view. Hence water productivity in rice cultivation has been the lowest. Fortunately, this aspect of rice cultivation is undergoing radical changes and technologies are being aggressively developed for more water productive cultivation practices. System of rice intensification , direct seeding under puddled soil, alternate wetting and drying are some of the options. Reducing crop duration without affecting productivity is another approach.

For improving productivity of irrigation water in wetland rice cultivation the following three approaches are suggested

1) Enhancing the water supply
2) Conservation of water
3) Increasing crop and water productivity

> "Rice grown under irrigated condition is facing the threat of water shortage. This is forcing a paradigm shift towards maximizing output per unit of water instead of per unit of land.
> (Dr. Manmohan Singh, Honorable Prime Minister of India)

The country's future rice production will depend heavily on developing and adopting strategies and practices that use irrigation water efficiently at the farm level. SRI is one such method which has a potential to produce more rice with less water. Until 1990, the impression was that rice yields better only under flooded conditions. Recent reports from International Water Management Institute, Colombo, however suggest that continuous submergence is not essential for obtaining higher rice yield. Further, experiences from studies on SRI in China and Sri Lanka during the last decade have conclusively demonstrated that unflooded soil is ideal for rice plant to grow well and yield better than under conventional method of continuous shallow submergence.

> System of Rice Intensification with the popular acronym "SRI" is a method of rice cultivation enunciated by Father Henry de Laulanié, a French Jurist priest of Madagascar in 1980s which involves the comprehensive effective management of resources- changing the way land,seeds, water and labour are used.

SYSTEM OF RICE INTENSIFICATION

The System of Rice Intensification, known by its acronym 'SRI', is gaining popularity among paddy farmers in several states. This method has the potential to improve productivity of land, capital, water and labour simultaneously. This system developed in Madagascar in 1980s has been tried successfully in 40 countries across the world. SRI is a system of growing rice which involves principles that are at times radically different from the traditional ways of growing rice. It involves planting of single and young seedlings with care instead of conventional method of multiple and old seedlings from the nursery. SRI spaces rice plants more widely and does not depend on continuous flooding of rice fields. It uses lesser seed, chemical inputs and promotes soil biotic activities in and around the root zone, due to liberal application of compost and weeding with a rotating hoe that aerates the soil. These changed practices with lower inputs lead to enhanced yields with considerable savings of inputs, especially the water which is becoming scarce over the years.

1. OUTLINE OF SRI PRACTICES

The System of Rice Intensification, basically refers to a particular set of practices which improve plant health and yield. In view of several advantages with this method, it has caught attention of major rice growing countries and is presently being tried as an innovative practice in several Indian states *viz.*, Tamilnadu, Tripura , Orissa, Punjab Chattishgarh, West Bengal, Manipur, Bihar and Andhra Pradesh.

What are the principles of SRI ?

SRI which is relatively a new method of growing rice involves a set of practices for plant, soil, water and nutrient management. It is a revolutionary technology in the sense that it tries to change traditional practices especially with respect to water management that existed for thousands of years. The greatest potential of SRI is realized when all the six important practices are adopted together.

SRI Principles that underlie SRI practices are more important than the practices themselves. These include

- Rice is not an aquatic plant. Although rice can survive when grown under flooded (hypoxic) conditions, it does not really thrive well in such a soil environment. Under continuous submergence, most of the rice plant's roots remain in the top 6 cm of soil, and must have degenerated by the start of the plant's reproductive phase.
- Rice seedlings lose much of their growth potential when transplanted beyond 15 days of age. This potential is preserved by early transplanting in conjunction with other SRI practices.

- It is important to avoid trauma to seedlings, and especially to their roots, during transplanting. Stresses such as drying out of the roots of seedlings will delay the resumption of plant growth after transplanting and reduce tillering ability and root development.
- Wider spacing of plants leads to greater root growth and accompanying tillering, provided that other favorable conditions for growth such as soil aeration are provided. With intact root systems, there is a positive correlation between tillering and grain filling.
- Soil aeration and organic matter create beneficial conditions for plant root growth and for consequent plant vigor and health. This results in greater abundance and diversity of microbial life in the soil and helps plants to resist pest and disease damage.

SRI encompasses six basic principles which are achieved by following practices

Principles and corresponding practices of SRI

S.No.	Principles	Practices
1	Very young seedlings should be used, to preserve the plant's inherent growth potential for rooting and tillering	8 – 15 day old seedlings with 2- 3 leaves grown in raised bed nursery are transplanted
2	Transplanting single seedling per hill should be done quickly, carefully, shallow, and skillfully, in order to avoid any trauma to the roots which are the key to plant establishment	Single seedling planted with minimum time interval between pulling out from the nursery and planting at a shallow depth very carefully
3	Reduce the plant population radically by spacing the hills widely and squarely so that both the roots and canopy have room to grow and access nutrients, sunlight, etc	Planting at 20 x 20 cm, or 25 x 25 cm, or 30 x 30 cm using a rope or marker based on the soil nutrient status
4	Provide the growing plants with sufficient but never excess water so that the roots do not suffocate and degenerate.	Up to panicle initiation: Irrigate to 2.5 cm depth after previously ponded water disappears and fine hair line cracks are formed. After panicle initiation : Irrigate to 2.5 cm water one day after previously pounded water disappears

5	Rice crop performance will be improved by active soil aeration through better root growth	Inter-cultivation with cono weeder at 10-12, 20-22, 30-32 and 40-42 days after planting between the rows in both directions
6	Use of more organic manures of different kinds	Promoting pre- *kharif* green manures, FYM and vermicompost, crop rotations with legumes and crop residues, etc.,

Source : Uphoff, 2005

The basic six practices of SRI are

1. Transplanting young (8-15 day old/ 2- 3 leaf stage) seedlings singly
2. Careful transplanting at shallow depth
3. Adoption of wider spacing (25 cm x 25 cm)
4. Water management to keep soil moist by alternate wetting and drying
5. Inter-row weeding using rotary weeder and
6. Use of organic manures such as FYM/Compost/Green leaf / Crop residues/ Biofetilisers

The above six practices form the 'SRI HEXAGON' and adopted together they have profound effect on the growth of rice plants (Fig 2)

Fig. 2 : SRI HEXAGON

When young seedlings are planted at 16 plants per sq.m, the field will not look like a planted field and usually farmers practicing for the first time will be shocked. The real effect will come when the intercultivation with weeder is done for the first time and they see a sudden spurt in tillering and this amazing response of the crop continues to impress the farmers (Fig. 3). To achieve the benifits of SRI, the agronomic practices to be followed have been modified over the years based on practical experiences and thus differ a bit from those proposed initially.

What SRI does ?
Exploits the genetic potential of rice plants
Creates a more favourable growing (below-ground and above-ground) environment
Enhances bio soil fertility
increases resource (seeds, water, nutrients, labour, land) use efficiency

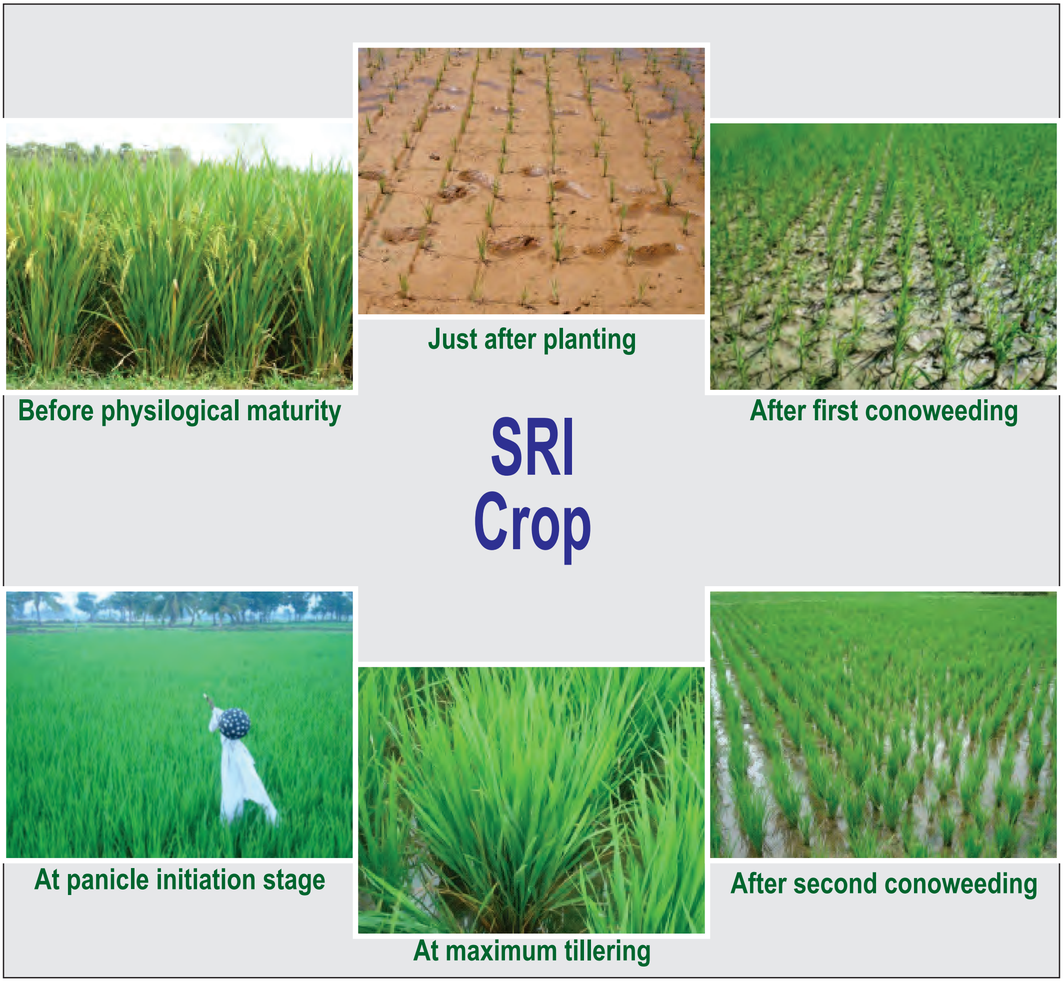


Fig. 3. Progressive growth of rice plants under SRI

2 DETAILED PACKAGE OF PRACTICES FOR SRI

2.1 Selection of Suitable fields

- Select well leveled fields with good drainage
- Well laid irrigation and drainage channels are prerequisite for SRI adoption
- Avoid saline/ alkaline and inundated low lying fields
- Test the soil for available nutrient status
- Test soil for population of plant parasitic nematodes particularly of root-knot nematodes

