Location Specific Adoption of System of Rice Intensification

Anuradhapura District, Sri Lanka

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Financial support provided by the Department of Foreign Affairs and Trade (DFAT), Australian Government and technical and coordination support by Oxfam

OXFAM

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Title: Location Specific Adoption of System of Rice Intensification

First published: December, 2014

Published by: Oxfam Australia, No. 15, Rohini Road, Colombo 06, Sri Lanka

Phone: +94 112 585 855-6 Fax: +94 112 556 175

URL: http://www.oxfam.org.au

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Graphic Design & Printed by:

S & S Graphics
Kirindiwela Road,
Warapalana.
0775 599 588

ISBN: 978-955-4785-014

This book is dedicated to all SRI practitioners in Sri Lanka

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FOREWORD

Dr. Abhaya Balasuriya

The System of Rice Intensification (SRI) needs no introduction to Sri Lankan paddy farmers. At the same time, although it has existed for little over a decade in the country, its acceptance is almost insignificant. Only a handful takes the system seriously while most are either silent observers or have rejected it.

What is SRI? The answer is implicit in the name itself. SRI promotes further intensification of paddy farming, because "traditional" paddy farming is already known to be an intensive system. It is almost as if SRI aims to provide individual attention to every rice plant in a field. Its management practices have to be carefully followed in order to maximise efficiency in the use of the scarce resources, which are soil, water and nutrients.

It is no exaggeration to say that SRI attempts to address every individual physiological trait of the rice plant, by careful management of the plant and resources. The plant's tillering and its tiller-cycle, identified as the *phyllochron* are ostensibly helped by appropriate spacing, effective management of water and adequate nutrition. SRI also challenges the conventional belief that the rice plant can only perform with plenty of water.

Such positive statements lead to questions regarding its slow development over more than a decade of its existence in Sri Lanka. Some aspect of the system must be impractical. Those who do not promote this approach have been too critical in saying that SRI, a system developed and nurtured in Madagascar, cannot be superimposed in Sri Lanka. The counter-argument for that is that we should not *adopt* SRI but *adapt* it as the author insists to suit our rice cultivation tradition.

That also sounds like a simple solution, but the slow acceptance level of SRI is not something that we can set aside. There may be other reasons overriding that argument. As the author herself has noted, in Sri Lanka we consider paddy farming to be a system of intensive cultivation. One serious facet of this intensiveness is the demand it imposed on labour (until recent times). After being abandoned for extended durations, many paddy fields were converted to other uses. The powerful Agriculture Lands Act (No. 42 of 1973) of Sri Lanka stalled this conversion process to some degree. Yet it was ineffective in ending all such conversions. This is how we lost the numerous paddy fields of our country's landscape, particularly alongside highways. It was often stated that this conversion was due to labour shortage.

Supported by allied industries, it is said that paddy farmers became innovative and moved towards mechanisation of at least the most labour-intensive and time-consuming operation of harvesting. In the wake of uncertain weather patterns, the mechanisation of paddy harvesting turned out to be a blessing because farmers can now complete harvesting within a short period and avoid the vagaries of nature.

Thus there are negative points that may go against SRI. But the story does not end there. There are other aspects such as effective utilisation of limited resources, preservation of the environment and, in particular, a health-conscious proportion of the population that demands organically grown foods with less pesticide residues and other pollutants. SRI is equipped with answers to these issues that cannot be brushed aside.

In this backdrop the author's effort to draw the attention of policymakers to SRI has to be applauded. In this exercise she has been ably assisted by Oxfam Australia in Sri Lanka, which gave the necessary financial impetus. It is laudable that the author undertook the task of two series of both research-station and farm trials, employing four different methods of establishment that are popular at present and different types of organic matter on two rice varieties, one new improved (BG 358) and one traditional (*Kuruluthuda*). It is also good to note that the author has focused on the most potent problem of weeds, a possible deterrent in SRI, which advocates more spacing together with regulated or minimal irrigation.

The author has identified the need of the day: a holistic approach to SRI research. Integration of various attributes of SRI such as ecological friendliness, sustainability, farm mechanisation, health-safe products, resilience to climate change and effective water use is very timely. Increasing more location specific research with a thorough focus on farmers' actual constraints is necessary, if one wants SRI to be popular and feasible.

In any system there are bound to be positives and negatives. It is the responsibility of those who are interested in a system to improve the positives while making every effort to minimise the negatives. All those who promote SRI should revitalise enthusiasm for it and address the already identified gaps that seem to stand in the way. This can be achieved only by devotion to the effort, barring any harmful politicisation. I extend to the author all my best wishes in this pursuit.

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ACKNOWLEDGEMENTS

This study would not have been possible without the financial support of the Department of Foreign Affairs and Trade (DFAT) of the Australian Government granted through Oxfam Australia and the intellectual and logistical support of many individuals. First and foremost I would like to convey my gratitude and appreciation towards the farmers and their families in the selected villages who conducted the research in their paddy fields. I thank them for their patience when my supporting staff and I visited them many times during the research period and for providing us with the necessary information.

At the same time, I would like to extend my sincere thanks to the workers of the agricultural research farm at the Faculty of Agriculture, Rajarata University of Sri Lanka (RUSL) for helping me to conduct this research.

