

## System of Rice Intensification (SRI) As a Method of Stand Establishment in Rice

<sup>1</sup>D. Sumith de Z. Abeysiriwardena,

<sup>2</sup>W.M.W. Weerakoon and <sup>3</sup>W.M.A.D.B. Wickramasinghe

<sup>1</sup>CIC Agribusiness center, Pelwehera, Dambulla, Sri Lanka,

<sup>2</sup>Rice Research and Development Institute, Batalagoda, Ibbagamuwa, Sri Lanka

<sup>3</sup>Department of Agriculture, Natural Resources Management Centre, Gannoruwa, Peradeniya, Sri Lanka

**Abstract:** System of rice intensification (SRI) is promoted as a system of rice cultivation, by which extraordinarily high grain yields could be very easily obtained even in the tropics. To confirm this and to identify the proper position of SRI as a method of stand establishment in the range of stand establishment methods in rice, a study was undertaken at the Rice Research and Development Institute, Batalagoda, Sri Lanka under the tropical environment. When the grain yield was expressed in area basis as t/ha, grain yields of SRI, standard broadcasting and standard transplanting were found to be the same indicating that SRI was not able to give extraordinary yields as reported. However, SRI gave five and ten times higher yields than that of standard transplanting and broadcasting, respectively, when the grain yield was expressed in seed basis as t/50kg of seeds used for cultivation. This appeared extraordinary but was obvious because SRI used almost five and ten times less seeds than that of standard transplanting and broadcasting, respectively per unit land area. SRI was identified as one of the two extreme ends with the lowest seed requirement and highest sensitivity in yielding ability to changing environment in the range of stand establishment methods in rice. All the stand establishment methods tested including SRI ultimately ended up with the same grain yield through autonomous adjustments among yield components under proper management.

**Key words:** Grain yield • Rice • Stand establishment • System of rice intensification • Yield components

### INTRODUCTION

Rice (*Oryza sativa* L.) is one of the oldest crops cultivated on earth. It is consumed by nearly half the world's population and grown at least in 114 countries so that many people are engaged in rice cultivation around the world. Many scientists from different countries continue to work on rice to increase its productivity and quality and to reduce cost of cultivation. In this context, a rice cultivation system called 'System of Rice Intensification' (SRI) which has been developed in Madagascar with the help of Malagasy farmers is promoted in rice growing countries world wide since recent past.

SRI is being promoted as a 'system' of rice cultivation rather than a 'technology', by which a grain yield as high as 20t/ha or more or at least more than two times the yield level obtained with conventional methods could be

achieved despite the climatic and edaphic variability [1, 2]. An easily obtained extraordinary yield of 17t/ha under SRI using an inbred line reported in Sri Lanka having a tropical climate [3] is worth paying attention as the maximum yield so far reported by the Department of Agriculture, Sri Lanka was only 10t/ha [4] in large scale cultivation in farmers fields with a grate difficulty. However, Uprety [5] reported comparatively a lower yield level of 6.3t/ha with SRI, which was still more than two times the yield level of 3.1t/ha obtained with conventional methods. Theoretical yield potential of rice has been estimated to be 23.8 t/ha under the best environment if the length of the maturity phase of rice was assumed to be 40 days [6]. However, a yield of 20t/ha is practically a dream yield at present when the rice yield levels so far achieved with available technology in many rice growing countries covering diverse environmental conditions are considered. Based on the reports presently available outside SRI, no country

with subtropical environment has recorded anything beyond 15t/ha and no country with tropical climate has recorded anything beyond 11t/ha with inbreds, whereas the highest recorded rice yield in the world to date is 17.95t/ha reported in China with a hybrid rice under subtropical environment [7].

As SRI is a method where seed is saved tremendously, expressing yield in SRI in seed basis as t/kg of seeds used for cultivation is also important. At present no or little information is available in this direction. To our knowledge, only Amarasekara [8] reported rice yield in seed basis to show the benefit of saving seed in intensive transplanting. In addition, rice is a semi aquatic cereal that can produce many tillers in addition to the mother culm whereas other popularly grown cereals such as corn, sorghum, wheat and barley are uni-culm cereals. This unique feature of tillering ability of rice has led to a range of stand establishment methods depending on the utilization of the tillering capacity in rice. Basic stand establishment methods in rice are direct seeding, transplanting [9] and seedling broadcasting [10]. As SRI is basically a method of transplanting where heavy tillering is expected to compensate low seed rate, identification of its position in the range of stand establishment methods is important for its effective adoption by gauging its adaptability over diverse environments and practical feasibility as a method of stand establishment for increased productivity.