2.2 Selection of variety

Generally most of the high yielding varieties recommended for the region can be successfully grown under SRI (varietal response to SRI is under investigation). However, high tillering varieties and hybrids are most suitable for SRI

- Grow locally recommended and popular variety for good harvest.
- Hybrids are more suitable for SRI method and hence recommended for SRI

2.3 Seed rate

- Use 5 kg of seed for one hectare of main field, hence it is essential to select healthy, well filled bold seeds for SRI method which promotes healthy nursery and crop growth

Select healthy and bold seeds by adopting following method (Fig.4)

- Prepare a salt solution (1.08 sp.gr) required for seed dipping by mixing 1.65 kg common salt in 10 liters water
- Test the salt solution concentration with fresh egg which would float in the solution. If egg sinks, add more salt to increase the concentration.
- Pour the seed selected for nursery in the salt solution
- Stir the seed well in the solution, allow it to settle down, and discard the floating seeds.
- Select the seed which has settled down in the solution.
- Same salt solution may be used again to test another lot of seed
- Salt solution treated seed need to be wash with tap water thoroughly

Salt water preparation

Testing salt water with egg

Mixing seed in salt water

Selecting the settled seed

Fig 4 : Pictorial depiction of selecting bold seeds

2.4 Pre-soaking of seed

- Soak the selected seed for 12 hours in normal water and drain the water and incubate it in a gunny bag for about 24 hours to facilitate just sprouting and easy handling.

2.5. Nursery bed preparation

- Select about 100 m^2 nursery area preferably in a corner or adjacent to the main field (Plate 1 & 2).
- Raise nursery for each hectare of field with a gap of 2-3 days if area is more than a hectare to facilitate staggered and timely planting with available labour
- Prepare 5 beds of 1 X 20 m / ha (100 m^2) with sufficient provision of irrigation and drainage channels (30 cms) .
- In areas having nematode problem, apply neem cake @1-2 t/ha or *Pseudomonas fluorescens* talc formulation @ 20 g/m^2 in nursery beds.

Plate 1. Application of organic manures on the nursery beds

Plate 2. Uniform distribution of pre-germinated seeds on the beds

Raised Bed Preparation

- Prepare raised beds of 8-10 cm height by taking the soil from channels as the roots of 8-12 day-old seedlings grow upto 7.5cm deep

  Details of different layers for raised bed preparation

  Apply farm yard manure (FYM)/ vermicompost and soil alternately in 4 layers as follows:
- 1st layer : 1-2 cm thick well decomposed FYM/ Vermi compost
- 2nd layer : 2 cm soil
- 3rd layer : 3 cm thick well decomposed FYM/ Vermicompost
- 4th layer : 1 to 2 cm soil and mix them well
- Use wooden reapers/ planks or paddy straw bundles on all sides of nursery bed to support the raised beds
- Provide channels on all sides to drain out excess water

2.6 Broadcasting sprouted seed

Plate 3. Broad cast seed Uniformly

- Divide 5 kg sprouted seed lot into 5 equal parts and broadcast each lot on one bed at a time uniformly on the raised beds to ensure uniform distribution of seed
- It is desirable to broadcast the seed especially in the evening to avoid probable high temperatures (Plate.3)
- Cover the seeds with well decomposed FYM @ 25kg / bed just to cover seed followed by paddy straw to protect nursery from bird damage and to avoid scorching for 2-3 days (Plate .3)
- Sprinkle water on the beds twice or thrice daily (morning, afternoon and evening) with rose cans

2.7 . Preparation of Main Field

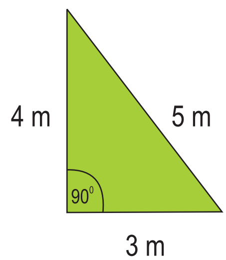
- Preparation of the main field in SRI is the same as in a conventional method. However, care should be taken to level the field perfectly with suitable levelers.
- Start preparing the main field immediately after nursery sowing.
- Apply well decomposed 10 t FYM or compost per ha before ploughing and incorporate it thoroughly with rotavator.
- Puddle the field with cattle /tractor drawn puddler twice
- Level the field well by using wooden planks and divide the field into small pieces and work with planks plot wise (Plate 4 & 5).
- Provide plot wise independent irrigation /drainage facilities for effective water management (avoid irrigating field to field).

Plate 4. Perfect leveling of the puddle field

Plate 5. Channels for every two meters to avoid inundation

2.8 Lay out of the main field

- Follow the *Pythagoras* method for getting straight lines



- The spacing recommended is 25 X 25 cm
- Make intersections of 25 X 25 cm distance for facilitating square transplanting of seedlings @ 16 seedlings per sq. m by running appropriate marker over the prepared main field both length wise and width wise (crisscross)
- Pull the markers at an even pace for proper marking.
- If markers are not available, use traditional transplanting chains marked at 25 cm distance with planting boards of 25 cm spacing (Plate 6 & 11)

Different markers for planting in SRI method

Plate 6. Planting chain marked with 25 cm

Plate 7. Wooden marker with 25 cm

Plate 8. Marking with roller marker

Plate 9. Iron marker

Plate 10. Roller marker to mark in both directions

Plate 11. Field after marking

2.9 Transplanting

- There should not be any standing water in the field at the time of transplanting.
- It is desirable to take up planting a day after final land preparation.
- Transplant 8-12 day old seedlings (2-3 leaf stage). It takes around 15-18 days to achieve 2.5 leaf stage during cold temperatures (winter season).
- Remove the seedlings by scooping out with the help of a thin metal sheet of 30 X 30 cm by inserting below the seed bed to get seedlings intact with seed and soil without damaging roots and avoid transplanting shock.
- Place the young seedlings @ one seedling / hill at each intersection of 25 X25 cm very gently at shallow depth (Plate 12 & 13)
- Interval between uprooting and planting should be minimum (not beyond an hour) and hence keep the nursery nearer to main field.
- Avoid transplanting nematode infected seedlings showing galls on the roots

Plate 12. Two and half leaf stage seedling (young seedling)

Plate 13. Careful transplanting

In SRI method, young seedlings are placed at shallow depth and therefore these seedlings establish quickly. Whereas in the conventional method 30- 35 days old seedlings are planted deep into the puddled soil and during the process the tips of roots face upward and hence they require time and energy to establish in the soil. Early establishment without transplanting shock in SRI facilitates to reduce the number of days for maturity.

2.10 . Water Management

- Maintain water at just soil saturation level by intermittent light irrigation (1-2 cm) coinciding with appearance of fine hair cracks (alternate wetting and drying)
- However, maintain thin film of water while operating the weeder and same water is retained for weed incorporation.
- Provide sufficient drainage channels to drain the excess water and also to avoid submergence (Plate 14 & 15).
- Maintain shallow submergence (2-3 cm) from Panicle Initiation to maturity
- Dry the field completely about 10-15 days before harvest

Plate 14 . Management of water at initial stages

Plate 15. Management of water at Tillering

2.11. Nutrient management

- In SRI method encourage application of organic manures as it enhances the macro and micro nutrient content in the soil in an eco-friendly way, helps in optimum utilization of some of the chemical fertilizers and protects the soil from degradation and other hazardous effects
- Apply FYM or well decomposed compost @ 10 -12 t/ha before ploughing and incorporate the same uniformly. Use different sources of organic manures rather than single source (Plate 16 - 19). It also helps in suppressing population of harmful plant parasitic nematodes while promoting build up of beneficial microbial feeding nematodes
- Apply and incorporate 50% of recommended fertilizers (NPK) through in-organics i.e 50: 30: 20 kg NPK in *kharif* and 60 : 30 20 kg NPK in *rabi* depending on soil test values. Though complete organic manuring is recommended for SRI, in case of short supply of organic manure this supplementation may be adopted for better yield
- Apply half the recommended N and total P and 75 % K as basal before last puddling and incorporate

- Apply second dose (25%) of N at the time of 2nd weeding (20 DAT) and final dose of 25 % N and remaining 25 % K a week before panicle initiation stage.
- Quantity of organic manures could be adjusted in such a way to supply 100- 120 kg N /ha through one or more sources depending on their availability and N content.
- Need based N can be applied with the use of Leaf colour chart to enhance the N use efficiency and for timely N top dressing
- Growing of green manure crops proceeding to *kharif* rice is the best organic source where rice is assured in *kharif*
- Though the initial recommendations was only the organics , the practicing farmers have adopted integrated nutrient management with major focus on organics but with addition of small amounts of inorganic fetilisers to meet the nutrient requirements. This is one of the modifications made while adopting SRI.

Plate 16 . Pre *kharif* green manure crop

Plate 17. Well decomposed FYM

Plate 18 . Vermi compost

Plate 19. Azolla a source of manure

Different sources of Organic manures

Nitrogen management based on leaf colour chart (Real time N management):

Farmers will be benefitted significantly if they can adjust the N input to actual crop demand. One way of doing it is with leaf colour chart (LCC). These measurements help to monitor plant N status in the field and determine the time of N top dressing. Leaf color chart has been developed at DRR for the tropical indica rice varieties with suitable modifications.

LCC readings were normally taken once in a week starting from 14 days after transplanting (DAT) for transplanted rice (Plate 20). The top most fully expanded leaf from the hill is chosen for measurement of colour number ranging from 1 to 7. Leaf should be placed on colour chart to match the colour. The leaf colour of the ten randomly selected, top fully expanded leaves is compared with the ratings given on the chart. When the average leaf colour is less than 4, top dressing of N @ 20-35 kg/ha is recommended. LCC values were positively correlated at all growth stages and also indicative of grain yield of cultivars.