A special acknowledgement goes to our field supervisors Nilantha Sanjeewa and Pulasthi Sathayapriya, who assisted me in conducting both the farm and research station activities and the laboratory analysis of the collected samples. Chathurika Lakshani and AMKR Bandara of the Faculty of Agriculture, RUSL deserve a special thank you for helping me in analysing the data.

I wish to thank the staff at Oxfam for the cooperation extended to me and the cordiality shown to me at all times. Chaminda Fernando of Oxfam along with the regional SRI network members contributed enormously to the study by facilitating the field activities related to our research. I am certain that their support enriched our thinking and added more value to the research. I thank them for their kind support and cooperation.

I wish to express a deep sense of gratitude to Dr Abhaya Balasuriya of the Faculty of Agriculture, RUSL, who provided invaluable comments and editing support on many parts of this book, which no doubt resulted in improving the quality of the final product.

My special thanks also go to Professor YM Wickramasinghe of RUSL for reviewing this book and providing valuable suggestions to improve the content, and to Milan Samarakoon of RUSL for designing the cover page.

My sincere thanks are extended towards numerous members, both in the academic and non-academic staff at the Rajarata University, who rendered enormous support in financial and administrative matters.

GAS Ginigaddara,
November 2014.

EXECUTIVE SUMMARY

There are several documents written in the form of books and reports about the System of Rice Intensification in Sri Lanka. This book makes a fresh attempt at appraising the location specific nature of SRI through the results of two experiments undertaken in the Anuradhapura District.

SRI has a set of principles. These principles have different practices that are followed at different levels by rice farmers in various locations. The ability of the rice plant to grow in a semi-aquatic environment and to reach the plant's maximum growth potential when adequately spaced with soil amendments are the predominant principles of the system. SRI management practices that underline the above principles mainly include transplanting seedlings that are 8-12 days old, transplanting a single seedling per hill, careful handling at transplanting, adding plenty of organic matter, alternate wetting and drying and manual weeding coupled with incorporating of weeds for better aeration of soil.

Although SRI was first introduced to Sri Lanka in the early 2000s, its adoption and adaptation are still slow. The lack of location specific research and findings within the country is one possible reason for its poor adoption rate. In addressing this gap, two experiments were undertaken in Anuradhapura, as research station and farm trials, giving priority to different establishment methods and the addition of different types of organic matter to the rice fields. In a survey conducted in early 2013 in Sri Lanka, it was recognised that farmers encountered the problem of farm labour for establishment and weeding. In addition, these farmers were not aware of the type of organic matter that should be incorporated and its relationship with rice yield. These specific issues were addressed in our experiments. This research experimented on plant establishment method, its relationship with labour use, the type of organic matter added and its relationship with weed growth using two rice varieties, namely, *Kuruluthuda* (traditional variety) and BG 358 (new improved variety - NIV).

Five types of organic matter–rice straw, cow dung, green manure, compost and a mixture of them all–were tested in the research station trail. Weed growth, plant growth and yield of the two rice varieties were measured against the different types of organic matter. Weed growth did not show a significant relationship with the type of organic matter or the variety. Grain yield and its components also did not show significant differences, either among different types of organic matter or between varieties. This explains the negligible effect on weed growth, rice growth and rice yield depending on the type of organic matter applied in SRI fields. SRI farmers have the freedom to apply any type of organic matter, singly or in a mixture in their paddy fields.

Four methods of plant establishment (broadcasting, manual SRI transplanting, machine row seeding and parachute transplanting) were tested in three locations (Thambuttegama, Thalawa and Eppawala) with the two rice varieties *Kuruluthuda* and BG 358. Labour use under different establishment methods, plant growth and yield were measured. Farmer perceptions were recorded with respect to SRI, organic farming and different establishment methods. Broadcasting reported the lowest labour usage in establishment, while manual SRI showed the highest labour usage. Some shoot and root growth characteristics such as number of tillers, leaf area index (LAI), shoot dry biomass, root depth, total root length and root dry weight, at maximum tillering (MT), were significantly different among different establishment methods. In Eppawala and Thambuttegama, parachute transplanted rice showed the highest number of tillers at maximum tillering, while broadcasted rice showed the lowest number of tillers at MT. LAI also showed a similar variation. Root depth, total root length and root dry weight reported significant differences among different methods of establishment. Manual SRI and parachute transplanted rice reported comparatively higher root growth. Almost all yield parameters showed significant differences among different establishment methods. Manual SRI transplanting reported the highest grain yield and yield parameters, while broadcasted rice reported the lowest yield and lowest values for yield parameters. A majority of the farmers interviewed showed interest in the parachute method of transplanting due to its simplicity and low labour usage. At the same time, some farmers preferred broadcasting over other methods due to the minimal attention needed for its maintenance after the initial broadcasting.

The location specific nature of SRI is important for its sustainability. Addressing farmers' real constraints and modifying it to suit their situations may contribute to increased farmer adaptation of SRI. This envisages the promotion of more location specific research to recognise the level of modifications needed to match the conditions of the location for the sustainability of the system.