Adoption of inappropriate technology may lead to yield losses, failures in achieving expectations, increased risk of cultivation and finally farmer frustration. Thus, obtaining extraordinary yields as high as 20t/ha or more or even doubling the present yield levels under the tropical environment by adopting SRI has to be confirmed, while identifying the position of SRI in the range of stand establishment methods for its effective adoption in rice cultivation. Therefore, the objectives of the present study were; 1) to compare SRI with standard transplanting and broadcasting with respect to yielding ability in area basis as t/ha as well as in seed basis as t/kg of seeds used for cultivation and 2) to identify the proper position of SRI in the range of stand establishment methods in rice, using three rice varieties with different maturity durations under the tropical environment.

## **MATERIALS AND METHODS**

Two field experiments were conducted over two consecutive years at the Rice Research and Development Institute, Batalagoda, Sri Lanka under the tropical

environment. The first experiment was a two factor factorial experiment factors being method of stand establishment with three levels namely SRI, standard transplanting and standard broadcasting and varieties with two levels namely variety with 3 month maturity duration (Bg 300) and variety with 4 month maturity duration (Bg 403). The second experiment was also a two factor factorial experiment factors being method of stand establishment with two levels namely SRI and standard transplanting and soil condition with two levels namely rich and poor soils. Rich soil was a deep (22-25 cm deep) soil with added organic matter at the rate of 10 t/ha, while poor soil was a shallow (10-12 cm deep) soil with no added organic matter. The variety used in the second experiment was Bg 357 which belongs to 3½ month maturity duration. All the varieties used in both experiments were improved varieties with high tillering capacities and yielding abilities.

Both experiments were conducted in Randomized Complete Block designs each with three replications. Gross plot size of both experiments was 6m × 3m, while the net plot size after removing a 30cm border around the plot to get rid of the border effect was 5.4m × 2.4m.

Each of the stand establishment methods was adopted with a specific set of management practices unique to each method to maximize yield. Management practices for SRI were adopted as discussed by Uphoff and Fernandes [3]. For the SRI treatment, young undisturbed seedlings (less than 10 days old) were placed on the soil surface at a spacing of 30cm × 30 cm between plants at the rate of one plant per hill to promote plant growth with profuse tillering to its full potential by minimizing plant to plant competition. Although farmers are advised to start with the spacing of 25cm × 25cm, often the 35cm × 35cm spacing has been reported to be the best for SRI, while even a wider spacing of 50cm × 50cm has been suggested when soil quality is excellent. However, based on SRI spacing trials previously conducted, the spacing of 30cm × 30cm has been found to be the best spacing for SRI under the tropical conditions at RRDI, batalagoda, Sri Lanka where very poor soils for which the spacing of 20cm × 20cm has been suggested, are not found (unpublished data). Even under the different soil fertility conditions which of course did not represent extremes such as very poor soils in the second experiment, the same spacing of 30cm × 30cm was used in SRI for comparative purposes as other stand establishment methods were not supposed to change their plant densities depending on the fertility status of the soil. Thus the seed rate for SRI was 10kg of seeds/ha.

The field was irrigated to keep it at field capacity without maintaining a level of standing water until 45 days after planting to promote tillering. Weeding between rows was done manually by a rotary weeder every two weeks after planting and fertilizer was applied as recommended by the Department of Agriculture, Sri Lanka. The fertilizer recommendation of the Department is the adoption of Integrated Plant Nutrition System. For the transplanting treatment, 15 days old seedlings were planted at a spacing of 15cm × 15cm between plants with 2-3 seedlings per hill. Seed rate for standard transplanting was 50 kg of seeds/ha. For the broadcast sown treatment, pre-germinated seeds were directly sown in the plots at the rate of 100 kg/ha (180 g /6 m × 3 m plot). In both, the standard transplanting and broadcast sown plots, a standing level of water about 3-5cm high was maintained in the field from 5 days after transplanting or broadcasting till 2 weeks before harvesting except during herbicide application. Weeds were controlled chemically and the fertilizer was applied as recommended by the Department of Agriculture, Sri Lanka.

