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How System of Rice Intensification Conserve Resources, Benefits Environment and Resilient to Climate Change

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Abstract

Conventional paddy production is the world's largest single consumer of water and uses 34-43% of the total world's irrigation water or 24-30% of the total world's freshwater withdrawals. Water scarcity constrains agricultural production, particularly for rice, one of the most important global food crops. Adopting a system of rice intensification (SRI) can raise yields and income while using lesser water and other inputs. Additional benefits of SRI are diminished greenhouse gas (GHG) emissions, less runoff water pollution, and greater climate resilience. Changes in crop and water management practices for growing rice offer improvement in food security, could conserve resources, benefits the environment, and be adaptable to climate change. Evidence to support these facts is discussed here in this paper.

Key words: Rice, Growth, Climate change, Greenhouse gas emissions, Flooding rice

Introduction

Increasing water scarcity, rising costs of inputs, growing environmental degradation, and climate change poses severe threats to agricultural production (Nelson *et al*., 2009). Rice is a staple food for billions of people and is the largest consumer of water within the agricultural sector and increasing water shortages threaten its sustainable production to feed human beings. Existing rice production practices rely heavily on high seed rates, mineral fertilizers, chemical biocides, and irrigation water. Conventional paddy production is the world's largest single consumer of water and uses 34-43% of the total world's irrigation water or 24-30% of the total world's freshwater withdrawals. It gives negative impacts on soil health and water quality while increasing production costs and lower returns (Peng *et al*., 2010).

Growth in yields for rice has stagnated since the end of the 20th century (Sheehy *et al*., 2007; Ray *et al*., 2012) and its demand is continuously increasing (GRiSP, 2013). This trend can be altered either by developing high-yielding and well-adapted rice cultivars or by exploiting prevailing agro-ecological potentials including genetic resources suited to varying climate regimes, or both (Xiong *et al*., 2014).

The System of Rice Intensification (SRI), an integrated soil-crop-nutrient-water management methodology developed in Madagascar, increases grain yield with less water consumption (Thakur *et al*., 2011a), and it also has other benefits (Stoop *et al*., 2002; Thakur and Uphoff, 2017). The efficacy of these modifications in rice production management has been demonstrated in China, India, and 60 plus other countries (http://sri.ciifad.cornell.edu/countries/).

In this paper, we will discuss how this method of rice cultivation could conserve resources (seed, water, chemical nutrients/pesticides, and labor) to improve the income of the farmers. Also, facts about its benefit to the environment and climate resilience will be presented.

Resource conservation and income enhancement through SRI

Under SRI management, very young seedlings are transplanted singly, one per hill in a square grid pattern in a wider spacing of 20 x 20 cm or more, depending on the varieties used and the nutritional status of the soil (Thakur *et al*., 2011b). The use of single seedlings and wider spacing reduces plant population per m^2 by 80-90%, thereby, reducing seed requirements and cost by 80-90%.

SRI management practices advocate keeping rice fields moist by adopting or irrigating alternate wetting and drying (AWD) at least during the vegetative stage, which discourages to keep continuous flooding (CF) (Stoop *et al*., 2002). Thakur *et al*. (2011a) reported an increase in grain yield by 48% with an average water saving of 22% in SRI than continuously flooded scientific management practices (SMP). They found that water productivity with AWD-SRI management practices was almost doubled (0.68 g l^{-1}) compared to CF-SMP (0.36 g l^{-1}). Also, under SRI, water productivity increased by 73%, from 3.3 to 5.7 kg ha-mm^{-1}. The highest SMP grain yield and water productivity were with the 1-DAD (days after the disappearance of ponded water) treatment (4.35 t ha^{-1} and 3.73 kg ha-mm^{-1}), while in SRI grain yield and water productivity was the greatest at 3-DAD (6.35 t ha^{-1} and 6.47 kg ha-mm^{-1}) (Thakur *et al*., 2014).