ABBREVIATIONS

ATS	-	Association Tefy Saina
AWD	-	alternate wetting and drying
CIIFAD	-	Cornell International Institute for Food, Agriculture and Development
DF	-	degrees of freedom
DW	-	dry weight
EC	-	electrical conductivity
FYM	-	farm yard manure
ILEIA	-	Centre for Learning on Sustainable Agriculture
LAI	-	leaf area index
LSD	-	least significant difference
MT	-	maximum tillering
NIV	-	new improved variety
OM	-	organic matter
RUSL	-	Rajarata University of Sri Lanka
SRI	-	system of rice intensification
WASSAN	-	Watershed Support Services and Activities Network

1 INTRODUCTION

The staple food of Sri Lankans is rice (*Oryza sativa* L.). Hence rice based production systems are dominant in Sri Lankan agriculture. In conventional rice production, farmers use a large amount of fresh water as a production input. The intensification of conventional rice production systems was a major concern of the government of Sri Lanka in the last two decades. The government also introduced a paddy fertiliser subsidy in the last decade to motivate rice producers. Almost all land resources suitable for rice production have been exploited with the aim of achieving self-sufficiency in rice.

At present, such intensified conventional rice production is being criticised as it causes negative environmental and health externalities. Important among them are soil degradation with lowered soil fertility, depletion in water table, aggravation of air pollution, bad health effects such as chronic kidney failures and cancers to both farmers and consumers and the growing vulnerability of rice to some pests and diseases. At the same time, farmers engaging in input-dependent conventional rice cultivation face problems of higher input costs and lower marginal increases in output, resulting in lower profits. Under these circumstances, farmers are reluctant to cultivate rice and they attempt to diversify into alternative crops, making the future of rice production uncertain.

The dominant irrigation practice adopted by conventional rice farmers in Sri Lanka is flood irrigation, which uses large amounts of water. Farmers secure irrigation water from major and medium scale irrigation schemes, reservoirs and other water storages for their cultivation. A certain percentage of rice lands are rain-fed. Sri Lanka is facing a minor scarcity of irrigation water, especially during drought periods, but it could develop into a crisis in the near future.

The system of rice intensification is a production technique that could provide solutions for most problems that have resulted from intensified conventional rice production practices. Moving away from conventional practices could reduce the amount of water needed to harvest a higher yield that will not depend on agrochemical inputs. This should bring down production costs and increase income. However, because SRI requires more labour at least initially and supplies of organic matter are often limited, addressing these constraints is necessary for the system to acquire wider acceptance among Sri Lankan farmers. This study attempted to evaluate these options for the farmer.

2 WHAT IS SRI?

The system of rice intensification came about accidentally in the 1960s in the humid highlands of Madagascar. It was developed on poor soils with low pH, low CEC, low available P, and high concentrations of soluble Fe and Al with a rainfall ranging from 1000 to >2000mm (Oldeman, 1990). Father Henri de Laulanié, a Jesuit priest, worked continuously on the system and recognised its massive potential to increase yield from poor soils. Later, management practices were further developed as a package of activities and started to become popular around the 1980s (Stoop and Kassam, 2005). The term SRI was popularised through research and technology transfer programmes that were funded by various development oriented organisations in other regions of the world including rice growing areas in South and Southeast Asia (Fernandes and Uphoff, 2002). However, it should be noted that the current SRI is not uniform in terms of practices adopted by farmers in different locations as many changes have been and are still being introduced.

2.1 Principles

SRI consists of a set of principles accompanied by a set of basic management practices as explained by Uphoff and Randriamiharisoa (2002) and Stoop et al. (2002). The principles of SRI explained below are paramount as they are the driving forces of the practices.

1. Rice is not an aquatic plant - This is despite lowland rice originating as an important cereal crop that is even able to tolerate flood conditions. In submerged (anaerobic) conditions, rice roots become generally short and thick with high porosity as a result of aerenchyma formation (Pradhan et al. 1973). Aerenchyma are internal, longitudinal and continuous gas spaces extending from shoot to root formed by separation or breakdown of specific cells. These gas spaces provide a pathway for oxygen transport from shoots to roots. Thus, more rice varieties when grown under upland conditions extend their root systems up to a distance of more than one metre, but when grown under flooded or anaerobic environments, rice roots seldom grow beyond 40 cm (Yoshida 1981). Over time, farmers selected cultivars better adapted to anaerobic conditions (O'Toole 2004). But rice is a semi-aquatic plant that has the ability to overcome oxygen limitations for a considerable period of time during its growth (Das and Uchimiya 2002). Continuous flooding is non-essential for the growth of rice. Rice can also be grown in lowland and upland situations.

In SRI, rice is irrigated alternately allowing rice fields to dry intermittently during its vegetative growth period. This is achieved through controlled irrigation. With this type of water management system, the root system of rice grows deeper, more widespread and stronger. Thus, uprooting a rice plant that grows under SRI requires five to ten times more force than uprooting a rice plant that grows under conventional submerged conditions in the same location. These details further prove that it is not necessary for rice to grow under flooded conditions.

2. Rice loses its growth potential when transplanted with older seedlings - The rice plant has an in-built pattern of physiological development and it produces tillers in a regular sequential pattern, which is analysed in terms of *phyllochrons* (Katayama 1951; Uphoff 2002). A *phyllochron* is a recurrent period of plant growth that is common in all plants of the family Graminae and during which the rice plant produces one or more phytomers i.e., units of a tiller, a root and a leaf from its meristem. Therefore, to bear a maximum number of tillers, the rice plant has to develop as many *phyllochrons* as possible during its vegetative phase.