Grain yield of rice can generally be expressed in two ways. Seed basis as grain yield per unit amount of seeds used for cultivation (t/kg of seeds used for cultivation) and area basis as grain yield per unit area cultivated (t/ha). The amount of seeds required for standard transplanting of one hectare (50 Kg) was considered as the base when grain yield was expressed in seed basis. Grain yield in both the experiments were expressed in terms of t/ha as well as in terms of t/50 kg of seeds used for cultivation as different seed rates were used by different stand establishment methods. Standard transplanting and broadcasting used five and ten times more seeds, respectively than that of SRI. In addition, necessary information on different stand establishment methods in rice was collected to place SRI in its proper position in the range of stand establishment methods in rice.

Plots were harvested at physiological maturity and grain yield data were recorded at 14% moisture. Total biomass/m<sup>2</sup>, number of panicles/m<sup>2</sup>, number of spikelets/panicle and filled grain percentage were also recorded in the first experiment to explain grain yield variation among treatments and to identify the position of SRI in the range of stand establishment methods in rice. Data were statistically analyzed and DMR test was used for mean separation wherever necessary. Before the analysis of grain yield data expressed in terms of t/50 kg of seed used for cultivation, they were transformed using log transformation to overcome the problem of error heterogeneity observed in the original data.

## RESULTS

Both the trials were maintained well and no missing data were recorded. As anticipated, the broadcast sown crop covered the ground very quickly in contrast to the SRI crop which could cover the ground fully only at late booting stage in the first experiment. At every growth stage of the rice crop, SRI plots were looked impressively greener than that of rest of the plots. SRI always produced relatively bigger plants and bigger panicles which would have not been expected with relatively closer spacing.

Grain yield as expressed in terms of t/ha and t/50kg of seeds used for cultivation, total biomass/m<sup>2</sup>, number of panicles/m<sup>2</sup>, number of spikelets/panicle and filled grain percentage of Bg 300 and Bg 403 under different stand establishment methods including SRI in the first experiment are presented in Table 1. The interaction effect of Variety × Stand establishment was found to be not significant at 5% probability level when the grain yield was expressed in terms of t/ha as well as in terms of t/50kg of seed used for cultivation in the first experiment indicating that grain yield responses of both varieties to different methods of stand establishment were the same irrespective of variety differences particularly in maturity duration. Similarly the interaction effect of Variety × Stand establishment with respect to total biomass/m<sup>2</sup>, number of panicles/m<sup>2</sup>, number of spikelets/panicle and filled grain percentage were also found to be not significant at 5% probability level. This again indicated that responses of both varieties to different methods of stand establishment with respect to all the characteristics recorded were also the same irrespective of the variety differences particularly in maturity duration. This allowed studying the average response of varieties to different methods of stand establishment with respect to all the characteristics recorded in the first experiment.

Grain yields of Bg 357 as expressed in terms of t/ha and t/50kg of seeds used for cultivation under different stand establishment methods including SRI and under rich and poor soil conditions in the second experiment are presented in Table 2. The interaction effect of Soil condition × Stand establishment was found to be significant at 5% probability level, when the grain yield was expressed in terms of t/ha as well as in t/50 kg of seed used for cultivation indicating that yield response of rice from poor to rich soil was different between SRI and standard transplanting. Thus, SRI and standard transplanting were compared separately under rich and poor soil conditions.

**DISCUSSION**

**Grain Yield:** When the grain yield of rice was expressed in terms of t/ha in the first experiment, grain yield among SRI, standard broadcasting and standard transplanting was found to be the same (Table 1). This was due to the autonomous adjustments between yield components, particularly between the number of panicles/m<sup>2</sup> and number of spikelets/panicle as a result of their phenotypic plasticity, differently in different stand establishment methods ultimately leading to the same grain yield. Although, Singh *et al.* [11] reported higher grain yield in SRI than that of conventional transplanting, unlike most workers they observed yield differences as low as 0.79t/ha. Thus, SRI can not be considered as a system of rice cultivation that can give extraordinary high yields as reported [1-3] under the tropical environment. However, SRI gave five and ten times higher yields than that of standard transplanting and broadcasting, respectively, when the grain yield was expressed in terms of t/50kg of seeds used for cultivation (Table 1). This was obvious because SRI used almost five and ten times less seeds than that of standard transplanting and broadcasting,

respectively per unit land area, while giving comparable grain yield/ha to standard transplanting and broadcasting. Based on the same principle, even standard transplanting has given two times higher grain yield in terms of t/50kg of seeds used for cultivation than that of broadcasting.