Colour charts are well accepted by farmers and use of colour charts to determine the time of top dressing of N not only reduces the N requirement (37.5-50 kg N/ha) but also enhances N use efficiency. It also reduces the built up of pests and diseases due to over dose of N application. Thus, the leaf colour chart may be useful to avoid the under or over dosing of fertilizer N and it also improves the N use efficiency in SRI method.

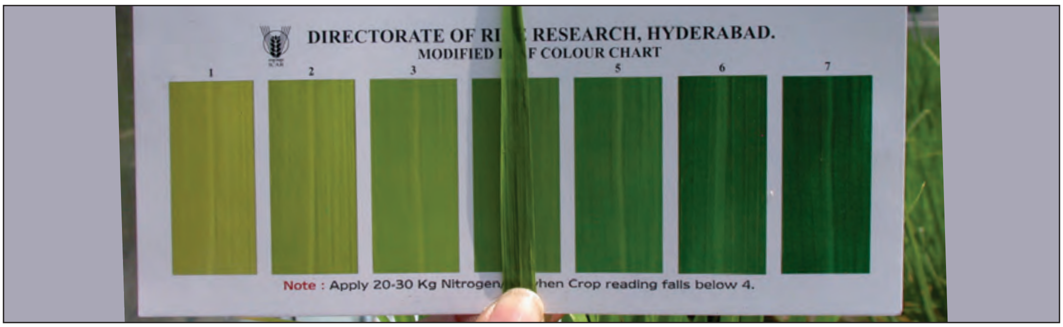


Plate 20 : Leaf color chart developed at DRR

Amount of N required at different growth stages

Crop stage	Time of application (Days)			Dose of N required (kg N /ha)	
				Kharif	*Rabi*
After transplanting	14-28	14-42	14-63	20	25
Maximum tillering stage	29-48	43-70	64-85	30	35
Flowering stage	After 49	After-71	After 86	20	25
Crop duration (days)	110	125	145		

2.12. Weed Management

- Weed growth is generally more in SRI due to wider spacing and alternate wetting and drying. Effective and timely weed management is crucial for the success of SRI
- Adopt invariably mechanical weeding so as to incorporate the weeds and to provide aeration to soil
- Start weeding from 10 days after transplantation (DAT) using suitable mechanical weeder and perform at least 4 weedings at an interval of 10 days (Pic 38 & 39)
- Take up manual weeding to remove weeds not incorporated by weeder
- Efficient weeders have been developed to suit their local situations by the innovative farmers themselves (Plate 21-29)
- The markers and weeders developed by Acharya N.G. Ranga Agricultural University (ANGRAU) are quite popular

Plate 21. Mandava weeder

Plate 22. Engine mounted weeder

Plate 23. Cono weeder for different soils

Plate 24. Three row weeder

Different types of weeders

For Details Contact :

Dr. Aum Sharma, Principal Scientist and University Head, FMP, AICRIP on Farm Implements & Machinery (ICAR) ANGRAU Rajendranagar, Hyderabad - 500 030 Ph : 040- 2401 5011 Ext : 438

Plate 25. Demonstration of motorised weeder

Plate 26. Motorised weeder operated by farmer (Mr. Gopala Swamy)

Plate 27. Weeding at early stage

Plate 28. Weeding at 20 DAT (stage)

Among the different practices, the contribution of weeding operation is significant in influencing the yield as compared to other SRI practices.

Plate 29. Healthy rice crop after weeding with conoweeder

2.13. Management of Pests and Diseases

It has been widely reported by farmers and often documented by researchers that the pest incidence is low in SRI compared to conventional method of rice cultivation. The healthy and vigorous plants under SRI method make them resist the attack by pests and diseases. Some of the SRI practices like wider spacing, weed free condition, absence of stagnant water and use of organic manures make the micro-environment non-conducive to major pests like Brown plant hopper (BPH) and gall midge and diseases like blast and sheath blight.

Most of the plant protection practices followed in SRI are similar to IPM/IDM practices recommended for the management of insect pests and diseases in rice. Hence the incidence and damage of major pests and diseases are low in SRI as compared to normal method of cultivation. For example, planting of seedlings in wider spacing (25 x 25 cm) in SRI increases aeration and exposes rice plants to more sunlight resulting in reduced plant hopper incidence. Similarly working with a cono weeder (4 times at 10 day interval) helps in greater soil aeration and incorporation of weeds in the soil in SRI method. As most of these weeds act as alternate hosts to major pests, their removal at regular intervals reduces the pest incidence and restricts further spread and development. In the tillering stage, vigorous plant growth with more number of tillers and more number of leaves may attract defoliators such as cutworms, ear cutting caterpillars and leaf folder. However, significant increase in number of tillers and leaves should be able to sufficiently compensate for loss due to defoliation.

Though SRI plants have more capacity to tolerate pest attack, initial management of pests immediately after planting may pose a problem for the farmers. As 8 – 15 day old seedlings are used for planting, these tender seedlings may not be able to withstand severe hispa and thrips damage as these may severely affect the plant growth. Stem borer is another pest which may become severe if not properly managed. Leaf mite may create havoc at vegetative stage due to favourable conditions in SRI method. In fields having Root-knot nematode, care should be taken to keep its populations under check by adopting integrated nematode management practices suggested for both nursery and main field. In case of severe nematode infestation, apply carbofuran (3G) @ 1 kg a.i/ha in nursery and 45 days after transplanting in main field

All the practices of SRI contributes for reduction in pests and disease buildup in addition to healthy plant growth .

- Monitor the field regularly
- The pest and disease problems are comparatively less in SRI as compared to normal method. However, use preferably natural/ bio-pesticides whenever necessary to keep pests below economic threshold level.

- Adopt integrated pest management practices by choosing resistant varieties, conserving and augumenting bio control agents and using safer, low dose pesticides at appropriate doses based on the need.
- SRI practices such as avoiding continuous flooding, application of organic manures, frequent inter-culture and incorporation of weeds, minimal use of biocides etc. promote build up of beneficial nematode and microbial population which in turn improves soil health and nutrient availability.
- Profuse root growth observed in SRI may enhance nematode tolerance and compensate yield loss caused by nematodes to some extent.

Economic thresholds for major insect pests and diseases in rice

Insect Pest	Economic thresholds	Disease	Economic thresholds
Stem borer	5-10% dead hearts or 1 egg mass /m ^{2} or 1 adult moth / m^2 30-35 moths /Pheromone trap/week	Blast	5 % leaf damage or 1 -2 % neck blast damage / m^2
Gall Midge	5% silver shoots (at active tillering stage)	Sheath blight	10% tillers /m^2
BPH/ White backed plant hopper	10-20 insects per hill	BLB	2-5% leaf damage/ m^2
Green leaf hopper	2 insects / hill in tungro endemic areas. 10 - 20 insects /hill in other areas	RTV	1-2 GLH/ m^2
Leaf folder	3 freshly damaged leaves / hill at active tillering stage		
Gundhi bug	1 nymph / adult per hill		
Hispa	2 adults /larvae/hill		

2.14 Harvesting and post-harvest technology

- Thresh as early as possible preferably a day after harvest and store the seed at 14 % moisture content
- Drain out water from the field when grains in the lowest portion of the panicle are in the dough stage (about 20 days from 50% flowering).
- Allow the grains to harden and harvest 30-35 days after flowering when stalks still remain green to avoid grain shedding.
- See that moisture content of paddy is around 20 to 24 per cent at harvest
- Harvest the crop at physiological maturity to avoid yield reduction due to shattering

3. POSITIVE EFFECTS OF MAIN PRINCIPLES OF SRI ON GROWTH, YIELD AND SOIL PARAMETERS

3.1. Raising seedlings and nursery management

The use of younger seedlings (8-15 days old/ two to three leaf stage) in SRI is a distinct departure from conventional cultivation where seedlings of 25 days and more are used. Recommended seedling age for transplanting in conventional cultivation is usually 1 week per month of duration of the crop (seed to seed) and thus for 105 days short duration rice, 25 day old seedlings and for 135 days medium duration rice 32 day old seedlings are recommended.

The duration of seedling age will increase during winter season (18-20 days) depending on the prevailing temperatures. Proper care has to be taken to get healthy seedlings during winter. The area required for raising nursery for an hectare is only 100 m^2 which is ten times lesser than the normal method. (Plate 30 & 31) .

Plate 30. SRI nursery bed

Plate 31. Seedling removal from SRI nursery

Actually, the merits of lower plant density have been known in Tamil Nadu for about a century ago. A report by the Royal Commission on Agriculture in India published in 1928 stated that 1,20,000 copies of a leaflet on “single seedling method of paddy cultivation” were distributed in the Madras Presidency, which covered a huge area now assumed within Tamil Nadu, Andhra Pradesh, Kerala and Karnataka states. So at least 80 years ago, agricultural specialists in British India were already promoting single-seedling rice planting.

In 1911, several farmers published articles in Tamil language on single-seedling planting. The Single-seedling planting was developed by a local farmer, while concurrently another farmer developed *gaja* planting with wider spacing. This *gaja* method employed inter-row spacing of 1½ feet (45 cm), intra –row spacing of 1 foot (30 cm), resulting a plant population of only 7-8 plants m^{-2}. Yield of

6004 kg ha^{-1} was obtained with *gaja* planting methods in Thanjavur district, which was 2.7 times more than obtained from the same field, the previous year when using bunch planting. It was fascinating that such high yields were being obtained by farmers with their own innovations a century ago, when no chemical fertilizers were applied/available.

3.2 . Water management in SRI

Although it is generally assumed that rice requires an abundant supply of water, it can be cultivated with the same supply of water as other cereals and the distinguishing feature lies in the fact that unlike other cereals it can tolerate standing water or swampy condition for its growth. Rice is not an aquatic plant and does not necessarily need to be grown under inundated conditions. The physiological changes in the rice plants under SRI are not confined to water management but are a result of the synergistic effect of all the practices followed and hence comparison with flood irrigation alone is incorrect.

SRI advocates growing rice plants with sufficient but never excess water so that the roots do not suffocate and degenerate and the agronomic management aims at allowing a shallow irrigation of about 2.5 cm when previously irrigated water has completely disappeared, a kind of alternate wetting and drying management (Plate 32 & 33). Intermittent irrigation helps to increase the root activity which is closely related to carbon assimilation.