In rice, each tiller produces another tiller two *phyllochrons* later, provided that the growing conditions are conducive. This makes the tiller growth curve potentially exponential. If the plant is transplanted carefully, at the initial growth stage, plant trauma is minimised and the result is rapid growth with short *phyllochrons*. The length of *phyllochron* reflects the "speed" of the rice plant's "biological clock" (ATS and CIIFAD 2007). When seedlings are transplanted at three or four weeks of age, their "biological clock" is slowed and the plants' *phyllochrons* are longer, resulting in a fewer number of tillers prior to flowering.

If the plants are transplanted later than the third *phyllochron,* when the plant has more than just two tiny initial leaves or is 8-12 days old, the seedlings will lose much of their tillering potential. Also, closely spaced plants in soil that is too dry or too wet and nutritionally deficient, will have longer *phyllochrons* (CIIFAD, n.d.). Therefore, transplanting rice fields with younger seedlings of 8-12 days or shorter than the third *phyllochron* would help the rice plant to explore its maximum growth potential.

3. Trauma is reduced with careful transplanting of seedlings - This is considered a very important principle of SRI. If the transplanting is done carefully, the plant experiences fewer traumas and recovers from the shock of transplanting more quickly than at a later stage in its development (Uphoff et al*.* 2002). This preserves the plant's potential for much greater tillering (30 to 80 tillers per plant, and possibly 100 or more), more root growth and grain filling, provided that other SRI practices are used concurrently to help plants realise this potential.

Moreover, it is recommended that transplanting is completed within 15 to 30 minutes after the tiny seedlings have been gently uprooted from the seedbed. The tiny seedlings should be placed horizontally on the soil so that the tip of the root can easily resume its downward growth. In this way, the leaves of the seedlings will not become yellow and the plant will start to grow again within a few hours. Then plants have time to adjust to their new environment before the first tiller starts to grow (Rabenandrasana 1999).

4. A hill should be transplanted with a single seedling - Instead of planting in clumps of three to four seedlings (and sometimes more) in the conventional rice production system, using just one seedling minimises competition between and among the shoots and roots of multiple seedlings. Plant growth rate and final grain yield of single seedling transplanted rice is higher than multiple seedling transplanted rice (San-oh et al. 2004). A plant population with a single seedling per hill has shown enhanced light intercepting characteristics and accumulation of nitrogen and slower leaf senescence during the ripening stage than a population consisting of hills with three plants per hill (San-oh et al. 2004).

Single seedlings per hill minimises the shading effect on lower leaves keeping them photosynthetically active for a longer duration, which will ultimately maintain higher root activity due to the enhanced capacity of the plant to supply oxygen and carbohydrate to the roots. Larger numbers of crown roots, increased root length density and cytokinin content are favourable root growth characteristics of rice planted with a single seedling per hill (San-oh et al. 2006).

5. Reaching maximum growth potential requires adequate spacing - Rice plants that are transplanted at a very early stage have more chances of exploring full growth potential. Adequate spacing and other favourable conditions encourage prolific rooting, both vertical and horizontal, more tillering and more grain filling. Root systems that have grown deeper absorb nutrients in deeper layers and widespread horizontal roots absorb nutrients in shallow layers resulting in profuse plant growth with a maximum number of tillers and grains.

6. Soil amendments are necessary to secure microorganism growth - SRI recommends adding plenty of organic matter to rice growing soils. Among the immense benefits of adding compost are improving the soil's physical, chemical and biological properties that contribute significantly to growing a healthy and sustainable crop. Much larger root systems of SRI rice, when compared with conventionally grown rice, are due mainly to the addition of ample organic matter and its effect on the improvement of soil structure and plant biology. Well-grown root systems provide access to a much larger pool of nutrients (Uphoff 2003).

Management methods matter a great deal for the supply and availability of nutrients in the soil. Intermittent irrigation, where alternate wetting and drying (AWD) regimes are imposed to SRI fields as the water management technique (Tabbal et al. 2002), is a practice where soil is alternately oxidised and reduced. Both aerobic and anaerobic microorganisms can grow and die in AWD conditions and their continuous decomposition supplies nutrients to the soil. Enhancing the availability of water-soluble phosphorus is an important phenomenon that occurs due to AWD (Turner and Haygarth 2001).

2.2 Management Practices

Management practices in SRI vary from location to location and even season to season due mainly to variability in soil, geographical conditions and climatic conditions. Listed below are some recommended practices that farmers in different parts of the world follow with appropriate alterations.

1. **Transplanting at 2-3 leaf stage -** Transplanting young seedlings, usually 8 to 12 days old and certainly less than 15 days old.

2. **Transplanting a single seedling per hill** - Instead of planting in clumps of 3-4 seedlings SRI recommends a single seedling per hill.

3. **Careful handling and quick transplanting of seedlings** - Seedlings should be uprooted gently from the nursery and handled carefully since seedlings with two or three tiny leaves are very delicate.

4. **Wider spacing** - Although SRI has no fixed spacing, wider spacing than the conventional rice culture is recommended for better rooting, more tillering and more grain filling. SRI follows a square pattern ranging from 25x25 cm^2 to 50x50 cm^2. The spacing is dependent on soil fertility; the more soil fertility there, the greater the plant spacing.