When yield of Bg 357 was expressed in terms of t/ha, both SRI and standard transplanting gave comparable yields on the average (Table 2). Under both, SRI and standard transplanting, Bg 357 has given a higher yield in rich soil than that of in poor soil as anticipated. However, yield of standard transplanting was higher than that of SRI in poor soil whereas both standard transplanting and SRI gave comparable yields in rich soil indicating that SRI was more sensitive to changing soil environment than standard transplanting. When the yield of Bg 357 was expressed in terms of t/50kg of seeds used, SRI gave five times higher yield than that of standard transplanting on the average (Table 2). This was again obvious because SRI used five times less seeds than standard transplanting per unit land area although both SRI and standard transplanting gave similar yields per unit land area. Even when the yield was expressed in terms of t/50kg of seeds used for cultivation, SRI appeared to be

Table 1: Grain yield as expressed in terms of t/ha and t/50kg of seeds used for cultivation, total biomass/m<sup>2</sup>, no. of panicles/m<sup>2</sup>, no. of spikelets/panicle and filled grain percentage of Bg 300 and Bg 403 under different stand establishment methods at the Rice Research and Development Institute, Batalagoda, Sri Lanka in the tropical environment

Characteristic	Stand establishment†								
	System of rice intensification (SRI) (Seed rate-10 Kg of seeds /ha)			Standard transplanting (Seed rate-50 Kg of eeds/ha)			Standard broadcasting (Seed rate-100 Kg of seeds/ha)		
	Bg 300	Bg 403	Mean	Bg 300	Bg 403	Mean	Bg 300	Bg 403	Mean
Grain yield t/ha	6.90	5.98	6.44a	6.82	6.54	6.68a	6.95	6.50	6.72a
t/50kg of seeds used for cultivation	34.50	29.90	32.20a	6.82	6.54	6.68b	3.47	3.25	3.36c
Total biomass (g/m <sup>2</sup> )	700	760	730ab	750	890	820a	620	740	680b
No. of panicles/m <sup>2</sup>	135	180	157c	175	245	210b	190	300	245a
No. of spikelets/ panicle	147	110	128a	112	94	103b	88	72	80c
Filled grain (%)	83	70	76b	85	82	83a	88	85	86a

†Mean separation was performed only for mean values so that mean values with the same letter within a row are not significantly different at 5 % probability level

Table 2: Grain yield of Bg 357 as expressed in terms of t/ha and t/50Kg of seeds used for cultivation under different stand establishment methods in rich and poor soils at the Rice Research and Development Institute, Batalagoda, Sri Lanka in the tropical environment.

Method of yield expression	Stand establishment†					
	System of rice intensification (SRI) (Seed rate-10 Kg of seeds/ha)			Standard transplanting (Seed rate-50 kg of seeds/ha)		
	Poor soil	Rich soil	Mean	Poor soil	Rich soil	Mean
t/ha	5.20c	8.20a	6.75	6.00b	8.70a	7.35
t/50 Kg of seeds used for cultivation	26.50b	41.00a	33.75	6.00d	8.70c	7.35

†Values (not the means) with the same letter within a row are not significantly different at 5 % probability level.

