International Journal of Innovative Agriculture & Biology Research 6(2):27-38, April-June, 2018

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System of Rice Intensification: A Review

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ABSTRACT
The system of Rice intensification acronym as (SRI) was developed in the last two decades is an effort to find sustainable agricultural practices that can lead to higher productivity, optimum use of capital labour, less input cost and less requirement of water. SRI, harmonizes the elements of soil, water, light and plant, it allowed the plants to achieve their fullest potential. Normal broadcasting of rice on the farm consumes 100Kg/ha^{-1} while planting required 30-60Kg seeds per hectare. In SRI only 4-10Kg of seeds is required per hectare. Farmers were inclined to accept (and participate in) a recommended practices since the practice is profitable, compatible with existing farming practices, simple to use, relevance to their labour use, farm inputs marketing, credit, community values and crop situation. SRI is found to be an integrated agro-ecologically sound approach to irrigated rice. It is also a designer innovation that efficiently uses scarce resources and protects ground water from chemical pollution and more dependent to poor farmers. Single seedling per hill (San-oh, A.T; *et al.*, 2006). Seedlings are recommended to be transplanted within 15-30minutes after uprooting in a shallow depth of 1-2cm deep with a recommended spacing of 25x 25cm^2 or more depending the soil fertility. About 25-50 % of water is saved in system of rice intensification. There were more tillers in SRI plants, having 35-50, even 80-100 or more compared to common ones with 5-10. Number of tillers/plant and number of grains/panicle (fertile tillers) were also higher in the method. SRI, was found to benefit farmers more in terms of more income with less input, given higher yield with lower investment and beneficial to poorer households. Crops mature sooner 10-20days, compared with conventional ones. There is less economic risk and creates better environment for rice and lowers the risk of environmental friendliness as little or no chemical fertilizer is required. With all these merits, it has some draw backs such as where areas are not kept continuously flooded, weeds presents problems. It is labour demanding and is considers labour intensive for many farmers. However, farmers are more comfortable with and skilled with SRI. Yield was also found to be higher in SRI with 8t/ha^{-1} as against 3/ha^{-1} under conventional paddy. Therefore, the system of rice intensification is the best option for rice production in order to meet up with the demand of the increasing population.
Keywords: System of rice intensification, fertile tillers, chemical pollution.

INTRODUCTION

The system for rice intensification (S.R.I) was developed by French Priest Father Henri de Laulani in Madagascar in the 1980's in an effort to find sustainable agricultural practices which lead to higher productivity, optimum use of capital and labour, less input cost and less requirement of water. System of rice intensification (S.R.I) is an acronym that is defined as 'system for rice intensification'. The System of Rice Intensification (SRI) is a way of harmonizing the elements of soil, water, light and plant to allow the plant to achieve its fullest potential, which is often hidden when inappropriate techniques are used (Zotoglo, 2011). SRI, as opposed to traditional rice production, involves alternate wetting and drying

(AWD) of rice fields (Kepha, Bancy and Patrick, 2014). Research and demonstration plots in several tropical countries have shown SRI techniques as productive resource-saving and environmentally benign when compared to conventional or traditional rice production (Namara, *et al*., 2004: Sato and Uphoff, 2007; Sinha and Talati, 2007).

In the broadcasting, one has to use a minimum of 100kg of rice seeds for one hectare, in planting one required about 30-60kg of seeds or so. But in SRI, only 4-10kg of seeds are required for one hectare (Randriamiharisoh, R, et al (2006). Therefore, this reduces input cost for the farmers and also less drudgery.

Principles of system of rice intensification (SRI): Laulanie established the following six key elements of SRI (Uphoff, 2007). The key physiological principle of SRI practices is to provide optimal growing conditions to individual rice plants so that tillering is maximized and phyllochrons are shortened, which is believed to accelerate growth rates (Nemoto *et al*., 1995).

