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Review

Potentials of system of rice intensification (SRI) in climate change adaptation and mitigation. A review

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How to increase food production using less water is one of the greatest challenges of the future. Crops and livestock use 70 percent of all water withdrawals and up to 95 percent is some developing countries. Paddy alone consumes about 60 percent of it. By 2025, 1.8 billion people are projected to be living in countries or regions with absolute water scarcity. To ensure food security for the growing population, expansion of rice-cropped area and continuous intensification of rice cultivation would likely increase greenhouse gas emission. Data on trade-offs between rice yield increase, water management and reduction in greenhouse gas emissions are urgently needed for innovation in cropping techniques. Modification of current cropping technique might be a way to reduce greenhouse gas emissions from rice soils. In this respect, System of Rice Intensification (SRI) has been introduced as an efficient, resource saving, and productive strategy to practice rice farming. Water management practices proposed for the SRI, cycles of repeated wetting and drying, were found to be beneficial to rice plant growth through increased nutrient availability leading ultimately to higher grain yields. In many countries, SRI have been producing average yields around 8 t/ha, twice of the present world average. With good use of these methods and with build-up of soil fertility, in microbiological as well as chemical and physical terms, yields can surpass 15 t/ha, pushing beyond what has been considered a yield ceiling for rice. SRI is reported to reduce greenhouse gases emissions up to 40%, water saving 25-65%, reduction in incidence of major rice pests and diseases, resistance to storm damage and drought, high economic return and shorter crop cycle. These make SRI technology relevant to the climate change adaptation and mitigation.

Key words: Cropping technigue, yield, climatic change, greenhouse gas emissions.

INTRODUCTION

The challenge of the ever increasing water demands to produce more food to feed the burgeoning world population has worsened further by climate change (Ndiiri et al., 2012). Rice is the most commonly grown cereal crop that requires large amount of water when grown under conventional practices. Apart from being one of the important staple crops consumed by majority of the population (approximately >70%), much of the rice is produced by small farmers under irrigation with high production costs. However, this is likely to become quite difficult with the dwindling water resources, competition with other sectors on the use of the water, as well as problems posed by the impacts of land use/cover and climate change.

While climate change will have both positive and negative impacts on the yield of crops , some crops will produce more while others will suffer, negative impacts have outweighed positive impacts to date (IPCC 2014b). Already, it is estimated that climate change has reduced global yields of wheat by 5.5% and of maize by 3.8% (Lobell et al., 2011). By 2090, it is projected that climate change will result in an 8-24% loss of total global caloric production from maize, soybean, wheat and rice (Elliott et al., 2015). However, the decline in productivity will vary. For example, Sub-Saharan Africa will be hit particular hard; it is estimated that across Africa maize yields will drop by 5% and wheat yields by 17% by 2050 (Knox et al., 2012).

To improve food security, in Sub-Saharan Africa we must increase the resilience of water resource base and intensify rice productivity. To counteract this, good water management and agronomic practices must be tested for their suitability under local environment.

System of rice intensification (SRI), which originates from Madagascar, is an approach that provides a new avenue for significantly increasing rice yields per hectare (Vishnudas, 2009). The suitability of SRI has been reported in various studies. In Kenya, studies indicate that under SRI practice, the yield of rice ranges from 6 to 8 ton/ha, water saving could be up to 25%, healthy grains can be produced that weigh 100-110 kg per bag, and it produces quality grains with stronger aroma (Mati, 2012; Ndiiri et al., 2012). In Madagascar, it has been reported that SRI can increase the rice yield by 25 - 100% while reducing the amount of water use to 25 - 50% and is considered as an incentive to a rice grower (Satyanarayana et al., 2007). In China, it has been reported that up to 46% of water saving has been attained under SRI practice and yield increase of similar value (Xiaoyun et al., 2005). In Tanzania, it has been reported that SRI increased the rice yield by 24.28% while reducing the amount of water used to 64.67% (Kahimba et al., 2014).All these studies provide evidence on the suitability of SRI practice in saving water use while increasing yields to feed the growing population.