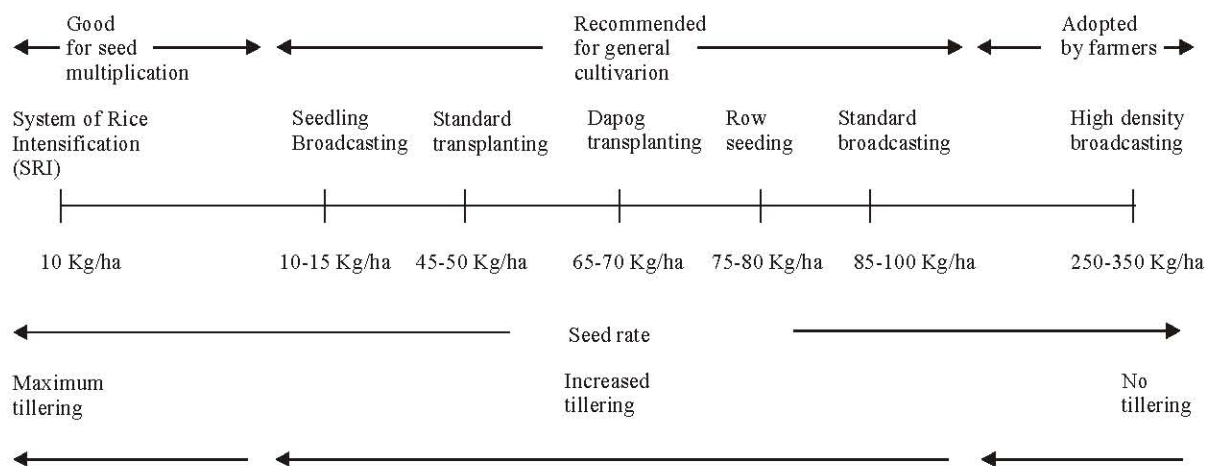


Fig. 1: Range of stand establishment methods with their associated seed rates and special features in rice cultivation

more sensitive to changing soil environment than standard transplanting because percentage yield loss in poor over rich soil was more under SRI (36.6 %) than that of under standard transplanting (31.0 %).

SRI was not able to give extraordinary yields as reported under the tropical environment, when grain yield was expressed in terms of t/ha. In fact, SRI appeared somewhat inferior to standard transplanting in the poor soil and in sensitivity to changing soil environment with respect to grain yield/ha in the second experiment. However, if the grain yield was expressed in terms of t/50kg of seeds used for cultivation, the yield level of 26-41t of SRI could be considered extraordinarily high when compared to that of 6.0-8.7t of standard transplanting and 3.36t of broadcasting, irrespective of the variety. Grain yield ratio between t/50kg of seeds used for cultivation and t/ha was 5, 1 and 0.5 in SRI, standard transplanting and standard broadcasting, respectively. For example, yield levels of 4-5 t/ha expressed in area basis is equivalent to the yield levels of 20-25t/50kg of seeds used for cultivation, expressed in seed basis in SRI. These yield levels in SRI expressed in seed basis are, however, comparable to reported yield levels (20t or more) in SRI expressed in area basis. An intensive method of transplanting, very similar to SRI, had been practiced and promoted in Sri Lanka even as early as in 1907 [8] and a seed basis grain yield of 228 measures per one measure of seed or 11.4t/50kg of seeds used for planting had been reported with traditional varieties. However, the yield in area basis had been only 0.72t/ha.

**Stand Establishment and Yield Components:** Grain yield of SRI was comparable to that of standard stand establishment methods in rice (Tables 1 and 2). Even the

total biomass/m<sup>2</sup> of SRI was not significantly different from that of either standard transplanting or standard broadcasting (Table 1). Although SRI used 10 and 5 times less seed rates, it produced only 1.56 and 1.33 times less panicles/m<sup>2</sup> than that of standard broadcasting and transplanting, respectively indicating the highest capacity of effective tillering in SRI. Of course number of panicles/m<sup>2</sup> in SRI was significantly lower than that of standard transplanting and broadcasting because complete compensation of number of panicles/m<sup>2</sup> was not possible with 30cm × 30cm spacing only through tillering (Table 1). However, Thakur *et al.* [12] reported that number of panicles/unit area was comparable under SRI and standard transplanting probably because the spacing they used was 25cm X 25cm. Although the number of panicles/m<sup>2</sup> was comparatively lower, the number of spikelets/panicle was comparatively much higher in SRI in the present study indicating the ability of rice in making autonomous adjustments between yield components. Thus, SRI can be considered as a 'method of stand establishment' rather than a 'system' as proposed by Uphoff and Fernandes [3], which is just a variant of transplanting where tillering ability in rice is maximally utilized to save seeds. The range of stand establishment methods in rice with placing SRI in its proper position in the range and their associated seed rates based on the utilization of tillering capacity and special features are presented in Fig. 1.