There are six principles guiding system of rice intensification (SRI), these are:

i. seedlings get transplanted at a much younger age;
ii. only single seedling, instead of a handful of seedlings get planted in each hole;
iii. increased use of organic fertilizer to enhance soil fertility;
iv. intermittent water application to increase wet and dry soil conditions, instead of continuous flood irrigation;
v. plants are spaced wider apart instead of close, dense planting, with seed rates of 50-100 kg/ha, plants were set out carefully and gently in a square pattern, 25x25cm or wider if the soil is very good; the seed rate is reduced by 80-90%, netting farmers as much as 90 - 95 kg of rice per hectare and
vi. rotary weeding to control weeds and promote soil aeration.

In Nigeria, for instance some agencies were identified to be involved in rice related activities including training and demonstration of SRI. These agencies are Commercial Agriculture Development Project (CADP), Fadama III Project, IFAD/FGN/ Community-based Natural Resource Management Programme (CBNRMP), Sasakawa, National Food Security Programme (NFSP), Green Earth Implementation Initiatives (GEIDI) and the Upper Benue River Basins Development Authorities (UBRBDA)

History and background of system of rice intensification (SRI):

Modern rice farming requires innovation, which systematically adapts scientific knowledge to rice farming. Innovation is an idea, method, object which is regarded as new by an individual (Rogers, 1995, Singh and Mishra, 2007; Peter, *et al.*, 2012). According to Rogers (1995) adoption is a decision to incorporate a new practice into existing practices. It is a mental process consisting of learning, deciding and acting over a period of time.

A farmer is more inclined to accept (and participate in) a recommended practice if the practice is profitable, compatible with existing farming system, divisible, simple to use, has relevance for his labour use, farm inputs, marketing, credit, community values and crop situation (Agwu, 2004; Ekong, 2008). Other factors as mentioned by Bose *et al.*, (2012) include farm size, value of farm products sold, farming experience, leadership role, empathy and availability of farm credit.

In 1983 after two decades of experimentation Fr. Henri de Laulaníe, a Jesuit priest in Madagascar, synthesized the "système de riziculture intensive" (French) and "system of rice intensification" (English). Under the pressures from a drought and shortages of rice seeds, he started to experiment at his agricultural school near Antsirabe (1500 m elevation). The experiments initially focused on transplanting very young rice seedlings of just 10-15 days old in a fairly wide spacing (25 x 25 cm^2) of single seedlings. A square planting pattern was used to facilitate mechanized weeding. The rice was not grown in flooded paddies, but in moist soil, with intermittent irrigation. Under such conditions Laulaníe observed tremendous increase in tillering and rooting as well as number of panicles and larger panicle size, contributing to spectacular grain yields.

In 1990, Laulaníe helped to establish a Malagasy NGO called Association Tefy Saina (ATS) and became its technical advisor. ATS began introducing SRI with farmers in a number of communities in the country. In 1994, Cornell International Institute for Food, Agriculture and Development (CIIFAD) started working with ATS to introduce SRI as an alternative to slash and burn cultivation. From 1998, CIIFAD has become increasingly active in drawing attention to the potential of SRI also in other major rice growing areas in Asia (Uphoff, 2002), leading to a serious controversy with scientists of some established rice research Institutes (Stoop *et al*., 2002).

System of rice intensification: Laulanie (1993) and Uphoff (2001) described the system of rice intensification and suggested that SRI represents an integrated and agro-ecologically sound approach to irrigated rice (*Oryza sativa* L. var. *Indica*) cultivation, which offer new opportunities for location-specific production systems of small farmers. SRI is a designer innovation that efficiently uses scarce land, labour, capital and water resources, protects soil and groundwater from chemical pollution, and is more accessible to poor farmers than input dependent technologies that require capital and logistical support (Uphoff, 2004). SRI methods can lead to superior phenotypes and agronomic performance for a diverse range of rice genotypes (Lin *et al*., 2006).