A meta-analysis of published evaluations from 8 countries revealed that SRI methods raised total water productivity (including rainfall) by 52%, with 78% greater productivity of irrigation water. SRI management gave higher crop yield with, on average, 35% less irrigation water (Jagannath *et al*., 2013). Physiologically, SRI phenotypes have been found to synthesize twice as much carbohydrate in their leaves per unit of water taken up by the roots (Thakur *et al*., 2010). With water constraints for agriculture becoming more severe, water-efficient phenotypes with greater water productivity will become ever more important. SRI experience shows that this is possible to achieve with existing genotypes. Water saving and greater water productivity with SRI practices have been confirmed by studies in countries as varied as Afghanistan (Thomas and Ramzi, 2011), China (Zheng *et al*., 2013), India (Satyanarayana *et al*., 2007; Thakur *et al*., 2011a), Indonesia (Sato and Uphoff, 2007), Iraq (Hameed *et al*., 2011), Kenya (Ndiiri *et al*., 2013), and Sri Lanka (Namara *et al*., 2008).

Researchers from China found that rice yields with hybrid varieties were as much as 2.5 t ha^{-1} higher when planting fewer plants (less seed), switching from flooding to AWD (less water), and providing half of the N soil amendments in organic form rather than 100% as chemical fertilizer (Lin *et al*., 2009).

In Asia, where 90% of the world's rice is produced, rice cultivation is already relatively labor-intensive. While some studies of SRI labor requirements have shown it to require more labor, e.g., in Bangladesh (Latif *et al*., 2009), most evaluations have found SRI to be labor-neutral, e.g., in Cambodia (Anthofer, 2004) and Indonesia (Sato and Uphoff, 2007), or labor-saving in China (Li *et al*., 2005) and India (Sinha and Talati, 2007). For the adoption of SRI under labor-shortage conditions, mechanization for land leveling, weeding, and transplanting should be adopted.

An evaluation of rainfed SRI experience in West Bengal reported an average of 67% increase in net income ha^{-1} compared to farmers' current practices (Sinha and Talati, 2007). A broad evaluation of SRI economics in India conducted across 13 states and 2,334 farmers sampled surveyed found that even partial SRI use increased rice farmers' incomes by 18% (Palanisami *et al*., 2013).

Reduction in global warming potential and water quality benefits

Keeping rice fields unflooded, as well as, reductions in mineral fertilizer and other agrochemical use, also contribute to diminishing net greenhouse gas emissions from rice paddies as seen in studies from India (Rajkishore *et al*., 2013; Jain *et al*., 2014; Gathorne-Hardy *et al*., 2016), Vietnam (Dill *et al*., 2013) and Korea (Choi *et al*., 2014). Jain *et al*. (2014) found that with SRI production management, there was a 62% reduction in CH_4 emission accompanied by a 23% increase in N_2O emission, however, a net reduction of 28% in global warming potential. An evaluation of SRI in India calculated that SRI's 60% average yield increases were accompanied by 40% lower net GHG emissions ha^{-1}, with also 60% less groundwater depletion, and 74% less fossil-energy use kg^{-1} of rice produced (Gathorne-Hardy *et al*., 2016). Pollution in runoff from paddy field water is also diminished (Choi *et al*., 2014).

Climate-resilience through SRI

The more-robust plants, with better roots, and shoot growth, under SRI production management are better able to tolerate water stress (Zheng *et al*., 2013; Thakur *et al*., 2015) and withstand pests/diseases (Pathak *et al*., 2012; Visalakshmi *et al*., 2014). Namara *et al*. (2008) found in Sri Lanka that under drought conditions, SRI plants produced and stored more photosynthates, with 30% more grain-bearing tillers, more grains per panicle, and 38% higher grain yield.

SRI plants were found to better tolerate strong winds and rain with less lodging (Chapagain and Yamaji, 2010), as well as cold stress (Sudhakar and Reddy, 2007). Further, a shorter crop cycle with SRI management (Uzzaman *et al*., 2015) reduces exposure of rice plants to both biotic and abiotic stresses at the end of their season, when maturing and particularly vulnerable to losses. Greater tolerance to climate-related stresses can be attributed to the positive effects that SRI management practices have on more root growth and more abundant and diverse life in the soil, having stronger and greater prolific shoot growth with more grain-bearing tillers.

Conclusion

Altering conventional rice-growing practices of flooding rice paddies, using chemicals and lots of seeds will have both economic and ecological benefits, demonstrated under SRI. SRI production system helps to get higher yields despite changing climatic conditions while lowering production costs and making it more profitable for farmers, using less water, fewer agrochemicals, and greater income. SRI production system also offers additional benefit for the environment and climate-resilience.

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