In one extreme end of the range of stand establishment methods in rice, rice crop is allowed to have only the main culm of the rice plant with the maximum number of mother culms or panicles per unit land area (uni culm approach). Although not tested in the present study, this is practically achieved by high density broadcasting

with 250-300 Kg of seeds/ha [13, 14] which is a direct seeding method where no adequate space among plants is allowed for tillering. Very high seed rates are used in some parts of Sri Lanka particularly to smother weeds in rice [15]. However, this practice has not yet been identified and published as one extreme method of stand establishment. In this method, competition among plants is maximized so that plant growth is retarded resulting small but comparatively more number of panicles per unit land area [14] with a minimal weed growth due to high plant density [15]. Microclimate within the crop canopy under this situation is, however, very conducive to occurrence of pests and diseases [13]. The practical implication of this extreme method of stand establishment is that it saves cost on labor and weed control at the expense of seed paddy while obtaining profitable yields.

In the other extreme end of the range of stand establishment methods in rice, rice crop is allowed to have as many tillers per plant as possible with the minimum number of mother plants or culms per unit land area. SRI as a method of transplanting falls into this extreme. In this extreme method of stand establishment, competition among plants is minimized by maintaining an ample and uniform space between plants so that individual plant growth is enhanced to the full potential with profuse tillering. If tillering is suppressed SRI will fail so that the success of SRI is totally dependent upon the tillering capacity of the crop. Therefore, tillering has to be promoted in SRI to achieve its potential yield so that specific management practices for SRI have been developed [3] to promote heavy tillering at the highest rate possible to achieve maximum effective tillering and uniformity of maturity among tiller panicles. In this method, the panicles are relatively bigger but the number of panicles per unit land area is relatively lower. SRI produced the lowest number of 157 panicles/m<sup>2</sup>, while having the highest number of 128 spikelets/panicle. However, SRI had the lowest percentage of filled grains probably because source was not enough to fill large number of spikelets per plant (Table 1). The unique feature of SRI is that it saves seeds at the expense of additional labor needed for careful manual transplanting, weed control and water management. Although seed requirement of SRI is as low as 10kg of seed/ha [1], SRI requires an estimated 38-54% more labor than standard transplanting in rice.

The stand establishment methods that fall midway between two extreme methods in rice are seedling broadcasting [10], dapog transplanting, standard transplanting, standard broadcasting and row seeding or drilling [9] which are recommended and commonly

adopted in rice growing countries. In these methods, both the mother culms as well as the tillers are considered equally important. However, in broadcasting, emphasis is more towards the mother culms than tiller number with an increased seed rate, while in transplanting and seedling broadcasting emphasis is more towards tiller number than mother culms with a decreased seed rate. Although seed rate was 2 times less, number of panicles/m<sup>2</sup> was less only 1.16 times in standard transplanting than that of standard broadcasting indicating that effective tillering in transplanting had been comparatively much higher. However, number of panicles/m<sup>2</sup> was still lower, but number of spikelets/panicle was higher in transplanting than that of broadcasting. Thus, both stand establishment methods ended up with the same grain yield while having the same filled grain percentage (Table 1). Seedling broadcasting combines advantages of standard transplanting and broadcasting into one method without sacrificing grain yield while saving labor by avoiding transplanting and seeds by reducing seed rate [16]. In row seeding, adequate space between rows is given for tillering while adopting direct seeding and no significant grain yield differences have been found between transplanted and row seeded crops if good management practices are used with each method. Similarly, no difference in number of productive tillers as well as in grain yield between standard and dapog transplanting has been reported [9].

Each of the stand establishment methods while having its own advantages and disadvantages is associated with a specific set of management practices unique to each method depending on the tillering requirement to maximize grain yield. All the stand establishment methods including SRI ultimately end up with the same grain yield through making autonomous adjustments among yield components if properly managed, as in the present study (Table 1). Any of the extreme methods, SRI or high density broadcasting, may not be recommended for general cultivation because both these extremes have more disadvantages than advantages but may be recommended for specific situations. The best situation where SRI can be recommended is for the rapid multiplication of rare varieties of which only few seeds are in hand. In addition, farmers having very small holdings and adequate family labor but without sufficient income to buy enough seeds may adopt SRI only if water management is possible. However, it has to be noted that complete drainage which is a requirement for profuse tillering in SRI is practically difficult during peak rains in the majority of low lying rice fields in rice growing countries particularly in the tropics.