Transplanting of single seedling per hill: Under SRI management it can be suggested that early transplanting provides a longer vegetative growth period, and single seedling per hill reduces the competition and helps minimize the shading effect of lower leaves. This helps lower leaves to remain photo synthetically active, for much longer, and in turn, root activity remains higher for a longer period due to the plant's enhanced supply of oxygen and carbohydrates to the roots (Horie *et al*., 2005). Further, higher root activity, in turn, supplies cytokinin to the lower leaves, delaying senescence and helping to maintain photosynthetic efficiency of the plant at latter growth stages. This outcome has been confirmed by a finding where a single seedling per hill had higher yield compared to three seedlings per hill (San-oh *et al*., 2006).

Mishra *et al* (2006) have linked single transplanting per hill to increases in root length, density and activity and their inter-dependence with above-ground canopy development, particularly resulting in prolonged photosynthetic activity by older leaves.

Transplanting of young seedlings (8–12 days old): Recent trends in recommendations for rice cultivation are to increase the density of plant population. Considering the fact that arable land and incoming light are limited (in a land area basis), most research for improving rice yield have been oriented to: (1) increasing biomass production by improving radiation and its efficient use; and (2) increasing the harvestable biomass relative to the non-harvestable portion for the sake of a higher Harvest Index (HI), the ratio between grain biomass and total plant biomass. This thinking has led to a breeding strategy that aims to create a cultivar producing more grains but fewer tillers (Khush, 1993). The growing conditions under SRI facilitate an optimum environment for tillering expression (Laulanié, 1993).

Transplanting of seedlings into a muddy field: Seedlings are raised in an un-flooded, garden-like nursery and then transplanted within 15–30 minutes after uprooting. SRI seedlings are heavier and sturdier compared to seedling grown in conventional nursery beds (Stoop, 2005). Transplanting should be done carefully to avoid trauma to the plants' roots, and also quickly to avoid their becoming desiccated. Shallow transplanting is recommended, only 1–2 cm deep, with roots laid in the soil as horizontally as possible. While plunging them into the soil vertically inverts the seedlings' root-tips upward, slowing the plants' recovery from the shock of transplantation and delaying their resumption of growth.

Drained field conditions could induce higher root activity by enhancing root respiration and root revitalization, resulting in greater leaf area, higher photosynthesis activity, resulting in higher yield (Tsuno and Wang, 1988). This finding has been complemented by high root activity contributes to a higher photosynthetic rate (Osaki *et al*., 1997) and the growth of shoots is very much dependent on root growth (Nikolaos *et al*., 2000). Super high yielding cultivar has larger root systems compared to other indigenous cultivars (Terashima *et al*., 1988). Therefore, root quantity and root activity both are required for raising yield (Xuan *et al*., 1989).

Wide spacing of 25×25 cm^2 or more depending upon soil fertility: Plants grown with wider spacing have more area of soil around them to draw nutrients and have better access to solar radiation for higher photosynthesis. Spacing is critical in modifying the components that influence final grain yield. The supply of resources mainly depends on the root system activity. So, it can be suggested that wider spacing allows roots to grow abundantly along with production of more tillers per plant.

Long duration varieties perform better with wider spacing than short duration varieties, Stoop (2005) suggested that long-duration varieties perform better under SRI management.

Mechanical weeding: One of the main purposes for flooding rice paddies with some controlled drainage is for weed control (Sahid and Hossain, 1995). Rice fields are kept under standing water until aquatic weeds develop. Once they start to invade the rice field, the field is drained in order to kill the aquatic weeds. Thereafter, rice field is re-flooded with standing water again when terrestrial weeds start to dominate. This is the traditional way for managing weeds in conventional flooded rice systems.

With SRI, weeds are controlled by the use of mechanical weeding with a rotary pushed weeder. The system relies on early and frequent weeding which varies from 3 to 4 times throughout the cultivation period. The first in the series of weeding is done about 10 days after transplantation and the others in a frequency of 10-20 days Tech, C, (2004).