From the agronomic point of view, SRI practice is considered as a representation of empirical practices that vary in a manner that significantly reflect conditions (Dobermann, 2004). Therefore, the knowledge on the principles and the bio-physical mechanisms are imperative under a range of different agro-ecological environments (Stoop et al., 2002). On-farm participatory research activities under well defined farming-systems approach are necessary so as to adequately validate the practical relevance and risks associated with practising SRI under local conditions (Stoop et al., 2002). This paper reviews the practices and potentials of SRI practices in adapting and mitigating climate change.

Rice production practices

Conventional rice production method

Conventional rice production is a farming practice characterized by continuous flooding (more than 15 cm water level, 1.7Lts/sec/ha), late transplanting (21-35 days after seed germination), and high seed rate use 30- 40 kgs/acre. Most of the rice in Tanzania is as by far the predominantly irrigated crop and small quantities grown along river valleys bottoms and low lands. About 90% of rice in the country is grown under continuous flooding, a practice that requires large amount of water (Mdemu et al., 2004). The shortage of water across the country brought about by climate change leads to low exploitation of suitable land for irrigation. Tanzania is one of the most vulnerable countries to climate change. Extreme climatic conditions, for instance droughts have already affected production of rice (Paavola, 2008).

System of rice intensification (SRI)

Overview and Origin of SRI

The SRI was developed in Madagascar in the 1980s by Father Henri de Laulanié, SJ, after he had spent 20 years working with Malagasy farmers and on his own trial plots to learn how rice could be grown with less reliance on external inputs. The resource-limited farmers with whom Laulanié worked were not able to benefit from Green Revolution technologies that required purchase of new seeds and chemical fertilizer (Laulanié, 1993; Uphoff, 2006). The Malagasy non-governmental organization (NGO) that Laulanié established with Malagasy friends in 1990, Association Tefy Saina, worked with the Cornell International Institute for Food, Agriculture and Development (CIIFAD) from 1994 to 1998, helping to implement a conservation and development project funded by the US Agency for International Development. The challenge was to give farmers living around the rain forest within Ranomafana National Park some attractive alternative to their slash-and-burn rice cultivation, which was reducing the remaining biodiversity. An evaluation of soils in the peripheral zone indicated that these were extremely unfavorable in terms of acidity, cation exchange capacity, and available phosphorus (Johnson, 1994). Yet on these soils, farmers using the SRI methods recommended by Tefy Saina field staff, over three successive seasons, averaged 8 t ha^{-1} yields instead of only 2 t ha^{-1}, obtained previously. This increase was achieved without adopting new, improved varieties; without relying on chemical fertilizers but just applying compost made from available biomass; and with less irrigation because paddy fields were not kept flooded, just intermittent irrigation and drainage were practiced (Bilger, 1996; Hirsch, 2000). These results were achieved with methods that contradicted the prescriptions of the Green Revolution: no new or improved varieties were involved, and requirements for seeds, water, and fertilizers reduced. The benefits of SRI have now been seen across a wide range of ecosystems, in all of the major rice-producing countries in Asia, and from coastal West Africa (Ceesay et al., 2006), Tanzania (Kahimba, 2014; Kombe, 2012), to the dry interior climate of Mali's Timbuktu region on the edge of the Sahara Desert (Styger et al., 2010).

From the subsistence farmer's perspective, SRI can be defined as the use of the existing assets differently, yet increasing the yield and reducing water use but producing healthy and quality grains with strong aroma (Katambara et al., 2013).

Principles of SRI

The SRI practice consists of applied principles ranging from seed sorting, sowing, transplanting younger seedlings, weeding, and water management, all within the growing period of rice plants. A brief explanation of the principles is given below (Katambara et al., 2013).