Increased water productivity to the extent of 38 % due to water-saving coupled with higher grain yield in SRI has been reported (Table 4) in sandy loam soils. Exposing the soil to the air, repeatedly done in the SRI irrigation practice prevents various diseases and root rot induced by the excessive reductive conditions of the soil.

Table 4. Water saving and water productivity increase in SRI

Conventional method		SRI		Water saved (%)	Reference
Water used*	Water productivity	Water used	Water productivity		
15143 (m^3 ha^{-1})	0.398 kg grain m^{-3} water used	10259 (m^3 ha^{-1})	0.613 kg grain m^3 water used	32.2	Thiyagarajan *et al*., (2005)
1578 (mm/ha)	0.34 kg grain kg^{-1} water used	1272 (mm/ha)	0.40 kg grain kg^{-1} water used	19.4	Choudhury *et al., (2005)*
14933** (m^3 ha^{-1})	0.29 kg grain m^3 water used	9189(m^3 ha^{-1})	0.57 kg grain m^3 water used	38.4	Mahender kumar *et al.*, (2007)

*·Irrigation + rainfall ** Based on the amount of water used for irrigation (sandy clay loam soil)*

Water requirement of rice was about 1500 mm /ha on an average including rainfall to produce 3000 kg /ha under conventional flooded irrigation (5000 liters per kg of paddy production). SRI can reduce the requirement by 30-40 % without any yield reduction (3500 liters per kg of produce).

Plate 32. Moist SRI field

Plate 33. SRI field devoid of surface water

Apart from getting higher yield and using less water with SRI, the benefits of fuel saving in pumping ground water and avoiding water conflicts among farmers relying on the same source of water should be considered. Thus so far, SRI farmers using the recommended irrigation methods have not observed reduced grain yield. Instead, unflooded soil conditions appear to favour increase in grain yield.

3.3. Inter-cultivation with weeder

In describing the practices of stable and high-yielding rice cultivation, Matsushima (1980) stated that intertillage /inter-cultivation after rooting of the transplanted seedlings and the practice of removing the soil around the base of the plant / hill by hand to make the hill spread out promote tillering (Plate 34). Matsushima found that it was difficult to conduct this practice due to labour shortage but his desire to mechanize this practice was not realized. Now after two decades, his desire has been fulfilled in SRI where in a mechanical weeder was used 3-4 times in between hills, which not only incorporates the weeds but also does a inter-cultivation operation which results in some earthing up action also. A sudden burst of tillering was always noticed after the weeder is used. SRI practicing farmers feel that the pruning of the roots by the weeder has similar influence like the pruning the shoots of guava, grapes, mango etc., Increase in yield due to weeder use was also recorded showing significant positive effects of inter-cultivation which actively aerates the soil and indicated that among the SRI principles, weeder use may be more important than other SRI practices .

Plate 34. Earthing up of rice plants

A number of modifications have been made in the design of weeders used in SRI (Plate 35) and many farmer innovations (Plate 36) have taken place. While marginal farmers engage their own family labour in operating the weeder, medium and large farmers face labour problems. A power operated weeder is the most wanted one by these farmers but a solution is still evading.

The inter-cultivation also results in some earthing up effect and new roots formed above the original soil level because of weeder operation

Plate 35. Type of weeders used by farmers

Plate 36. A gauge wheel type weeder designed by a farmer.

The earthing up effect of weeder helps in

- Sufficient anchorage
- Prevention of lodging
- Covering and incorporation of weeds and fertilizers
- Checking further tillering (ineffective tillers)
- Providing better aeration

3.4 . More organic sources in preference to mineral fertilizer

SRI does emphasize the importance of the soil organic matter content and soil health. The soil characteristics will be improved by the use of organic manures, which however, doesn't imply necessarily a complete elimination of chemical fertilizer. SRI does not "emphasize organic sources to the exclusion of mineral fertilizer" but rather it emphasized organic fertilization *in preference to* mineral fertilization.

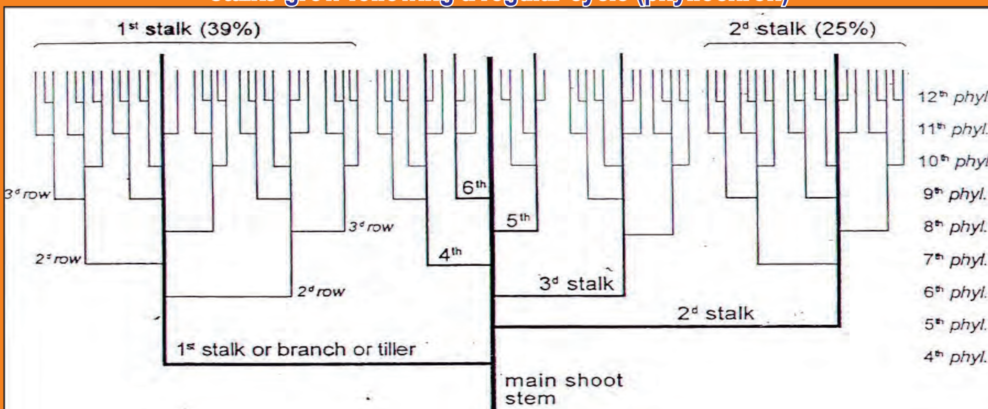
In Tamil Nadu, integrated nutrient management is recommended for SRI. Farmers who had forgotten the use of organic manures are showing a renewed interest in them because of SRI. Application of farmyard manure and other decomposed vegetative materials are obviously beneficial, since these enhance soil biota while improving soil structure as well as water absorption and retention.

In Tamil Nadu, growing *Gliricidia* on bunds and fences is a recommendation that goes along with SRI, as this increases the ready availability of organic material at field level. Moreover, positive interaction between organic manures and chemical fertilizers is also well known. Advocating the use of organic materials of different sources is profitable for farmers and beneficial for soil health and water quality, since it broadens the number of options for farmers.

3.5 Plant growth and soil parameters

- Young seedlings (less than 15 day old) grown from a garden like raised bed nursery are stronger and keep the soil particles intact when removed. This not only avoids transplanting shock but also aids in quick establishment and retains the potential for profuse tillering and strong root growth (Fig. 5). Further, young seedlings of less than 15 day old with four phyllochrons are reported to put forth large number of tillers and dense root system (Katayama ,1951).

Fig. 5 Diagram of possible stalks of a rice shoot stalks grow following a regular cycle (phyllochron)



Source : Katayama, 1951

- Transplanting at a wider spacing (16 hills /m^2) provide ample light and soil space which encourages luxurious growth of roots and tillers supporting synergistically. For example, about 60% of photosynthates formed in the shoots are translocated to roots for its growth which pervasively explore soil for water and nutrient to supply to the aerial parts. Wider spacing also creates favorable micro-climatic conditions for plant growth similar to that as 'border/edge' effect. But, the uniqueness of SRI is that such phenomenal growth is seen uniformly all through the field which more than compensates for low plant density.
- Rice plants grown without the use of inorganic fertilizers and biocides are vigorous, strong and less susceptible to pests and disease incidence, and are slow in senescence.
- Accumulation of nitrogen and dry matter production is greater in vegetative organs of plants grown under SRI as compared to those which are grown under conventional method.
- Remobilization/partition of stored photosynthates from the vegetative organs is 1.4 to 3.0 times (66.9%) more with SRI practices.
- Uptake of nutrients as well as their use efficiencies are also favoured by SRI cultivation.
- Good water management practice of keeping the soil moist but not continuously flooded

contributes immensely to the growth of larger roots in aerobic soil environment while hypoxic conditions prevalent under continuously submerged condition inhibit and degenerate root growth.

- Nearly 78% roots are known to degenerate by flowering stage in flooded soil which is almost prevented under SRI. Healthy and vigorous root system is the magical effect of SRI(Plate 37).

Plate 37. Rice plant having vigorous root growth in SRI compared to Conventional TP

- The aerenchyma tissues formed in response to prevailing hypoxic conditions impairs the capacity of the plants for nutrient uptake. In contrast, rice grown under SRI conditions does not form aerenchyma and avoids root degeneration.
- SRI conditions permit more oxygen and nitrogen fluxes to reach rhizosphere which favours higher microbial activity and N-fixation.
- Soil aeration under SRI prevents intense soil reduction and reduce the build up of toxic concentrations of ferrous iron which is a major problem in acid soils.
- Rotary weeding churns up the surface soil, removes and incorporates weeds while aerating the top 10 cm of soil layer. This ideally benefits biological N fixation and N mineralization.
- Addition of organic manures such as FYM and compost/including weed biomass enriches soils with carbon which triggers biological processes by diverse microflora in the soil and also promotes plant growth promoting rhizoflora (PGPR).

3.6 The rice crop exhibits a different phenotypic potential under SRI (Plate 38 to 47)

Plate 38. Profuse tillering

Plate 39. New roots due to earthing up by weeder

Plate 40. Higher SPAD Values in SRI

Plate 41. Lesser SPAD Values in Conventional

Plate 43. Lodging resistance of SRI crop

Plate 44 .More than 100 panicles from single seedling

Plate 45. Delayed maturity in Conventional

Plate 46. Early maturity in SRI (7-8 days)

Plate 47. Higher yield attributes in SRI

> The yield of 6 t ha^{-1} recorded by the Tamil Nadu farmer about a century ago even before the arrival of chemical fertilizers shows that the yield potential of rice could be tapped by innovative agronomic practices similar to SRI.

3.7. Reasons for healthy and successful crop under SRI

- Planting of young seedlings prolongs the vegetative growth period in main field before panicle initiation and facilitates the production of maximum number of tillers.
- The aerobic conditions created by alternate wetting and drying and cono weeding facilitates profuse root growth and tillering
- Mechanical weeding with cono weeder facilitates soil churning and incorporation of weeds which adds biomass to the soil
- Activity of the beneficial microbes in the root zone is enormously increased due to aerobic condition.
- Maximum utilization of available carbon and efficient uptake and translocation of nutrients due to favourable conditions
- Proper utilization of fertilizers, which would otherwise be leached out due to excess water under traditional method of cultivation.