Intermittent irrigation during vegetative growth stage: It was reported that 25-50% water could be saved by intermitted irrigation without any adverse effect on rice yield (Ramamoorhy *et al*., 1993). Growth is not harmed when plants are exposed to limited water condition during their vegetative stage (Boonjung and Fukai, 1996). Plant adopts osmotic adjustment at the vegetative stage which contributes the mostly noticeable mechanism of dehydration tolerance in the rice plant (Steponkus *et al*., 1980). But, any drought stress at later stages in plants which are not exposed to such drying treatment can cause great loss especially when plants are in the early reproductive phase (Toole,, *et al* 1981). Thus intermittent drying in the vegetative stage may not only induce root growth into deeper soil layers but could also help the plant to develop xenomorphic characteristics. Intermittent drying also improves soil, stimulates tiller development and alters sink-source relationships.

A key justification for promoting intermittent irrigation as part of SRI (Stoop *et al*., 2002; Uphoff 2003; Randriamiharisoa *et al*., 2006) is the stated assumption that rice is not an aquatic plant and that under continuous submergence most of the rice plant's roots remain in the top few cm of soil and degenerate by the reproductive phase so it is believed to improve oxygen supply to rice roots, thereby decreasing aerenchyma formation and causing a stronger, healthier root system with potential advantages for nutrient uptake (Stoop *et al*., 2002).

When the rice plant, especially upland cultivars having fewer aerenchyma compared to lowland-cultivars, is grown under continuously flooded condition with dense planting pattern, it retards the function of lower leaves and so the root activity, resulting in 78% root degeneration at the time when flooded rice plants commence flowering (Kar *et al*., 1974), i.e. at a time when peak root activity is required by plants to achieve higher yield. Also, the lower oxygen in the rhizosphere and continuous soil submergence results is more accumulation of carbon oxide around the roots which speeds up the root senescence.

Addition of organic manure instead of chemical fertilizer: The incorporation of organic manure into the soil can bring beneficial effect to root growth by improving the physical, chemical and biological environments in which root grow (Yang *et al*., 2004). Under continuous water logging condition, there is significant decrease in root growth (Satranarayana, *et al* 2006), whereas under intermittent irrigation, the incorporation of organic matter improves root morphological characteristics and root activity of rice plant. It has the effect of increasing root density, active absorption area, root oxidation ability and nutrient uptake (Yang *et al*., 2004).

SRI advocates argue that the most extensive root system of SRI plants and the improved structure and biological condition of soil were achieved by compost application, which provide access to much larger pool of nutrients. The advantages from using compost have been seen from factorial trials (Uphoff, 2003), but if organic matter is not available, SRI practices can be also used successfully with chemical fertilizer.

The SRI methodology: SRI is a unique innovation in that the productivity of four factors of production-land, labour, capital and water can be increased at the same time, not requiring trade-offs. The first thing to stress is that SRI is a combination of practices (a) that need to be used with appropriate adaptation to local conditions, and (b) that have synergistic effect on one another. The extent and mechanisms of such synergy have not been well studied, so what is reported here comes mostly from observation, though there are some thesis research projects that have given some precise and systematic measurements, which support what has been observed. The basic strategy with SRI is to create soil, water and nutrient conditions favourable for the growth of young plants. There are three dramatic observable and measurable effect:

There is much greater root growth. A test of root resistance, which is a proxy for measuring total root development (Toole and Soemartono, 1981) found that it took more than 5 times as much force (53 kg) to uproot a single SRI rice plant as to pull up a clump of three rice plants conventionally grown (28 kg) (Joelibarison, 1998).

There is much greater tillering, with SRI plants having 30, 50, even 80 or 100 or more tillers, compared to the more common number of 5 to 10 tillers. Why rice plants have so many tillers with SRI management methods can be explained by the physiology of rice, like other grain producing members of the poaceae (grass) family, in terms of phyllochrons. These are intervals of plant vegetative growth discovered in the 1920s and 1930s by a Japanese researcher (Katayama, 1951). Unfortunately, they are little known in the English-speaking world (Allaby, 1998; Nemoto *et al*., 1995).