Sorting out of the seeds: Although other approaches used in sorting out rice seeds may exist but in SRI, the defective seeds are separated by flotation-sink method in brine water. Good seeds are the ones that sink in brine water capable of floating a raw egg. Generally, the concentration is not substantial to cause an effect on the selected seeds.

(ii) Raising seedlings in garden like nursery: This ensures a careful management of seedlings and easy uprooting as well as transplanting.

(iii) Uprooting and transplanting time: The time between uprooting and transplanting should be between 15 - 30 minutes and the roots should be kept moist during this time

Early transplanting of 8 to 15 days old seedlings, in addition to the provision of adequate buffer for the seedling from being damaged during transplanting, full tillering and optimal production occurs when the seedlings are transplanted before entering the fourth phyllochron of growth.

(iv) Single, wide spaced transplants: This ensures that the plants have enough space for tillering as well as to allow a mechanical weeder to pass through without harming the plants. Adoption of wider spacing at 25 cm x 25 cm in a square grid pattern. The field should be well puddled and leveled. After leveling the field, a wooden or steel marker can be used to make grids of 25 cm x 25 cm.

(**v) Early and regular weeding**: This ensures that weeds do not compete with the rice plant. In addition, mechanical weeders aerate the soil. The roots need oxygen so as to be strong and healthy for optimal tillering and development of healthy rice grains. In SRI the minimum use of water increases weed infestation that compete with rice for water, air, nutrients and light and hence timely weeding is needed. Field wetting and drying requires more weeding, especially at initial growth stages before full canopy development, than the common practice, as weeds tend to grow more rapidly under aerated soil conditions. The following principles need to be adhered to. Weeding is done after 10 days of transplanting; depending on how best the land was prepared, the intensity of weeds and the type of weeds. Weeding may be repeated twice in every 10 days; Spike-teethed rotary tools are recommended to manual weeding because this way, weeds are mixed into the soil as green manure. It also enhances the tilth. For better performance, there should be sufficient moisture in the field to facilitate easy pushing while avoiding sticking of the soils on the weeder. Chemical spraying can also be used to control weeds (URT, 2015).

(vi) Judicious water management: Wetting and drying of the field makes the rice plant healthy since the roots are supplied with moisture as well as air. This allows the root to uptake adequate nutrients from various soil horizons. Wetting and drying of the fields use less water and improve soil aeration and promote roots elongation that allows more tillering and rapid growth of paddy plants. Irrigation depends on the development of cracks that appear on the soil surface. The idea is to keep the soil moist and not saturated to allow air to get into the soil for the benefit of the roots and soil organisms (URT, 2015).

(vii) Use of fertilizers: Organic and/or inorganic fertilizers are recommended in SRI cultivation as they give better response and improve soil health. Application of FYM / compost before ploughing and incorporation into the soil is recommended. In case of short supply of organic fertilizers, supplementation by inorganic fertilizers may be adopted for better yields depending on soil test values at the time of preparation of the field.

(viii) No use of herbicides: The non-use of herbicides favours the sustainability of the ecosystem and the microorganisms whose activities are suitable for the growth of rice plants.

Potentials of SRI in relation to Climate Change Adaptation

The enhancement of crop production through SRI agroecological management practices is impressive. But what effect, if any, do they have on the climatic challenges facing world agriculture? These methods evidently can make rice production more resilient under a variety of adverse climatic conditions that are foreseeable in connection with projected future climate change, and they may countervail to some extent the drivers of climate change (V&A Program, 2009).

Drought resistance and increased yield

Farmers widely report that crops in SRI withstand considerable water stress if the crops can be sustained through their first 3 to 4 weeks of growth. In the summer season of 2009, much of India was affected by failure of the monsoonal rains, causing widespread crop loss. Farmers who used SRI methods in the state of Orissa, India reported little or no loss of yield due to low rainfall or pest damage ("SRI method to deal with erratic monsoon" 2009). In Tamil Nadu, the minister of agriculture attributed the increased rice production, to the spread of SRI methods despite reduced crop area to lesser and erratic rainfall ("Rice intensification project a boon to farmers" 2009).