4. INTRODUCTION OF SRI IN INDIA

SRI was introduced in India in 2000 when researchers at the Tamil Nadu Agricultural University (TNAU) initiated experiments involving SRI principles in a collaborative project on growing rice with less water. TNAU results in 2000-02 were followed by evaluations on farmers' fields. In 2003, a package of SRI practices were evolved and tested in 200 farmers' fields through a state government initiative to compare the performance of SRI and conventional cultivation in the Cauvery and Tamiraparani river basins. The results showed an average increase in grain yield by 1.5 tons/ha in both basins with reduced input requirements, and even 8% reduction in labor needed per hectare. This evaluation provided a basis for officially recommending SRI adoption to farmers in 2004.

Concurrently, in Andhra Pradesh, Acharya N.G. Ranga Agricultural University (ANGRAU), introduced SRI in farmers' fields during *kharif* season in 2003, after a team of scientists led by Dr. Alapati Satyannarayana , Former Director of Extension visited SRI fields in Sri Lanka. Trials in farmers' fields were conducted in all districts of the state. These results generated nationwide interest as they showed significant yield increases over conventional irrigated rice cultivation. Data from SRI experiments across India show an increase in grain yield up to 68 % (Table.5).

Plates 48-50 SRI fields in different states (A.P, Tripura and Tamil Nadu)

Table.6. Grain yields recorded in SRI evaluation across India

Location	Grain yield (t/ha)			Source
	Conv	SRI	% inc overConv	
Regional Agricultural Research Station, Shillong, Assam(2007)	3.1	4.5	45.2	
Agricultural Research Station, UAS, Kathalagere, Karnataka(2005)	8.8	10.2	15.9	
Main Rice Research Station, AAU, Bawagam, Gujarat	4.7	7.5	37.1	Chauhan et al., 2008
Birsa Agricultural University, Ranchi, Jharkhand	4.3	5.0	16.3	Singh et.al., 2009
Tamil Nadu Rice Research Institute, TNAU, Aduthurai (2005)	4.7	7.1	48.9	Rajendran et. al., 2005
14 Research stations, ANGRAU, Andhra Pradesh (2007)	4.9	5.7	16.6	Mallikarjuna Reddy et. al.,2007
Indira Gandhi Agricultural University, Raipur, Chattisgarh (2007)	4.3	5.1	17.8	Shrikant Chitale et al., 2007
Agricultural Research Institute, Patna, Bihar (2007)	3.9	6.1	55.1	Ajaykumar et. at., 2007
Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puduchery (2007)	2.2	3.7	68.3	Sridevi and Chellamuthu, 2007
ICAR complex , Umiam Meghalaya (2007)	4.7	5.2	10.2	Munde et.al.,2007
Central Rice Research Institute, Cuttack, Orissa (2006)	5.6	7.0	25.0	Rao.et al., 2007

Source : More rice with less water (WWF, 2008)

5. RESEARCH EXPERIENCES OF SRI

Response of SRI method on grain yield across the locations: The results of multi location trials (MLT) conducted by the Directorate of Rice Research, across India over the years (2004-2007) clearly indicated that the performance of SRI varied from location to location indicating that response of SRI is location specific. Data presented in Table 6 indicates that SRI recorded higher yield than conventional transplanting (TP) at half of the locations (10-12). The mean yield advantage of SRI over Conventional TP ranged from 7-20 per cent irrespective of soil and locations across the years (Fig. 6).

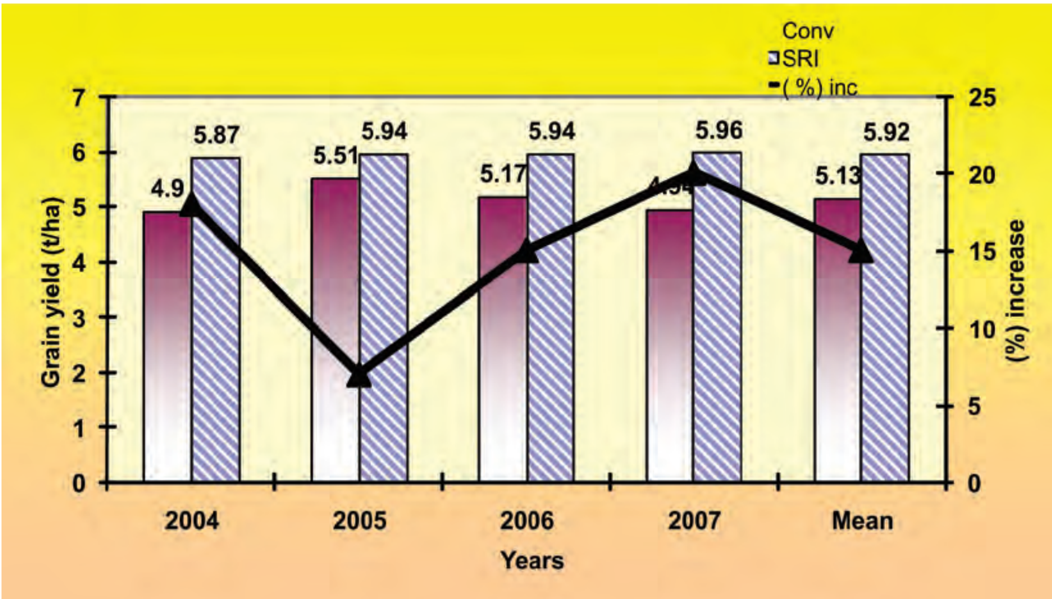


Fig. 6. Grain yield increase with SRI over Conventional TP (21 Locations) during *kharif* 2004-07

Table 6. Performance of SRI vs Conventional TP in different locations across India

S. No.	Item	Performance	No. of locations	Name of the locations
1.	SRI superior over Conventional (TP)	50% or more	19	Aduthurai,ARR'Nagar, Arundhatinagr, Jagdalpur, Kapurthala, Patna, Rajendranagar, Siriguppa, Titabar, Chatha, Coimbatore, Pantnagar, Umiam, Malan, Mandya, Maruteru, Nawagam, Pusa
2.	Conventional (TP) over SRI	5-10% yield advantage	3	Kapurthala, Karaikal, Sabour

Varietal response to SRI

Contrary to the perception that SRI method is genotype neutral, significant differences were observed between the varieties. In general, it was observed that hybrids (4 - 42% yield advantage) performed better over the varieties (2 -17%) under SRI as against Conventional. The hybrids KRH2, HRI 126 PHB-71 and DRRH2 performed better as compared to the varieties. Since seed requirement is quite low in SRI, this could be the best method for cultivating hybrids where the seed cost is relatively higher compared to inbreds. Most of the varieties generally performed better in SRI but some varieties performed much better than others. Therefore, to expedite the response of different genotypes to SRI practice at different locations, locally popular varieties of different duration were tested at 16 locations. Results indicated that, the performance of late and medium duration varieties, and hybrids was found better as compared to early duration varieties at most of the locations . It is imperative that, under SRI method, due to wider spacing, those varieties which have high tillering ability perform better as compared to the shy tillering ones.

Nursery area and seed saving

As a result of adopting wider spacing (25 X 25 cm) and planting of a single seedling/hill, there would be only 16 hills/m^2 as against 44/ m^2 or more in the conventional method. Sufficient nursery required for one ha under SRI could be raised using just 5 kg seed as against 20-30 kg/ha under conventional (TP). In case of hybrids, 66% seed cost could be saved by adopting SRI method. The significant seed saving will promote seed multiplication rate, purity of seed (single seedling planting) and faster availability/spread of released varieties. Further the nursery area for SRI method is just 100 m^2/ha which is one tenth of area required for Conventional (TP). There will be reduction in the cost of nursery preparation, labour and inputs for nursery, mainly water which is scarce during the period of nursery raising in both the seasons.

Saving of water

Systematic studies conducted at DRR by using digital water meters during wet and dry seasons 2006 and 2007, revealed that water saving in SRI could be up to 32%. SRI method received only 8906 m^3 of water which is 32% less of that for ST (13055 m^3/ha). Total water productivity of the SRI was 53% higher as compared to conventional method. (Table 7). SRI saved nearly 25% irrigation water without any reduction on yield compared to conventional transplanting (Chowdhury et al., 2005). Using intermittent irrigation, Thiyagarajan et al. (2002) reported water saving of 50% in SRI over the traditional flooding without any adverse effect on grain yield.

Table 7: Water productivity as influenced by conventional vs SRI method (Mean of two seasons)

Parameter	Method	Quantity	Percent over conventional
Water applied (m^3/ha)	Conventional	13055	
	SRI	8906	32.0 (reduction)
Water Productivity (kg/m^3)	Conventional	0.32	
	SRI	0.48	50.0 (increase)
Unit Water requirement (liters/kg grain production)	Conventional SRI	3125 2083	

Nutrient use efficiency and status of soil available nutrients:

Comparison of SRI and Conventional TP with respect to N, P and K uptake in both the *kharif* and *rabi* seasons' revealed that the nutrients uptake remained the same, but nutrient use efficiency was marginally higher in SRI (by 8, 8 and 12% for N, P and K, respectively, during *kharif* and 5% for N during *rabi*) compared to conventional (Fig.7). The amount of accumulation of nutrients that leads to more vigorous plant growth and higher yields is due to changes in capacities of the plant itself, particularly its root system. Soil analysis data indicated similar available nutrient status in SRI and conventional after two seasons of experimentation. Thus, SRI resulted in higher productivity during *kharif*, similar nutrient uptake and marginally higher nutrient use efficiency without depleting the soil available nutrients compared to conventional transplanting, after two seasons (Table 8).