5. **Adding plenty of organic matter** - Farmers in different localities are used to applying larger amounts of organic matter to SRI fields although no fixed rate of application exists. A variety of sources of nutrients is used according to the availability and soil fertility status. According to the Watershed Support Services and Activities Network (WASSAN) (2006), Indian farmers are using tank silt (40-50 tons ha^{-1}), farm yard manure (FYM) (15 tons ha^{-1}), and green manure such as Sunhemp and Sesbania, which are grown in the plots and incorporated into the soil at flowering. Vermi-compost can also be used in place of FYM or in combination with FYM as a good source of organic matter.

6. **Irrigating intermittently -** SRI follows intermittent irrigation, where alternate wetting and drying regimes are imposed in the field (Tabbal et al. 2002). Under AWD practices, the soil is wetted and dried intermittently during vegetative growth to keep the soil saturated or moist enough to avoid drought stress, which typically results in water saving as compared with continuous flooding. AWD practices in SRI have no recommended interval and the gap between two irrigations depends on the soil type and its water retention characteristics.

7. **Cultivating the soil -** SRI avoids chemical applications in controlling weeds and the rotary weeder (cono-weeder) is the most common equipment used in soil cultivation. Rotary weeders can be manually operated and machine operated. This method of soil cultivation prevents weed growth, aerates the cultivated soil and facilitates comfortable root growth. The number of weeding rounds varies from two to five, depending on weed growth and affordability. The first weeding is normally done at eight to ten days after field planting and this too may vary depending on weed growth of the location.

However, it is important to understand that SRI does not have a standard package of practices and that it may vary from location to location reflecting the local conditions of the farms. Farmers are encouraged to test and evaluate the various practices (for example age at transplanting and spacing).

When SRI was compared with conventional rice production practices, the differences that could be observed are listed in Table 2.1.

Table 2.1 Comparison of SRI practices and conventional rice production

Agronomic Practices	SRI Method	Conventional Production Method
Seed requirement (kg ha^{-1})	5-10	80-120
Age of seedlings (days)	8-15	20-30
Seedlings per hill (no.)	1	3 to 4
Spacing of hills (cm)	25 x 25 to 50 x 50	10 x 10 to 20 x 20 (usually in rows)
Transplants per m^2 (no.)	4 to 25	75 to 150
Water management	Moist soil/intermittent drying	Continuous flooding
Fertility management	Compost/ Organic manure	Basal mineral fertiliser + N top dressing
Weed management	3 to 4 rounds with rotary hoe	2 rounds; may use herbicides

Source: Stoop et al. 2002

3 LOCATION SPECIFIC NATURE OF SRI

When Father Henri De Laulanié arrived in Madagascar from France in 1961 he spent time with Malagasy rice farmers on improving their production as rice is the staple food in Madagascar. Father De Laulanié continued his research for about twenty years (1961-1980) and ultimately confirmed the remarkable growth and yield performance of the rice crop in the 1980s and there on. He observed and proved the rice plant's ability to produce a larger number of tillers when transplanted at a younger stage and the reduced tiller production in delayed transplanting. After further experimentation, SRI was popularised among more Malagasy farmers through the non-government organisation (NGO) called *Tefy Saina*, formed by Father De Laulanié himself. However, acceptance of SRI in Madagascar was slower than expected. From 1990 to 1994, only 38 Malagasy farmers had tried the new technique.

In the meantime, SRI began to be used beyond Madagascar and a few countries like China, Indonesia, India, Gambia, Japan and others including Sri Lanka tried the new techniques at a research level. For the most part, SRI was received by the scientific community with some indifference. The lack of scientific research to support SRI was one highlighted reason. Some rejected the published assessments of SRI (Dobermann 2004; McDonald et al. 2006; Sheehy et al. 2004; Sinclair and Cassman 2004).

Father De Laulanié confirmed a set of management practices for SRI after conducting twenty years of research on very poor boggy soil. These are:

- Planting tiny seedlings that are less than 15 days old
- Planting single seedlings per hill

- Planting in a square pattern of 25x25 cm^2 or wider if the soil is very good
- Applying a minimum of water daily to keep the soil moist but not always saturated. Fields were allowed to dry out several times to the cracking point during the growing period
- Adding plenty of organic matter

When this set of practices is introduced to different locations, they may not work in the same way as in Madagascar.

3.1 Adoption and adaptation

Adoption and adaptation are common terms used in technology transfer. Adoption is accepting technology without any modification, whereas adaptation is an application of technology with the modifications necessary to a given location. The adoption of a technology might create problems if it does not suit the specific location and its conditions. In the meantime the technology should provide opportunities for the farmers to conduct their own experiments and discover what is most suitable for their location. The transfer of SRI technology has this freedom and involves both adoption and adaptation.