Buffering of drought impacts was seen also in northern India (Sen and Goswami ,2010). Similarly, villages and rural areas in Sichuan province in China have been hit by drought. By complementing SRI methods of crop management with plastic mulching on raised beds, farmers have been able to increase their paddy yields while reducing water requirements. In Hehe village, SRI yield increase of 30% was accompanied with 70% water reduction. The drought resistance conferred by SRI methods had led farmers in the village to use them on 200 ha (3,000 mu) in 2009, with plans to extend SRI to 6,666.66 ha (100,000 mu) in 2010 (Zhou, 2009). In Xiangshui village, farmers received 7.7–9.0 t ha^{-1} with SRI methods in a water-short season and as high as 12 t ha^{-1}, instead of 4.5 t ha^{-1}. Farmers' reduced costs of production for weeding, land preparation, fertilizer, and irrigation more than offset their cost of mulching (Sheng, 2009). Surprisingly, SRI methods were reported to offer greater benefits in drought years than in normal years (Lv et al., 2009). With normal rainfall, SRI methods add 2.25 to 3 t ha^{-1} beyond usual yields, while in a drought year SRI management increased yields by 3 t ha^{-1} or even more compared to usual methods. In Kenya, studies indicated that under SRI practice the yield of rice increased from 6 to 8 tha^{-1}, healthy grains that weigh 100-110 kg per bag, and it produces quality grains with stronger aroma (Mati, 2012; Ndiiri et al., 2012). Also Omwenga, 2014 reported an increase of 46.4% above the conventional method of growing rice. In Madagascar, it has been reported that SRI can increase the rice yield by 25% - 100% (Satyanarayana et al., 2007). Also, in Tanzania, it has been reported that SRI increased the rice yield by 24.28% (Kahimba et al., 2014) and the yield levels ranges from 7.0 to 11.0 tons per ha (Tusekelege *et. al*., 2014; Kahimba et al., 2014; Katambara et al., 2013). In USA, it has been reported that SRI increased the rice yield by 42% (Kongchum et al., 2011).

Economic impacts

Lv et al. (2009) reported average net income ha^{-1} of $220 with usual methods but with SRI methods in a normal rainfall year, this could be raised up to US$1,500. In a drought year, it was calculated that farmers' net income were increased from a loss of US$550 ha^{-1} with usual practices to a profit of US$880 ha^{-1} with SRI. Such improvement is explainable at least in part because SRI plant roots grow deeper and continue to function right to the end of the crop cycle, whereas rice that is continuously flooded loses about three fourths of its root system by the flowering stage, when grain formation is beginning (Kar et al., 1974).

Tusekelege et al. (2014) measured profitability in terms of Return on Investment (ROI). The ROI was very high in SRI compared to the conventional methods. ROI was found to be approximately 254 of which is around the ROI being found by many scientists worldwide. The ROI in SRI was concluded by Uphoff (2009) that ranges from 78-452 worldwide. In terms of Benefit Cost Ratio (BCR) the results show that SRI is potentially more profitable in Tanzania. BCR ranged from 2.30 to 2.51. The study on SRI in Kenya, by Ndiiri et al. (2013), revealed BCR range from 1.76 to 1.88.

Resistance to storm damage

Farmers also report that SRI plants can withstand the effects of heavy wind and rain from storms, even typhoons and hurricanes. This happened in China and Pakistan, where "normal" fields of rice plants had lodged by the force of the storm, whereas SRI fields continued to stand upright so no crop was lost. Having stronger root systems could explain this resistance to lodging, but the tillers (stalks) on SRI plants are thicker and stronger, which could be due to a greater uptake of silicon facilitated in aerobic soil and a lower planting density. Controlled trials have shown that the percentage of rice plant lodging is reduced by intermittent, as opposed to continuous, flooding, younger seedings (14 versus 21 days), and wider spacing (Chapagain and Yamaji, 2009).