With SRI methods we find a reversal of the relationship between number of tillers per plant and number of grains per panicle (fertile tiller). This has been previously reported in the literature to be negative (Khush and Peng, 1996). But with massive root growth, rice plants become "open systems" and contravene the law of diminishing returns. With SRI grown plants, the relationship observed (now in three different analyses) is positive, reversing the sign previously observed. This is what makes possible going from 2 Mt/ha to 8 Mt/ha.

Beneficial effect of SRI: SRI is showing that in many cases farmers' income can be increased by using less rather than more external inputs. The fact that SRI can give higher yields with lower investment of capital make attractive and beneficial for poorer households. One of the benefit identified in the GTZ Cambodia evaluation was that SRI farmers could make fewer cash outlay at the start of planting season, when their cash reserves were lower (Anthofer *et al.*, 2004). SRI reduces farmer's application of synthetic fertilizer and crop protection biocides, with beneficial effect on soil and water quality and health.

Water saving with SRI: The most direct benefit of SRI is through reductions in water requirements. Rice is the 'thirstiest' crop in the world, requiring several thousand litres of water to produce 1 kg of rice when using conventional rice-growing methods with continuous flooding. SRI alternative water management methods can reduce this by 25-50%, while raising yields 50-100% or more. This alone should be enough justification for using SRI methods wherever water is not an abundant and effectively free good. One social benefit, hard to quantify, is the advantage of reducing the amount of conflict over water (Uphoff, 2003). The realization that rice does not require or produce its best when in standing water comes as quite a surprise to many persons, who have accepted the conventional wisdom. However, that belief is wrong, as shown by research (Guerra *et al.*, 1998). Water productivity can be increased from two times to even six times (Ceesay *et al.*, 2006). Yuan (2002) reported that the research held on China National Hybrid Rice Research and Development Centre, that the water applications could be reduced by as much as 65% on SRI plots compared with conventional irrigated ones and same time yield was 16 t/ha in trials with a Super-1 hybrid variety grown with SRI methods is 35.6% higher than the 11.8 t/ha achieved with the same hybrid in conventional, water intensive methods. Similarly, water saving with SRI was calculated as 40% in Indonesia, 67% in Philippines and 25% in Sri Lanka while conducting different trials comparing with that of conventional system (Sato, 2006; Lazora, 2004; Nemoto *et al*., 1995).

The relation of SRI and increase in grain yield of rice: There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by two to three fold compared to current yield levels (Uphoff, 2007). Husain *et al*. (2004) documented a 30% yield advantage for SRI in Bangladesh and Namara *et al*. (2003) showed an even larger benefit of 44% in Sri Lanka.

Increased grain yield under SRI is mainly due to the synergistic effect of modification in the cultivation practices such as use of young and single seedlings per hill, limited irrigation, and frequent loosening of the top soil to stimulate aerobic soil conditions (Stoop *et al.*, 2002). Further, combination of plant, soil, water and nutrient management practices followed in SRI increased the root growth, along with increase in productive tillers, grain filling and higher grain weight that ultimately resulted in maximum grain yield (Uphoff, 2001).