Several SRI scientists (Uphoff 2001; Stoop et al. 2002; and Uphoff et al. 2002) described the system of rice intensification as a methodology that evolved mainly through participatory on-farm experimentation conducted in Madagascar during the 1980s and 1990s. They suggested that SRI represents an integrated and agro-ecologically sound approach to irrigated rice cultivation, which may offer new opportunities for location-specific production systems of small farmers. Uphoff in 2002 stressed in one of his articles that SRI is not a "standard package" of specific practices, but rather represents empirical practices that may vary to reflect local conditions. Farmers are encouraged to test and evaluate the various practices (age of transplanting, spacing, etc) for themselves. Tripathi et al. (2004) in their research paper after a series of farm and research station experiments have concluded that trial performances of SRI could vary from location to location. Furthermore, they stressed that instead of making concrete recommendations to farmers in different locations they should be encouraged to do their own research into different SRI practices.

SRI involves a certain set of principles and a set of management practices that have been transformed based on the principles. These management practices may differ from location to location and sometimes from season to season, depending on the differences of the soil in different geographical locations and the climatic conditions in different seasons. Apart from that, in some locations they vary depending on the farmers' conditions, their general understanding, knowledge of manipulating the practices to suit their particular conditions and affordability.

Seedling age at transplanting is an important factor for uniform stand of rice (Paddalia 1980) and regulating its growth and yield (Bassi et al. 1994). Farmers and researchers in different world locations tested with different ages of seedlings and discovered that they performed well under their respective conditions. Ginigaddara and Ranamukhaarachchi (2011) have reported that rice seedlings that were 4 to 12 days old showed no variation with respect to tillering potential and growth dynamics under SRI in central Thailand. In recent studies of Makarim et al. (2002), 14-day-old seedlings have performed better than transplanting 21- to 23-day-old seedlings. McHugh et al. (2002) and Thiyagarajan et al. (2002) observed the highest yields with 8- to 15-day-old seedlings, transplanted at 25 hills m^{-2} in Madagascar and with 10-day-old seedlings in Sumatra. Krishna and Biradarpatil (2009) observed higher grain yields of 3.25 t ha^{-1} with 12-day-old seedlings than with 8-, 16- and 25-day-old seedlings. The yield decline of seedlings of the latter three ages was primarily attributed to the reduction in the number of tillers.

Farmers often believe that they can boost their yields by planting rice more densely with 50 or more than a 100 plants per square metre. In reality, wider spacing encourages more rooting, more tillering and more grain filling. In SRI, wider spacing is followed with a square pattern. In Madagascar, initially Father De Laulanié followed a plant spacing of 25x25 cm^2 on boggy soil with a poor nutrient condition (De Laulanié 1993). Later, following research and farmer level testing, variable spacing proved to provide better growth, development and yields at various locations. Consequently, a spacing starting from 20cm x 20cm to 50cm x 50cm is used in SRI in various locations all over the world. Plant spacing depends on inherent soil fertility and climatic conditions. De Laulanié (1993) further reported that the spacing in a SRI field is the farmer's choice. Every farmer should decide according to his own experience what kind of spacing suits him best, considering the variety of rice grown, the soil quality, the microclimate, the transplantation density and his own knowledge of rice cultivation. Thakur et al. (2010) proved in their research that a 20cm x 20cm spacing gives a significant rice yield in SRI. A farm experiment done in Kerala by Anitha and Chellappan (2011) revealed that planting one or two 15- to 20-day-old seedlings $hill^{-1}$ at 20cm x 15cm spacing and employing cono-weeding and intermittent irrigation are economically feasible technologies. Tripathi et al. (2004) reported that the yields obtained under SRI are significantly higher with a spacing of 20cm x 20cm (8821 kg ha^{-1}) than a 30cm x 30cm spacing (7627 kg ha^{-1}) and a 40cm x 40cm spacing (5747 kg ha^{-1}) in Nepal. Evans et al. (2002) reported higher grain yields at 20cm x 20cm spacing in a study conducted in 2000 at Khumaltar and Bhaktapur in Nepal as compared to 20cm x 15cm and 15cm x 15cm. De Laulanié reported in 2011 that at sea level in a hot tropical climate, 30cm x 30cm spacing is required, especially in summer.

SRI recommends a single plant per hill to explore the full growth potential of the rice plant. However, the number of recommended plants per hill in different locations varies from one to two for different reasons. In certain locations, researchers and farmers establish two plants per hill to avoid any loss of seedlings due to pest or other damage, which is possible since the seedlings are tiny and liable to damage by pests and other mechanical reasons (Ginigaddara and Ranamukhaarachchi 2011).

Although the addition of ample organic matter to SRI fields is one recommendation, the amounts have not been fixed. Farmers add different types and rates of organic matter, depending on their availability and affordability. The fertility status of the soil and the soil structure are the foundation for deciding on how much organic matter to add, but most SRI farmers in different localities do not take this into account when adding organic matter.

Alternate wetting and drying is a key practice in SRI. Depending on the conditions in the locality, the time duration of wetting and drying and the amount of water added always vary. In an experiment conducted in central Thailand, it was proven that one week of irrigation followed by three weeks of suspension gives a higher yield, compared with two weeks each of irrigation and suspension on an acid sulphate soil (Ginigaddara and Ranamukhaarachchi 2009). In an experiment conducted in the Mwea Irrigation Scheme in Kenya, it was proven that a 12-day drying regime yielded slightly less than an 8-day drying regime, although the difference was not statistically significant (Omwenga et al. 2014). In certain locations, wetting (irrigation) is done when the applied water layer has disappeared from the field. Therefore, the number of days of drying might vary accordingly. In certain locations the soil is kept moist (field capacity) without saturation in the vegetative stage (Anitha and Chellappan 2011).