Table 8:Soil properties as influenced by SRI vs conventional method (After 2 Seasons)

Treatments	pH	EC (dS/m)	SOC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
SRI	8.43	0.51	1.25	272.0	258	638
Conventional	8.44	0.51	1.18	251.0	256	609
C.D(0.05)	NS	NS	NS	NS	26	34

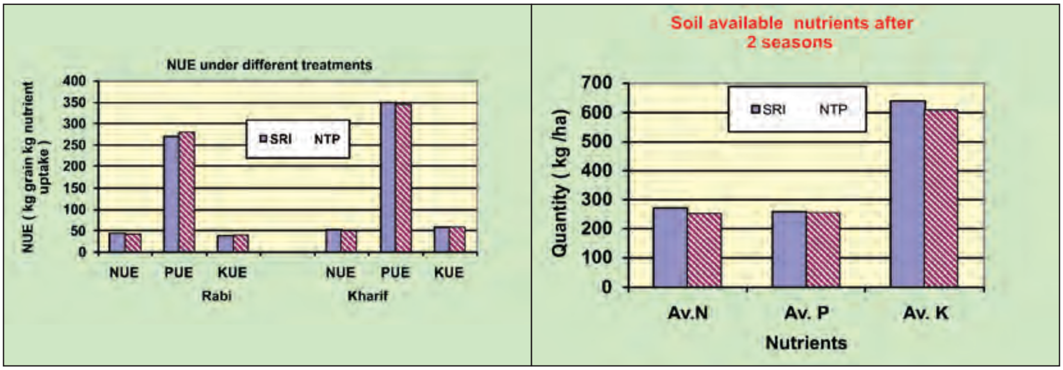


Fig. 7.Nutrient use efficiency and soil available nutrient states as influenced by methods of crop establishment

Influence of SRI on microbial activity

The dehydrogenage activity – a measure of microbial activity in the soil was estimated at two stages of crop growth in sandy clay loam soils comparing different methods of crop establishment indicated that the dehydrogenase activity did not differ at sowing (161-172). However, at vegetative growth stages, dehydrogenase activity was significantly higher in SRI over Conventional TP (Table 9). Further, SRI plots, generally had higher (7-25%) MBC, MBN and dehydrogenase activity only in post rainy season, as water management and controlled irrigation is practiced only during the post rainy season. (Kranthi, 2005).

Table 9. Influence of SRI on dehydrogenase activity (µg TPF/g soil/24h)

Treatment	At Sowing				At vegetative growth			
	MTU 1010	Shanthi	DRRH2	Mean	MTU 1010	Shanthi	DRRH2	
SRI	166	176	141	161	294	350	356	333
Conventional TP	139	204	174	172	214	321	275	270
SE+	18.5(20.7) NS		12.0 NS		54.3(36.0)NS		20.8 NS	
Mean	161	178	164		242	290	293	
SE+	7.4NS				45.7NS			
CV%	25				26			

NS = Not significant

SE in parentheses are to compare means within same treatment.

Influence of SRI on incidence of insect pests: The pest incidence studies indicated that yellow stem borer damage was high at all stages of crop growth period and its damage (dead hearts) was low in Shanti variety grown under SRI (7.0%) as compared to Conventonal method (11.4%). At reproductive stage, the damage (white ear heads) was high in SRI (28.3%) than conventional method (21.2%). The study through survey (SRI – adopted village) in Warangal district indicated that SRI had low pest incidence resulting in lower or no-pesticide application. The benefit cost ratio was higher for SRI method (1.77 and 1.76) in two villages of Warangal district, Andhra Pradesh than conventional method (Padmavathi et al., 2008). Similar results of low pest incidence in rice grown under SRI due to vigorous and healthy growth of plant coupled with wider spacing has been reported by Gaspenillo (2002), Gani (2004) , Ravi *et al.* (2007). Total abundance and species richness was high in SRI as compared to conventional method. Among various guilds, natural enemies were found more in SRI than conventional method of rice cultivation (Padmavathi *et al*., 2009).

Influence of SRI on soil nematodes: Nematodes in rice ecosystem play vital and mutually contrasting roles which may have beneficial or harmful effects on crop yields. Microbial feeding nematodes (MFN) that promote organic matter decomposition and nutrient cycling are beneficial to the plant growth while plant parasitic nematodes (PPN) that feed on rice plants inflict serious yield losses (Prasad and Somasekhar, 2009). The goal of any crop management system therefore should be to enhance populations of beneficial nematodes while keeping harmful PPN under check.

Soil nematodes are sensitive to water, nutrient and pest management practices. Application of high doses of organic manures / amendments and reduced use of chemical inputs in SRI system may encourage the build up of nematode antagonistic microbes that keep the populations of PPN under check. The toxic compounds released during the decomposition of certain weed plants also adversely affect the PPN.

Further, profuse root growth under SRI may also help in compensating yield loss caused by nematodes to some extent but it may be a short-term effect. Besides suppressing the population of PPN, application of organic manures also encourage the build up of microbial feeding nematodes which help in nutrient cycling (Randriamiharisoa *et al*., 2006). Therefore there is a need to increase our understanding of impact of SRI practices on the beneficial and harmful nematodes for sustaining the yield gains obtained with SRI in the long run.

The experiments in sandy clay loam soils indicated that, the total nematode abundance and abundance of PPN and MFN was more under SRI and Eco-SRI (organic SRI) systems as compared to the Conventional system. However, the relative abundance of PPN was lowest in Eco-SRI system and highest in Conventional system. In contrast to this, the relative abundance of MFN was highest in Eco-SRI compared to the SRI and ST systems. The PPN community in experimental plots was dominated by rice root nematode (*Hirschmanniella* spp.) and other minor ectoparasitic nematodes. More damaging ones like root-knot and lesion nematodes were either absent or low in numbers (Fig 8) . This may be the reason for higher yields obtained in SRI despite high density of parasitic nematodes. (DRR Annual Report, 2008)

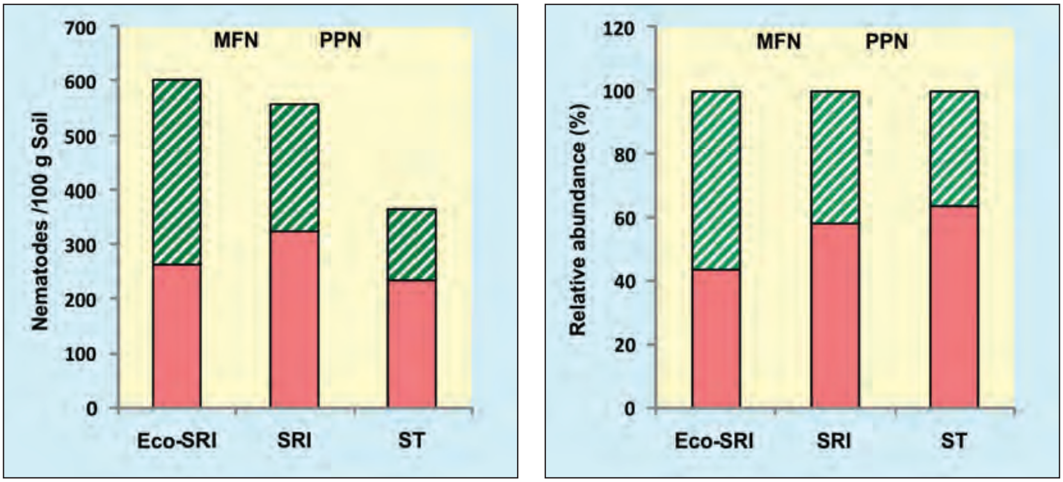


Fig.8. Population density (a) and relative abundance (b) of plant parasitic (PPN) and microbial feeding nematodes (MFN) in rice plots under different management systems (Eco-SRI= Organic SRI; SRI= System of rice intensification; ST= Standard Transplanting or Conventional System).

Reduction of the duration of the crop

Field experiments conducted for assessing the potential benefit of SRI especially in terms of reducing the duration of the crop with three promising high yielding varieties (2 varieties and a hybrid) indicated that the mean reduction of duration to 50% flowering and maturity was 11 days across seasons and varieties in SRI method over conventional method. Further SRI method recorded higher grain yield in both the seasons (1.4 t/ha) with reduced duration of crop and helped in sowing of succeeding crop in time. Due to reduction in duration and increase in yield, SRI recorded a higher per day productivity to an extent of 9.4 kg/ha/day and 21.7 kg/ha/day over Conventional TP during wet seasons of 2006 and 2007 respectively (Table 11). Similar reduction in duration and increase in per day productivity under SRI has been reported by Ramesh Babu (2007) and Subba Rao (2007). This reduction in duration also helps to reduce the water requirement and facilitates to avoid water stress specially rice grown in tail-end areas.

Table 11. Per day productivity of rice as influenced by methods of crop cultivation

Methods	*kharif* 2006			*kharif* 2007		
	DFF(days)	Grain yield (kg/ha)	Per day productivity (kg/ha/day)	DFF(days)	Grain yield (kg/ha)	Per day productivity (kg/ha/day)
SRI	104	5267	39.2	104	5604	41.8
Conventional	115	4284	29.8	115	4874	33.7
CD(.05)	2	321	NS	3	481	3.2

DFF: Days to Fifty percent flowering

Socio-economic studies and frontline demonstrations

Studies during the past 2 – 3 years have clearly indicated the superiority of SRI as a sustainable method of rice cultivation. Participant farmers could perceive a unique opportunity in SRI for increasing their income through higher productivity while saving on cost of seed/chemicals/water. Experiences with SRI conducted across several types of soils indicated that SRI may not be suitable in saline sodic soils due to less tolerance of rice at early seedling stages.

6. EVALUATION OF SRI

6.1.Cost-effective in Every Way

The System of Rice Intensification improves the yield with less water, less seed, and less chemical inputs than most conventional methods of rice cultivation. This means that the returns on inputs are higher, making the method potentially more profitable than most of the traditional methods. Initially it does require significantly more labour – mainly for preparing land, transplanting young seedlings and weeding. But with experience, this labour requirement would go down.

Most SRI farmers have found that as they get to know the methods better and gain confidence in them, their pace of work speeds up, and SRI actually becomes labour-saving. An assessment with farmers showed that for conventional planting 45 to 75 labourers were required while for SRI 22 to 48 labourers were used showing an average labour reduction of 42 %.

6.2 .Higher Yield

SRI improves the productivity of land, labour, water and capital used in rice cultivation. Implementation of SRI helped to improve the yield of local varieties considerably. The yield increase in SRI was 20 to 30 % compared to that under conventional method. However, the actual yield increases depend on how well farmers practice SRI. Table 11 shows the synergistic effect of SRI and also the effect of missing one of the principles. SRI practices of young seedling, single seedling, wider spacing and intermittent irrigation together brought an increase in yield of 48.8 % when compared to conventional method. It could also be seen that SRI without mechanical weeding resulted in lowest increase in yield (20.1 %) showing that it is very important. Missing any one of the principles reduces the synergistic effect. The individual effect of SRI principles could vary in different locations.