## CONCLUSIONS

SRI was not capable of giving extraordinary high grain yield or at least a significantly higher grain yield than that of properly managed conventional methods on area basis. However, its grain yield level on seed basis was comparatively very high owing to its low seed rate. SRI could be considered as one of the two extreme ends in the range of stand establishment methods in rice.

## REFERENCES

1. Uphoff, N., 2001. The System of Rice Intensification. Agro-ecological opportunities for small farmers? *Leisa Magazine*, December 2001, 15-16.
2. CIIFAD., 1999. Annual Report, 1998-99. Ithaca. NY: Cornell International Institute for Food, Agric. Development, 47.
3. Uphoff, N. And E. Fernandes, 2002. System of rice intensification gains momentum. *Leisa Magazine*. October 2002, 24.
4. Nissanka, W.M.B.S. and P.M.N. Dayaratne, 2002. Competitiveness as a self-motivation method to increase productivity in rice farming: A new extension approach to Yaya program. *Annals of the Sri Lanka Dep. Agric.*, 4: 393-398.
5. Uprety, R., 2006. System of rice intensification (SRI) a new method of rice cultivation: Experience in Nepal. Abstracts. 26<sup>th</sup> International Rice Research Conference and 2<sup>nd</sup> International Rice Congress 2006, October 9-13, 2006, New Delhi, India, 473.
6. Yoshida, S., 1981. Fundamentals of rice crop science. International Rice Research Institute, P.O. Box 933, Manila, Philippines, 90-92.
7. Duwayri, M., D.V. Tran and V.N. Nguyen, 1999. Reflections on yield gaps in rice production. International rice commission news letter. Food and Agriculture Organization of the United Nations, 49: 13-25.
8. Amarasekara, G.E., 1907. The result of transplanting paddy cultivation at Dikdeniya, Hanwella. *Tropical Agriculturist.*, Vol. XXVIII, No. 4, 145.
9. Rice Production Manual, 1970. Methods of raising seedlings and planting rice. International Rice Research Institute. P.O. Box 933, Manila, Philippines, pp: 78-88.
10. Yan, Z.D., 1988. Agronomic management of rice hybrids compared with conventional varieties. In: *Hybrid Rice*. International Rice Research Institute, P.O. Box 933, Manila, Philippines, 217-223.
11. Singh, S., V. Venkatachalapathi, S.S. Panihar and A. K. Singh, 2006. Enhancing rice productivity through system of rice intensification (SRI). Abstracts. 26<sup>th</sup> International Rice Research Conference and 2<sup>nd</sup> International Rice Congress 2006, October 9-13, 2006, New Delhi, India, 506-507.
12. Thakur, A.K., S.K. Chaudhari, R.B. Singhandhupe and R. Singh, 2006. Physiological basis of growth and development of rice under SRI (System of Rice Intensification). Abstracts. 26<sup>th</sup> International Rice Research Conference and 2<sup>nd</sup> International Rice Congress 2006, October 9-13, 2006, New Delhi, India, 482-483.
13. Rhind, D., 1950. Notes on the improvement of the yields of paddy in Ceylon. Department of Agriculture, Peradeniya, Sri Lanka, 10-11.
14. Irshadh, A.R.M., A.L.M. Nivas, S. Arulmageswaran and I.M.N. Chandrasiri, 2008. Effects of establishment method and population density on growth and yield of paddy (*Oryza sativa* L.) var Bg 250. Proceedings of the National Symposium 2008, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka, 18.
15. Weerakoon, W.M.W. and A. Abeysekera, 2000. Agronomic strategies to increase rice yields in Sri Lanka. Annual Symposium of the Department of Agriculture, Sri Lanka. September, 2000. 2: 435-451.
16. Jayawardena, S.N., S.W. Abeysekera, K.D.S. Kiriaththuduwege and H.M.J.K. Herath, 2004. Seedling-broadcasting as an alternative method to manual transplanting in hybrid rice cultivation. *Annals of the Sri Lanka Department of Agriculture*, 2004. Department of Agriculture, Peradeniya, Sri Lanka. 6: 277-281.