4 RESEARCH STATION EXPERIMENT: ORGANIC MATTER AND WEED GROWTH IN SRI

SRI was initially developed using chemical fertilisers, but drastic price increases in the late 1980s led to the use of organic fertilisers. This contributed to higher yields that were at times substantially greater (Uphoff 2002). SRI responds to organic matter better than to chemical fertilisers and thus emphasises the need to build fertility through organic means from the beginning. The addition of nutrients in organic form is optional and varies according to agro-ecological conditions.

In order to obtain the productivity gain at the lowest cost, SRI farmers manage their soil in different ways (Uphoff, n.d.). SRI farmers use different types of organic matter in different localities. Rice straw, compost, vermi-compost, poultry manure, cow dung, green manure etc are prominent forms while in some locations farmers use a mixture of organic matter.

Wider spacing and controlled water use in SRI make weed growth and its control problematic. Weeds perform aggressively under SRI as they receive more space with more chances of germination under less water in the field.

4.1 Methodology

An experiment to investigate the response of both improved and traditional varieties of rice to the different types of organic matter and their effect on weed growth was conducted at the research farm of the Faculty of Agriculture, Rajarata University of Sri Lanka during the 2013/2014 *maha* season (a cultivation season in Sri Lanka that falls between October and January each year). Rainfall at the experimental site in Anuradhapura ranged from 900mm to 1850mm and the great soil group is Reddish Brown Earth (RBE). The daily mean temperature ranged from 27^0C to 32^0C. The elevation is 89m above mean sea level. The chemical and physical characteristics of soil before starting the experiment are presented in Table 4.1.

Table 4.1 Chemical and physical characteristics of soil of selected site

Characteristics	Experimental site
Bulk density	1.77 g cm^{-3}
pH	6.92
Electrical conductivity	1.6 mS cm^{-1}
Organic matter content	1.64 ml mol^{-1}
Total nitrogen content	2.44 %
Available phosphorus content	0.345 ppm
Exchangeable potassium content	16.5 ppm

The experiment was conducted in a two-factor factorial design where the two factors were rice variety and type of organic matter. Two rice varieties and five types of organic matter were used in the experiment. The five types of organic matter used were compost, paddy straw, cow dung, green manure and a mixture of all in equal amounts. The two rice varieties were *Kuruluthuda,* which is a three-and-a-half-month-old traditional variety and BG 358, which is a three-and-a-half-month-old new improved rice variety. Altogether there were ten treatments and they were replicated thrice. Land was ploughed using a tine tiller up to a depth of 30cm and the second ploughing was done after two weeks. Puddling and levelling were done on the day of transplanting. Different types of organic matter were applied as per the treatment schedule, at the rate of 10kg m^{-2} to field plots that were 10m x 5m each in size, two weeks before the first ploughing. At the first ploughing, organic matter was properly incorporated to the soil. Two seedlings that were 8 days old were established per hill with 20cm x 20cm spacing in the plots, and irrigated for two weeks for better establishment in the field. Thereafter, a two-weekly irrigation regime was practised during the vegetative phase and a continuous water layer was maintained during flowering. Water was drained off two weeks before harvesting to allow for the grains to dry.

An integrated pest management technique was used to control pests and no pest or disease appeared during the cropping period. A single row rotary hoe was used to control weeds during the vegetative growth period of rice.

Chemical fertilisers were applied at half the recommended rate of the Department of Agriculture, Sri Lanka. Basal dressing was avoided and top dressing was applied at half its rate.

Plate 4.1. Preparing compost to be applied to treatments in the research field of the Faculty of Agriculture. Photo: Thilakasiri

Plate 4.2. Incorporating paddy straw at the ploughing stage in the research field of the Faculty of Agriculture. Photo: Thilakasiri

Plate 4.3. Marking the spacing for transplanting in the research field of the Faculty of Agriculture

Plate 4.4. Young seedlings ready to transplant in the research field of the Faculty of Agriculture

Plate 4.5. Transplanting young seedlings in the research field of the Faculty of Agriculture

Plate 4.6. Two 8-day-old seedlings planting per hill in the research field of the Faculty of Agriculture

Plate 4.7. Weeding with cono-weeders in the research field of the Faculty of Agriculture

4.2 Measurements and Observations

Plant growth parameters, both above- and below-ground were measured. Number of tillers, plant height, leaf area, shoot biomass, root depth, total root length, and root biomass were measured at the maximum tillering stage. LAI (Yoshida 1981) and root diameter (De Datta 1981) were calculated. Yield parameters after harvesting such as total number of tillers, number of productive tillers, panicle length, number of filled and ill-filled seeds per panicle, and 1000-grain weight were measured. A sample of plants in two square metres was harvested and grain yield at 13% moisture content was measured.

Weed growth was measured in terms of weed biomass. A one square metre block was randomly selected using a quadrant and all the weeds were harvested and dry biomass was measured. Weed diversity in one square metre was determined before ploughing, before the first and second weeding and after harvesting in each treatment.