Tolerance of abnormal temperatures

SRI crops' ability to withstand temperature stress has also been reported by farmers,.In 2006, researchers at the state agricultural University in Andhra Pradesh, India, serendipitously generated data on this effect while monitoring comparison plots of SRI and regular rice to assess pest damage (Sudhakar and Reddy, 2007). During a five-day period, 16 to 21 December 2006, average mean temperature dropped to 9.2 to 9.8°C, badly affecting most of the rice crop in the region. Average paddy yield from the conventionally grown trial plots in that season was just 0.21 t ha^{-1} whereas the yield of nearby SRI plots averaged 4.16 t ha^{-1}. In the preceding season, when temperatures were normal, the average yield on these plots with usual practice was 2.25 and 3.47 t ha^{-1} with SRI methods, with 54% increase. Ability to withstand the effects of abnormal temperatures is also likely to become more important in the future.

Pests and diseases resistance

With global warming, many insect pests and microbial pathogens are likely to become widespread (Rosenzweig et al., 2004). SRI farmers have reported no need of agrochemical use for the protection of their crop. They find this either unnecessary or uneconomic, as damage is not great enough to justify the cost of chemicals and labour.

This effect has been assessed by the National Integrated Pest Management (IPM) Programme of the Ministry of

Table1. Reduction in incidence of major rice pests and diseases with SRI production methods, average for trials in eight provinces of Vietnam, 2005–2006 crop year.

Disease/pest	Season	No. of provinces	Units	Farmer practice	SRI methods	Difference (%)
Sheath blight	Spring	9	Percent	18.1	6.7	63
	Summer	9	"	19.8	5.2	73.7
Leaf blight	Summer	6	"	36.3	8.55	76.5
Small leaf folder	Spring	6	Insects/m^2	107.7	63.4	41.1
	Summer	6	"	122.3	61.8	49.5
Brown plant hopper	Spring	8	"	1,440	542	62.4
	Summer	8	"	3,214	545	83

Source: (Dung, 2007).

Agriculture and Rural Development in Vietnam. Based on frequency or severity counts for the main rice pests and diseases on comparison plots in eight provinces, for two seasons, the program reported that the average for four pests or diseases was 55% lower in the spring season and 70% less in summer (Table 1). This quantifies less formal assessments in other countries.

Tusekelege et al. (2014) reported that yellow mottle virus infestation was reduced due to high canopy cover as compared to conventional practice. The evidence observed by the researchers and the farmer; Godfrey Joseph (Ilonga Msalabani irrigation scheme, Kilosa District, Morogoro-Tanzania) a farmer involved in the trial, he observed that ''about three quarters of rice grown in his experimental plot under conventional practice was seriously affected by rice yellow mottle virus disease while under SRI, only few plants were observed to be affected. This justifies that SRI practices reduces diseases spread/distribution hence can act as a natural control to some of the rice diseases.

Shorter crop cycle

Although it has been claimed by critics that SRI crops take longer to mature (Surridge, 2004),the opposite is more common because SRI rice crops mature usually 1 to 3 weeks sooner than the same variety when grown with older seedlings, close spacing, and continuous flooding.

The most detailed assessment of this has been done by the District Agricultural Development Office in Morang, Nepal. It found that eight rice varieties when grown with SRI methods on average matured 16 days sooner (Table 2). The average SRI yield for these 413 farmers was 6.3 t ha^{-1} compared with rice yields in the area with conventional methods of 3.1 t ha^{-1}. Getting doubled yield in less time reflects a marked change in plant phenotype. Shorter crop cycles have many economic advantages. The same field can then be used for a short-season crop, such as a vegetable, or a following crop, such as wheat, can be planted sooner to get higher yield. There is also the environmental benefit of further reducing crop water requirements. This phenotypical change in SRI is relevant for coping with climate change in that a shorter growing period reduces the crop's exposure to abiotic and biotic stresses, which are likely to increase with global warming. This will likely increase also extreme weather events. Many of the most agriculturally damaging storms and droughts come toward the end of the growing season. So being able to harvest a crop 1 or 2 week earlier can reduce the climatic hazards that a crop must face. In Tanzania, Tusekelege et al. (2014) observed that rice under SRI matures earlier than conventionally transplanted rice in both three experimental sites.