Table 11. Effect of the SRI components on grain yield of rice

Treatment	Seedling age (days)	No.of seedlings per hill	Weed management	Irrigation	Grain yield (kg ha^{-1})	Increase in grain yield (%)
T1	15	1	With weeder	Intermittent	7061	48.8
T2	25	1	With weeder	Intermittent	5864	23.6
T3	15	3-4	With weeder	Intermittent	6138	29.4
T4	15	1	Hand weeding	Intermittent	5698	20.1
T5	15	1	With weeder	Flooding	6425	35.4
T6 (conventional)	25	3-4	Hand weeding	Flooding	4745	-
				C.D (0.05%)	163	-

Seedling age:	*SRI – 15 days;*	*Conventional – 25 days*
Number of seedlings per hill:	*SRI – 1;*	*Conventional – 3-4*
Weed management:	*SRI – intercultivation with weeder ;Conventional – hand weeding*	
Irrigation:	*SRI – intermittent irrigation; Conventional – flooding*	

Source : Rajendran et al ., 2005

6.3. SRI improves the productivity of land, labour, water and capital in rice cultivation.

The table below summarises the key differences between conventional and SRI methods:

Table 12. SRI vs Conventional method of Rice Cultivation

Item	Conventional method	SRI method
Seed rate (kg ha^{-1})	50-60	5 – 7.5
Seedling age (days)	30	8-15
Plant spacing (cm)	15 x 10 / 20 x 10	25 x 25
Number hills m^2	50 - 66	16
Number of seedlings $hill^{-1}$	3-4 or more	Single
Water management	Continuous flooding	Only moist conditions with shallow water/saturation
Weed management	Weeds manually removed from the field or hebicides used	Weeds incorporated into the field by a weeder
Inter-cultivation	No	Weeder used 3-4 times in between hills

Cost benefit analysis of SRI

In general, the benefit cost ratio is relatively higher for SRI as compared to conventional method due to reduced inputs coupled with higher grain yield (Table13).

Table 13 cost of cultivation Rs/ha in conventional vs SRI method

S.No.	Activity	Cost in Rs. /ha	
		Conventional	SRI
1	Nursery Preparation	1850	950
2	Main field preparation	1625	1800
3	Transplanting	2250	2850
4	Nutrient Management	5000	5500
5	Weed Management	3000	2000
6	Water Management	1250	1750
7	Plant Protection	950	625
8	Harvesting	1500	1650
9	**Cost of Cultivation**	17425	17125
	Returns		
10	Sale of grain (4.t /ha Con: 4.5 t/ha for SRI)	28000	31500
11	Sale of Straw (4.5 t/ha for Con : 5 t/ha for SRI)	3600	4000
12	**Total Returns**	**31600**	**35500**
13	Net Profit	16875	21375
14	**Benifit -Cost Ratio**	**1:1. 81**	**1 : 2.07**

Price : Grain Rs 7000/ t ; Straw Rs 800/ t

6.4. Anticipated Impact of SRI in India

SRI has been criticized earlier by many scientists (Sinclair and Cassman,2004,Sinclair, 2004) describing the SRI results as " unconfirmed field observations " UFO's and scientifically accepted standards were not followed in the experimental work (Dobermann,2004). The criticisms are based on past research carried out on individual agronomic practices that have no comparison with those of combined practices followed in SRI. In earlier days one or two SRI practices must have been adopted but at present no other system advises farmers to transplant single seedlings carefully grown aerobically at 2-3 leaf stage with a density of 16 seedlings per m^2 and inter-cultivate them with weeder.

Further , SRI can't be compared with other water saving technologies like alternate wetting and drying (AWD) unless all other practices of SRI were also included. The trials conducted at DRR, DWR, TNAU and ANGRAU clearly established the advantage of SRI over Conventional method (Best Management Practices) in terms of higher grain yield and greater productivity of inputs (Kumar et., al,2010., Thiyagarajan 2005, Thakur et al ., 2010, Satyanarayana, 2007 Viraktamath and Mahender Kumar 2007). Further, BMP practices are mostly input driven practices. However, exaggeration and unnecessary hype created about SRI also became counterproductive to this method.

Sinclair (2004) commented that SRI emphasizes organic nutrients to the exclusion of mineral fertilizers and thus faces serious challenges in obtaining enough mineral nutrients from organic sources to achieve higher yields. However, SRI does emphasizes the importance of the soil organic matter content and soil health. In fact, most of the Indian farmers apply chemical fertilizers along with available organic manures.

India's population is projected to reach around 1.59 billion by 2050 there by it becomes the world's most populous country by 2035 itself . SRI method has the immense potential to increase rice production by enhancing productivity level with enormous savings in water and seed resources. The anticipated impact of SRI through various components assuming that about 10% of area (4.0 m ha) is brought under SRI is summarized in Table 14.

Table 14. Impact of SRI adoption in India in 10% of rice area

Component	Inputs used		Total estimate		Advantage due to SRI	
	Con	SRI	Con	SRI	Quantity	Economic terms
Seed use	50 kg/ha	5 kg /ha	0.20m t	0.02 m t	0.18 m t	Rs 180 crores
Irrigation water	14900 m^3	9200 m^3	5960 million m^3	3680 million m^3	2280 million m^3	
Additional area to be brought under irrigation (30% saving)			4.0 m ha	5.2 m ha	1.2 m ha	
Additional Production 1.2 m ha					5.0 m t	Rs. 5000 crores
Production Adv.	3.17 t/ha	4.17	12.68 m t	16.68 m.t	4.0 m t	Rs. 4000 crores

If the SRI is adopted even on just 4 m.ha (10% of the rice area) in India, there would be saving of seed worth 180 crores. The increase in area and production is estimated to be 1.2 m ha and 5.0 m. tonnes with is equivalent to Rs. 5000 crores. Assuming that 50% of the irrigation is ground water base than SRI would save energy to the tune of 40% equivallent to 600 mkWh which means saving of Rs. 250 crores as well as also saving of nearly 2280 million m^3 of irreplaceable ground water for future . This is apart from un accounted benefits such as health, nutrition and overall improvement in the rural economy.

Proposed states for adoption (A.P., T.N., Karnataka, M.P., U.P., Bihar, W.B., Tripura, Jharkhand, Punjab, Sikkim, J&K.)

6.5 Advantages of SRI

- Saving of 30 – 40% irrigation water, as the water requirement is less in SRI
- Saving of 85 % on seed, as the seed requirement is less (5 kg / ha as against 40-50 kg/ ha in Conventional method). This is very critical for hybrid rice cultivation as the cost of hybrid seed is relatively higher. Therefore, growing hybrids under SRI is more profitable
- Saving on chemical fertilizers, pesticides as organic manures / natural biocides application is emphasized.
- Even partial adoption of six recommended practices of SRI enhance the yield substantially (10-15 %)
- Crop duration reduced by 7-10 days due to absence of transplanting shock and faster establishment of seedlings
- SRI is most suitable for seed multiplication (Breeder and Foundation) as initial seed requirement is small and rouging is easy due to planting of single seedling and wider spacing .
- Increase in soil microbial activity and improves the soil health
- Seed quality under SRI is reported to be better.
- Providing healthy food and environmental protection due to non use of inorganic fertilizer and pesticides
- More yield with less cost of cultivation and hence more net returns and higher benefit cost ratio
- Overall SRI is one of the best options for sustainable rice production

6.6 . Constraints in adoption of SRI in India

- Some of the SRI practices such as planting young seedling in shallow depth, raising nursery may require skills and more labour, especially at the initial stages of adoption.

- Weeding is one of the most serious concern in SRI as weeds grow faster due to wider spacing

- SRI cannot be adopted everywhere. It may not be suitable in command areas where water release is highly uncertain and in low lands under uncontrolled water situations especially during *kharif* season. It is also not suitable in saline and sodic soils

Feedback from farmers indicated certain problems which need to be addressed for improving the efficiency of the technology and for its wider acceptance.

- Organic manure (FYM/compost) availability in large quantities and lack of support for organic manures. As quality organic manures (FYM/compost) are not available in sufficient quantities, farmers are finding it difficult to adopt this principle in *toto*.

- SRI practices such as planting young seedlings at shallow depth, raising specialized nursery require skills and need more labour, especially in the initial stages of adoption.

- SRI may not be suitable in command areas where water release is highly uncertain and in low lands under uncontrolled water situations

- Weeding is reported as one of the major constraints in adoption of SRI. Availability of soil specific cono weeder is still a problem and mechanized multi row weeders are yet to be developed to reduce the drudgery for farm labour. (a person has to walk 40 km /ha for weeding with cono weeder in one direction). There is need to engage more persons at a time for weeding. Farmers felt the need for mechanized multi row weeders (that can be repaired /fabricated locally) to reduce drudgery and cover more area per unit time.

7. COMPARISON OF SRI WITH CONVENTIONAL METHOD OF RICE CULTIVATION

Operation	Conventional Method	SRI Method
Nursery Preparation	Nursery bed is not necessarily to be nearer the main field. About 30- 40 kg/ha or more seeds is used . Chemical fertilizers are applied to the nursery. Water is flooded in the nursery.	Nursery bed is raised with sufficient organic manures and should be nearer to the main field. About 5 kg/ha seed is sown in the seed bed. Chemical fertilizers are not recommended.Small quantity of water applied at regular intervals
Main field preparation	No cross drains are made as inundation is common and drainage is not a priority	Careful ploughing, puddling, leveling, raking is done. Thirty cm wide channels are made at an interval of 2-meter across the field to drain excess water.
Transplanting	Generally older seedlings about 25 day old or more aged seedlings are transplanted @ 3-4 seedlings per hill. Seedlings are uprooted from the nursery; thoroughly washed to remove the soil Seedlings are generally not transplanted as quickly as in SRI method. Seedlings generally turn yellow and take about a week to establish due to transplanting shock.	Eight-twelve day old seedlings (2-3 leaf stage) are transplanted singly. The seedlings must be transplanted with their roots intact while the seed is still attached to the seedling. They must not be plunged too deep but placed gently at appropriate point on the planting grid. Square pattern of planting grid is preferred to facilitate weeding. Transplanting should be done quickly preferably within an hour after uprooting the seedlings. The root should not dry. Seedlings remain green and establish early.