Reduction in crop cycle: In Nepal, farmers using SRI methods have found that their crops mature 10 to 20 days sooner compared with the same variety grown conventionally. Dates of planting and harvesting are the least disputable agronomic data. In 2004, 22 farmers harvested their SRI rice on average 15.1 days' sooner, with 114% higher yield (7.85 vs. 3.37 Mt/ha); in 2005, with less favorable conditions, 54 farmers reduced their time to harvest on average by 19.5 days, with 91% higher yield (5.51 vs. 2.88 mt/ha). Harvesting sooner reduces crops' exposure to storm or other damage; it also reduces total amount of irrigation water needed (Satyanarayana *et al*., 2006). In 2005, 51 farmers in Morang district of Nepal, who used SRI methods planted the same variety of rice (Bansdhan), which normally matures in 145 days with standard practices. An analysis of time-to-harvest showed that the 9 farmers, who planted seedlings older than 14 days (because of labour or water constraints) harvested their SRI crop 6.5 days' sooner on average. The 37 farmers, who planted seedlings 10-14 days old, as recommended, harvested 14 days' sooner, while the 5 farmers who transplanted seedlings only 8 or 9 days' old got a mature crop in 124 days, three weeks earlier than expected. Average SRI yield was 6.3 Mt per hectare compared with 3.1 Mt/ha tons with usual farmer practices, and with less time (Uprety, 2006).

Less economic risk: SRI fields are able to withstand the adverse effect of drought, rain and wind that cause other rice fields to lodge Farmers using SRI methods are less subject to economic failures, even though SRI practices initially appear to entail greater risk. Two evaluations based on random samples of SRI users and non-users have found SRI methods to be less risky overall. The IWMI evaluation team in Sri Lanka calculated that SRI rice farmers were >7 times less likely than conventional farmers to experience a net economic loss in any particular season because of SRIs' higher yield and lower cost of production (Namara *et al*., 2004). Anthofer *et al*. (2004) concluded as "SRI an economically attractive methodology for rice cultivation with a lower economic risk compared to other cultivation practices".

Creating a better soil environment for rice: In continuously flooded soil, 75% of rice plants roots remain in the top 6 cm. of soil at 28 DAT (Kirk and Solivas, 1997) and never grow as deeply as plants can if the soil has not deprived of oxygen. But research on the physiological effect of SRI methods on the rice plant done at the China National Rice Research Institute found that root dry weight was 45% greater for SRI plants compared to the same variety conventionally grown, and roots extended 10 to 15 cm deeper (Tao *et al*., 2002).

In parts of tropics, soil temperature is not a constraint to growth. One advantage of growing rice in unflooded fields is that the soil not only has more aeration, permitting more O_2 and N_2 to reach the rhizosphere, but it gets warmed more by the sun, whose radiation is not reflected away by the surface of standing water. This can contribute faster plant growth in places like the higher latitude locations and elevations generally (Uphoff, 2003). Root growth and soil biota are promoted by managing rice plants, soil, and nutrients differently which very location to location.

Plant growth under SRI: Rice plants perform better when they are not flooded continuously and even better when the other SRI practices are followed. SRI demonstrations are already beginning to dissuade rice farmers from their long-held conviction that 'the more water, the better.' This is beneficial for the environment by reducing water applications to rice crops and it will also diminish methane emissions. SRI can make it profitable for farmers not to flood their rice fields. The belief that rice requires continuous flooding for best results (De Datta, 1981) is contradicted by SRI experience and scientific evaluations. That water stress reduces yields, well documented in the scientific literature, has been determined from evaluations of rice plants that were grown entirely with continuous flooding, so their roots are not well developed (as with SRI methods) and are, in fact, degenerating (Kar *et al*, 1974). The yield attributes, i. e. panicle length, number of panicles hill-1, total number of grains panicle-1 were significantly higher than other treatments during wet season in 14 days old seedlings + 25 × 25 cm spacing + water saving irrigation + LCC based N management + SRI weeding. During dry season, more panicle length, number of panicles hill-1 and filled grains panicle-1 were recorded in the treatment combination of 14 days old seedlings + 25 × 25 cm spacing + water saving irrigation + SRI weeding. The grain yield and water productivity were significantly increased at SRI weeding with 14 days defog seedlings planted at 25 × 25 cm spacing to achieve 7009, 5655 kg ha-1 and 0.610 kg and 0.494 kg per m^3 of water respectively in wet and dry season (Vijayakumar *et al.,* 2006).