It has been reported that young single seedling transplanted in a wide spacing benefits from growth factors like light, nutrients and water which results in optimal plant growth and big well filled grains.

Greater plant water use efficiency

A three-year evaluation of SRI practices conducted at the Indian Institute of Water Management (ICAR), Bhubaneswar, India, compared the functioning and performance of the most recommended rice variety in Orissa state under both SRI and best management (Thakur et al., 2010). The research revealed that the ratio of photosynthesis to transpiration was much higher in SRI rice plants than in the same variety of rice grown according to rice scientists' recommended practices. This ratio indicated a significantly higher more than doubled efficiency of plant water use. This is an important characteristic in the decades ahead as water becomes an increasingly constraining factor of agricultural production.

Physiological changes in rice plants induced by SRI management raise their water use efficiency, by 75% according to an analysis done in China (Zhao et al., 2009). Getting higher yield per unit of water was in part due to delayed senescence of roots and leaves. Experiments in India have calculated that SRI plants fixed more than twice

Table 2. Crop duration, in days, of rice varieties grown with SRI versus conventional methods (ranges are shown in brackets), Morang district, Nepal, 2005 main season

Variety	(N)	Standard duration[1]	SRI duration	Difference
Mansuli	(48)	155	136 [126–146]	19 [9–29]
Swarna	(40)	155	139 [126–150]	16 [5–29]
Radha 12	(12)	155	138 [125–144]	17 [11–30]
Bansdhan/Kanchhi	(248)	145	127 [117–144]	18 [11–28]
Barse 2014/3017	(14)	135	126 [116–125]	9 [10–19]
Hardinath 1	(39)	120	107 [98–112]	13 [8–22]
Sughanda	(12)	120	106 [98–112]	14 [8–22]
Average (total)	(413)	141	126 [115–133]	16 [9–25]

[1]Period of time, in days, reported by rice breeders for this variety to reach maturity.
Source; (Uphoff, 2007b).

as much carbon dioxide per unit of water transpired; 3.6 µ mol CO_2 per milli mol of water (H_2O) versus 1.6 µ mol fixed by conventionally grown rice plants (Thakur et al., 2010). An evaluation done in Gambia measured six times more rice yield per unit of water consumed by plants (Ceesay et al., 2006). In Kenya, it has been reported water saving could be up to 25to 32.4 % (Mati, 2012; Ndiiri et al., 2012; Omwenga, 2014). Also, in Madagascar it has been reported that SRI reduced the amount of water used to 25 - 50% (Satyanarayana et al., 2007). Also, in Tanzania, Kahimba et al. (2014); Kimaro et al. (2016) and Tusekelege et al. (2014) reported 64.7%, 50% and 50% reduction in water use, respectively. Kongchum et al. (2011) reported reduced water use by 29% in USA. Such considerations will become more important as water becomes scarcer as an agricultural input.