Spacing	Generally planting is done randomly with close spacing	Seedling should be planted precisely at a spacing of 25 cm X 25 cm or more depending upon the tillering capacity of the variety. About 16 to 20 hills per m^2 is maintained.
Nutrient management	Farmers generally do not apply balanced nutrients to soil. Farmers are using more nitrogenous fertilizers which promotes pests and give less emphasis on organic manures.	SRI is promoted as an organic culture. This promotes proper microbial activity in the soil. Farmers who do not have sufficient organic matter may use less amount of chemical fertilizer.
Water management	Inundation is a common practice. Standing water helps in weed suppression thereby reduce the problem of weeds	SRI requires root zone to be kept moist but not submerged. Alternate wetting and drying is followed till panicle initiation to keep soil aerated
Weeding	Hand weeding twice at 20 and 30 DAT is very common and weeds are removed from the field Herbicides are also used to control weeds	Since there is no standing water in the field, weeds tend to proliferate and hence requires frequent weeding. First weeding should be done 10-12 days after transplanting. Further weedings are required at an interval of 10-12 days. Weed bio-mass is generally mixed with the soil with weeder (Cono weeder) which enhances organic matter in the soil.

8. MODIFICATIONS OF SRI FOLLOWED IN DIFFERENT STATES

SRI has been adopted with many modification in different states due to practical field level problems however there is a significant improvement in the yield with reduced inputs in all states

	Andhra Pradesh	Tamil Nadu	Karnataka
Seed rate and age of seedlings	5 kg /ha 8-12 day old seedlings	7 -8 kg for single seedling 12-15 kg for double seedlings in problem areas. 15 day old seedlings	5 kg /ha 15 day old seedlings
Nursery	Raised bed nursery with sufficient quantity of well decomposed organic manures	On shallow raised bed covered with polythene/ gunny bags (mat nursery) Community nursery at staggered time was promoted Application of 1.5 kg of phosphorus (di ammonium phosphate) /2kg 17:17:17 NPK fertilizer.	Seedlings raised on plastic sheet (mat nursery)
Spacing (cm)	25 X 25	22.5 X 22.5	25 X 25 to 30 X 30
Fertiliser	Addition of organic manures over recommended NPK (100: 60:40 kg NPK/ha)	Recommended dose of fertilizers and additional green manure and FYM LCC based 'N' management for 'N' top dressing.	10 t/ha FYM in addition to 50% RFD (100:50:50 NPK/ha)
Irrigation	Alternate wetting Drying	Irrigation to a depth of 2.5 cm and allow to develop hair line cracks till next irrigation. SRI implementation was targeted on the water scarce tail end areas of basins	Moist or saturated condition is maintained up to flowering and thin film of water after PI
Weeding	2-3 times of weeding by cono weeder starting 10 days after T.P at 10 days	3-4 times cono weeding Use of motorized weeder is also in practice	3-4 times of cono weeding with 10 day interval

Satyanarayana,2006 *Jayaraman, 2010* *Ramachandra,2010*

Practice	Tripura	Orissa	Raipur	Meghalaya
Seed rate and age of seedling	5 kg ha 8 – 12 day old 1–2 seedling /ha	5-8 kg/ha 8 –12 days old seedling 2 seedling/hill	5-8 kg/ha 8-12 day old seedling single seedling/hill	5-8 kg /ha 15-20 day old seedlings 2 seedling/hill
Nursery	Raised bed nursery	Raised bed nursery	Raised bed nursery	Raised bed nursery
Spacing (cm)	25 X 25	25 X 25	25 x 25	20 x 20
Fertiliser	Recommended more organic manures in addition to inorganic fetilisers	Recommended NPK (60:30:30 kg/ha in Kharif 80:40:40 kg/ha in Rabi) 50 % organic + 50 % inorganic fertilizer (FYM or compost @ 10 t/ha)	Recommended dose of Inorganic fertilizer 90:60:40 Recommended to apply organics if available	INM (5 t/ha of FYM + 50% of NPK)
Irrigation	Alternate wetting and drying	Alternate wetting and drying	Alternate wetting and Drying Flooding3 days after disappearance of the water	Alternate wetting and drying
Weeding	Cono weeding for 2 – 3 times during crop season at 10 day interval	Mandava weeder is recommended over Cono weeder	2-3 times of cono weeding at 10 day interval	Adoption of cono weeder 2-3 times at 10 day interval
	Behrul, 2007	*Rao,K.S, 2010*	*Narendra Pandey et al., 2007*	*Munda and Patel, 2007*

9. STRATEGIES FOR UP SCALING THE ADOPTION OF SRI IN INDIA

The System of Rice Intensification (SRI) is showing an unprecedented promise of 'more with less'. Government is generally positive and has extended its support in the promotion of SRI.

The process of upscaling SRI is relatively slow owing to multiple constraints in its promotion and management intensity being one of the important factors. Integrated nature of SRI also throws multiple challenges in the areas of research, extension and policy support and there is a need to achieve coherence in these areas. The promotion of SRI in Tamil Nadu is the typical example of convergence of the different organizations in promoting SRI in a big way.

Research Approaches:

Due to increasing fertilizer costs that farmers are facing in India along with the irrigation water shortage and ever growing pollution / environmental problems that are foreseeable in future decades, there is a need to intensify research on SRI practices

- Adoption of SRI principles to specific eco-regions including identification of suitable cultivars , spacing requirements for different crop durations and soil fertility, fertilizers and labour saving equipments (motorized is essential weeder) is essential
- Cropping system approaches for utilizing the benefits of SRI on long term basis .
- Fabrication and popularization of the motorized cono weeders to overcome the serious problem of weeds and drudgery involved in weeding under SRI method
- Studies on water balance, schedule of water application under different soil and climatic conditions along with the relationships among root systems, nutrient uptake and yield
- Long term studies under SRI as compared to conventional method on pest and disease dynamics, soil health and nutrient balance
- Green house gas emissions under SRI *vs* Conventional for its ability to mitigate climatic changes
- Development of suitable tools for SRI eg. developing row seeders and transplanter incorporating SRI principles.
- Documenting reasons for dis-continuation of SRI
- Socio-economic impact studies on SRI in different situations and ecosystems

Extension Approaches

SRI is a knowledge and experience based method of rice production than input centric technology. The extension systems in vogue are mostly designed around input driven technologies. Subsidised demonstrations with 'progressive' farmers are the only methods used for extension of knowledge, which is not so encouraging.

- Finding appropriate drivers for the extension of SRI is crucial. The knowledge based and labour oriented technical processes can best be extended on the farmers' institutional platforms.
- Farmer Field Schools is another promising extension method that can be of great use in upscaling SRI.
- Formal public sector extension agencies should evolve ways of working synergistically with these groups/ farmer's platforms / Institutions.
- Compact demonstrations at block level will be having more impact rather individual demonstrations
- Training to all the stake holders including labourers will create the required impact for adoption

Policy Support

The state level government support for SRI is limited to extending subsidies for weeders and markers, field demonstrations

- Subsidies are extended at present for mechanical weeders. The labour for weeding is seen as a problem hence the support must be extended for engaging labour during initial seasons of adoption
- A group/ area based approach to weeding may be considered rather than an individual farmer centric subsidy.
- Labour training in weeding , transplanting operations would be of immense relief to farmers.
- The designs of weeder should also be diversified and be made amenable to local production.
- Staggered and community nurseries sown at different times at a village level can make available the required aged seedlings to farmers and coping with labour demand
- State support must be extended to green manure crops and for production of organic manures such as vermicompost , bio-fertilsers.
- Controlled irrigation in canal and tank systems for better management of water will lead to adoption of SRI in large scale.
- Convergence of different organizations working on SRI for large scale adoption

10. CONCLUSIONS

SRI is reported to be in practice in more than 40 countries and in major rice producing countries like India, China, Vietnam and Indonesia, the governments are actively promoting it though with different degree.

System of Rice Intensification is one of the options towards enhancing water productivity in rice cultivation. The system involves few modifications in nursery raising, age of seedlings at planting, planting geometry, nutrient and water management. Essentially , SRI practices create more favourable soil-water – plant atmosphere relationships than are achieved under conventional transplanting with continuously flooded fields. However, SRI can not be adopted every where and by every one

- Planting young seedlings and aeration by alternate wetting and drying and cono weeding has significant positive effects on crop growth and development.
- Rice plants grow profusely under SRI due to favorable rhizhosphere activity and the yields are reported to be 15 – 30% higher as compared to the conventional method of rice cultivation.
- The system is little intensive and requires adequate attention during crop growth. It would be difficult to adopt SRI in low lying/heavy rainfall areas and command areas during *kharif* season where water control is extremely difficult.
- Weeding is the most common problem is SRI. Manual cono weeding is laborious. Development and use of improved and mechanized cono weeders to suit different soil types would pave the way for adoption of SRI in wider scale.
- Capacity building involving Farmers and farm labourers have to be trained on the simple but crucial components of this system to make SRI popular among the farmers.
- Adoption of SRI wherever feasible would help us to march forward to face the looming water crisis which is becoming a threat for rice cultivation in future.
- Many farmers in India and elsewhere are still experimenting with SRI. SRI offers unlimited opportunities for exploration and innovation for local adoption in most of the ecosystems.
- The challenge for those mandated to popularise and promote it lies in the adoption of extension methodologies.

In India, interest in SRI started just 8 years ago, and already as many as 2 million farmers are growing their rice with all or most of the recommended SRI crop management practices in about 1.5 million ha distributed across >300 districts of the country. Against the back drop of water scarcity with concomitant pressure to produce more grain (*more crop per drop*), SRI with alternate wetting and drying irrigation is a promising option for rice growers , more attractive than other , presently available methods of rice cultivation.

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System of Rice Intensification technology (SRI) which requires less quantity of seeds, less nursery area, saves water and labour and enhances yield covering rice and other crops like sugarcane,should be popularised.

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SRI




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