Environmental benefits of SRI: SRI methods are not only beneficial for people but also for the natural habitat and biodiversity. Because SRI methods do not require chemical fertilizer, they enable farmers to reduce their fertilizer applications, or eliminate them altogether, producing yields as good or better by use of compost. This can contribute to both better soil and water quality and to improved soil health and human health. Not all farmers are willing to change to fully organic sources of fertilization, but SRI training and experience encourage reduced use of chemical fertilizer. An evaluation of 120 farmers in Cambodia who had used SRI methods for three years, with a doubling of yield, documented that farmers reduced their fertilizer use by 43% and their use of agrochemicals by 80% (Tech, 2004). When SRI was introduced to farmers in eastern Indonesia under a Japanese-funded project, farmers were advised to cut their applications of fertilizer (nitrogen, potassium and phosphorus) by 50% compared to what was recommended by the government. With this reduction in fertilizer use and a 40% reduction in water use, farmers' yields increased by 78% (3.3 Mt/ha) on average. These data are from 12,133 on-farm comparison trials covering a total area of 9,429 hectares (Sato and Uphoff, 2007). Because SRI methods increase rice plants' resistance to pests and diseases, farmers find that they can reduce or even eliminate their use of agrochemicals, many of which have adverse effect on soil and water quality. An evaluation of SRI in Vietnam in 2005-06 by the Ministry of Agriculture's National Integrated Pest Management (IPM) Program found that with SRI methods, the prevalence of major pests and disease was reduced by 40 to 80%. SRI thus makes it possible for farmers to grow more and better crops by reducing the application of chemical fertilizers and sprays. These environmental benefits can also contribute to better human health. SRI methods can also contribute to the conservation of biodiversity. This is most direct and obvious with respect to the biodiversity of rice species, making traditional local varieties more productive, profitable, and thus competitive with high-yielding varieties and hybrids. (Uphoff, 2006).

SRI with direct seeding: Farmers who have labour shortages that make transplanting difficult to utilize, have been adapting SRI concepts and methods to direct-seeded crop establishment methods, coupled with the other SRI practices. Their main objective is to reduce labour requirements. They will try to achieve this goal even if it means that their paddy yield may be somewhat reduced because they are most concerned with favourable economics, not just agronomics. Uphoff (2006) reported that a Sri Lankan farmer (Ariyaratne Subasinghe 2011) developed a method and evaluated by a rice scientist at Tamil Nadu Agricultural University in India (TNAU). Ariyaratne uses about five times more seed if he established his SRI crop with transplanted seedlings, i.e. he broadcasts seed at a rate of about 25 kg per hectare instead of establishing a nursery with 5 kg of seed per hectare. When the young plants are 10-12 days old in the field Ariyaratne simply 'weeds' it as if he had transplanted it with spacing of 25x25 cm. This 'weeding' radically thins the stand of rice, eliminating about 80% of the young plants. It leaves them in a square geometrical pattern, with usually one plant at the intersections of the weeding passes, and sometimes two or even three. Occasionally there is no plant within this intersected space, but then adjoining plants grow larger to fill in any open space. The goal is to have a sparse, evenly and widely spaced plant population. This methodology can reduce labour requirements for SRI by 40%, according to Ramasamy at TNAU, because there is no need to construct and manage a nursery, and also it eliminates the task of transplanting. All the farmer has to do is broadcast seed and then 'weed' the field just as he would have been done anyway after transplanting the crop. Ariyaratne says that he is confident of getting a yield of 7.5 mt/ha. While this is perhaps less than from a more carefully managed field, he has many competing demands for his labour time, and this gives him a respectable harvest with a much reduced expenditure of labour.

Possible limitations or disadvantages of SRI:

The most obvious drawback of SRI for most farmers is that when fields are not kept continuously flooded, weed control presents a problem. Use of herbicides is effective, but these do not have the positive effect of aerating the soil that is achieved when rotary hoes or cono-weeders, are used. Such implements not only remove weeds but create more favorable growing conditions for rice plant roots and for the majority of soil biota which are aerobic. This operation can be quite labour-demanding, but its timing is more flexible than for transplanting and farmers are inventing weeding tools that reduce the labour time required (Satyanarayana *et al.,* 2006).