Mitigation of climate change

Possible reduction in greenhouse gas emissions

Rice paddies are considered one of the most important sources of CH_4 and N_2O emissions, which have attracted considerable attention due to their contribution to global warming (Harris et al., 1985; Bouwman, 1990). Rice fields are presently one of the agricultural sector's main producers of methane (CH_4) given that methanogenic bacteria thrive in flooded soil conditions. Converting paddy soils from anaerobic to aerobic status will substantially reduce methane emissions. On the other hand, a switch to aerobic soil conditions could increase the production of nitrous oxide (N_2O) by aerobic bacteria, and this is a more deleterious greenhouse gas. A N_2O molecule contributes 12 times more to global warming than its CH_4 counterpart. We have thus been cautious about proposing SRI rice production as a way to help curb global warming because small increases in N_2O emissions could offset much larger reductions in methane. A recent evaluation in China of two of the main SRI practices has concluded, however, that the projected gains in methane reduction from (a) increasing organic fertilization of rice soils and (b) reducing the continuous flooding of paddy fields are considerably greater than any offset from generation of more nitrous oxide (Yan et al., 2009). This evaluation was done according to guidelines of the Intergovernmental Panel on Climate Change (IPCC) and considered much smaller changes in conventional irrigated rice production than are made with SRI. So, it appears that SRI could indeed make a net contribution to the reduction of greenhouse gas emissions. The modest changes that the Chinese researchers evaluated, which were less extensive than those recommended for SRI, reduced the methane production from paddy fields by almost 30%. Thesis research in the Nepal Terai, measuring methane and nitrous oxide emissions in comparable paddy fields with SRI or conventional management, found that CH_4 was reduced fourfold in SRI fields, whereas N_2O was reduced even more, fivefold, apparently due to the reduction in inorganic nitrogen for aerobic soil organisms to alter and due to SRI rhizospheres being more effective "sinks" for nitrogen in the soil (Karki, 2010).

Environmental potentials of SRI practice

Reduction in water requirements

SRI being an environment- friendly innovation is an additional benefit. Reduction in water requirements reduces the competition between meeting food needs and the needs of natural ecosystems, which is why the Worldwide Fund for Nature (WWF) has become involved in SRI evaluation and dissemination. Irrigated rice production is the single largest consumer of freshwater extracted from natural flows and reserves, surface and subsurface (Barker et al., 1999). Thus, SRI methods can reduce water demand if more widely used(Table 3). At the rice plant level, there is evidence that SRI-grown rice plants are physiologically more efficient in their use of water (Thakur et al., 2010; Zhao et al., 2009).

Table 3. Reductions in methane emissions due to various water management practices compared to continuous flooding (with organic amendments) in China

Mitigation practices	Seasonal emissions(kg ha^{-1})	Relative reduction (%)	Experiment
Mid season drainage	385	23**	Beijing ,1995
	312	44 ns	Hangzhou, 1995
	51	43**	Maligaya, 1997 DS
	25	7 ns	Maligaya ,1997 WS
Alternative flooding/drainage	216	61**	Hangzhou, 1995
	207	59**	Beijing ,1995
Mid season drainage and no organic matter	26	95**	Beijing, 1995
	239	57**	Hangzhou, 1995

** Statistically significant, ns; statistically not significant
WS = wet season, DS = dry season
(source: Wassmann et al., 2000)

Reduced use of agrochemicals

Fewer toxic agrochemicals are required to protect rice crops because SRI plants are more resistant to pests and diseases. Reduced use of agrochemicals means that there will be less accumulation of these substances in water and in soil systems, which should be a boon for both human and ecosystem health. With more reliance on organic means for maintaining soil fertility and with less dependence on inorganic materials, there will be improved water quality less build-up of nitrate in groundwater supplies and more biodiversity in soil systems.

CONCLUSIONS AND RECOMMENDATIONS

The SRI challenges the common notion that rice performs best under flooded conditions. Instead, intermittent irrigation is practiced in SRI during vegetative growth to keep the soil just saturated or moist enough to avoid drought stress, which typically results in water savings as compared to continuous flooding. Globally, the demand of water for irrigation purposes is increasing and is proportional to demand for food to feed a growing population. Conventional rice farming practices become technically unfavourable in this current environment of limited water resources. SRI practices have been reported of using less water, producing high yields, reduction of greenhouse gas emissions, rising farmers income and healthy grains which have stronger aroma.

The various components of SRI practice are empirical and site specific, hence more efforts are required to ensure that SRI is up-scaled and is widely adopted by farmers.

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Conflict of interests

The author declare that there is no conflicting interests.

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