SRI has been considered too labour-intensive for many farmers. This was given as a reason for dis-adoption of SRI by up to 40% of farmers, particularly poor ones, surveyed in one study done in Madagascar (Hossain, M.F; *et al* 2004). However, as farmers become more comfortable and skilled with the new methods, SRI is becoming labour-saving. In the Chinese study reported above, labour-saving was regarded by farmers as the main attraction of SRI, more than its water saving, and more than its yield and profitability increases (Lin *et al.,* 2006) with making agreement Tech (2004) reported that in Cambodia, 55% of 120 farmers who have used SRI for three years evaluated it as 'easier' to practice, whereas only 18% considered it 'more difficult'; 27% said there was 'no difference'. Similar report can be found that an evaluation done of 108 farmers in Madagascar who were using both SRI and conventional methods determined that while first-year users required 20-30% more labour/ ha, by the fourth year, SRI required 4% less labour and by the fifth year, 10% less (Barrett *et al*., 2004).

Although it previously appeared that the labour-intensity of SRI could be a barrier to its adoption, this seems now to be a transient constraint. Some previous studies, i.e. Namara *et al.* (2004) regarded SRI as a static technology rather than an evolving methodology modified by farmer learning. Farmers continue to find ways to reduce SRI labour requirements, such as the roller-marker designed to speed up transplanting and the improved weeders devised by farmers in Andhra Pradesh. Once farmers see SRI as saving labour as well as water and costs of production, it should become widely adoptable.

One common constraint identified by farmers is that many of them do not have access to as much biomass as is recommended for enriching the soil for SRI practices. As noted already, the other SRI methods can be used beneficially with chemical fertilizer, while saving water, if organic sources of nutrients are insufficient. Once farmers come to appreciate the merits of organic soil fertilization, and see the returns they can get from SRI, they begin making more use of available biomass sources and start harvesting and even growing biomass on non-arable areas (Satyanarayana *et al.,* 2006).

This is the main objective constraint on SRI adoption, since the methodology hinge on the application of small but reliably available water to the rice crop. In their first few weeks, tiny transplanted seedlings are vulnerable to inundation. This limits their use in monsoon climates where little effort has been made to promote drainage, thinking that maintaining flooded fields is beneficial for the rice crop. Investments in drainage facilities, innovations like raised beds, and better organization among farmers to manage excess water are more profitable with, so they are likely to increase. While water control is important for success with SRI, most of the other methods -- wider spacing, more organic nutrients, and reduced water application after flooding subsides can be beneficial even without such control (Satyanarayana *et al.*, 2006).

Yield and economic return:

Uprety (2004) reported that the average rice yield with SRI is 8t/ha, whereas the yield is 3 t\ha under conventional paddy. Udaykumar (2005) recorded by SRI method significantly higher seed yield/ha (2.94 t/ha) as compared to traditional method (2.37 t/ha). The percent increase in seed yield per hectare under SRI method was 20.25 over traditional method. Sita Devi *et al.*, (2009) reported that highly significant association between contact with extension agencies with the production level. They further reported that highly significant association between farm size with the production level. Badawi. T.A (2004) found that there was no significant association between size of family and utility perception of paddy growers. Amod, K.T., *et al*; (2014) reported that the net income increase with the increase in size of land holding in both SRI non SRI method of paddy cultivation. She further reported that there was marginal difference in educational level of SRI and non SRI method of sample respondents which shows that illiteracy may not considers as a constraint in adoption of SRI method of rice cultivation.

RECOMMENDATION

System of rice intensification is one of the best practices of improving rice productions with low input and maximum output (yield). It also maximises the system of production, land labour and capital. I therefore recommend the system to be adopted by both peasant and large scale rice farmers in order to be self-sustainable and to boost productions to meet the increasing demand of the populace.

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