4.3 Results

4.3.1 Plant growth characteristics

Of the growth parameters measured, the number of tillers and plant height showed significant differences between traditional and improved rice varieties with respect to different types of organic matter, while LAI and S:R ratio were not significantly different (Table 4.2). The number of tillers at maximum tillering was higher in BG 358, which is a new improved variety (NIV), than in *Kuruluthuda,* the traditional rice variety (Figure 4.1). The plant height recorded was highest in *Kuruluthuda* when compared with BG 358, irrespective of the type of organic matter applied (Figure 4.1). Traditional rice varieties characteristically produce a low number of tillers and higher plant height, compared with NIVs (Saito et al. 2005). Shoot to root ratio was higher in BG 358 than *Kuruluthuda,* irrespective of the type of organic matter applied (Figure 4.1). The higher number of tillers and leaves in NIV might be the reason for the higher S:R ratio of NIV.

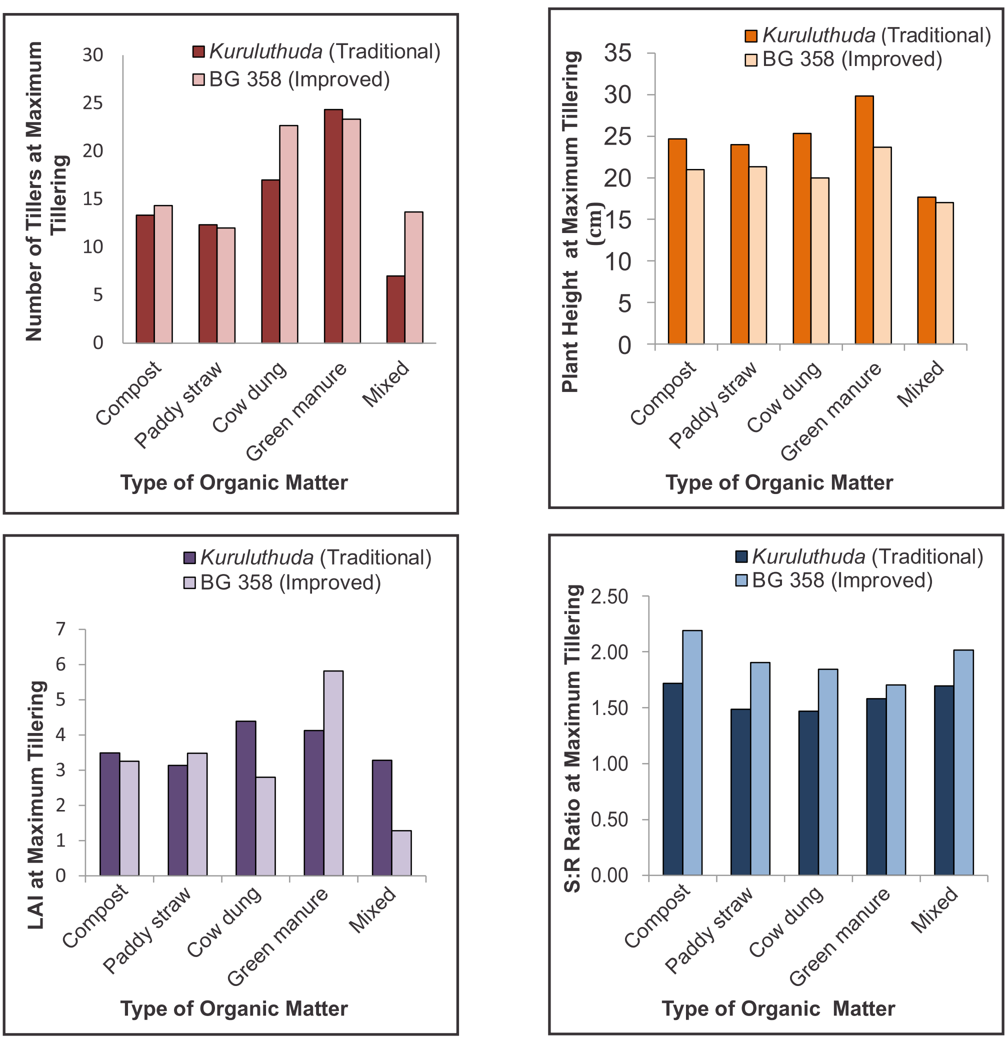


Figure 4.1. Shoot growth characteristics of rice with respect to organic matter

Table 4.2 Source of variation, degrees of freedom and mean squares obtained from analysis of variance for shoot and root growth parameters

Sources of Variation	DF	Mean Squares							
		Shoot Parameters at Mximum Tillering (MT)					Root Parameters at MT		
		No of tillers	No of leaves	Plant Height, cm	LAI	Shoot DW (g)	Root depth (cm)	Root length (m)	Root DW (g)
OM	4	191.33***	1938.11***	67.36**	5.57	78.56	177.81***	13.01***	43.62
VAR	1	43.20	360.53	102.67 **	0.95	12.02	165.67**	6.59 **	17.29
OM x VAR	4	18.70	180.78	7.13	3.35	37.27	5.40	1.22	26.55
CV %		20.79	19.63	11.40	38.22	44.06	16.33	21.98	51.26

OM – Type of organic matter; VAR - Variety; DW- Dry weight; LAI – Leaf Area Index; ***= 0.001; ** =0.01;

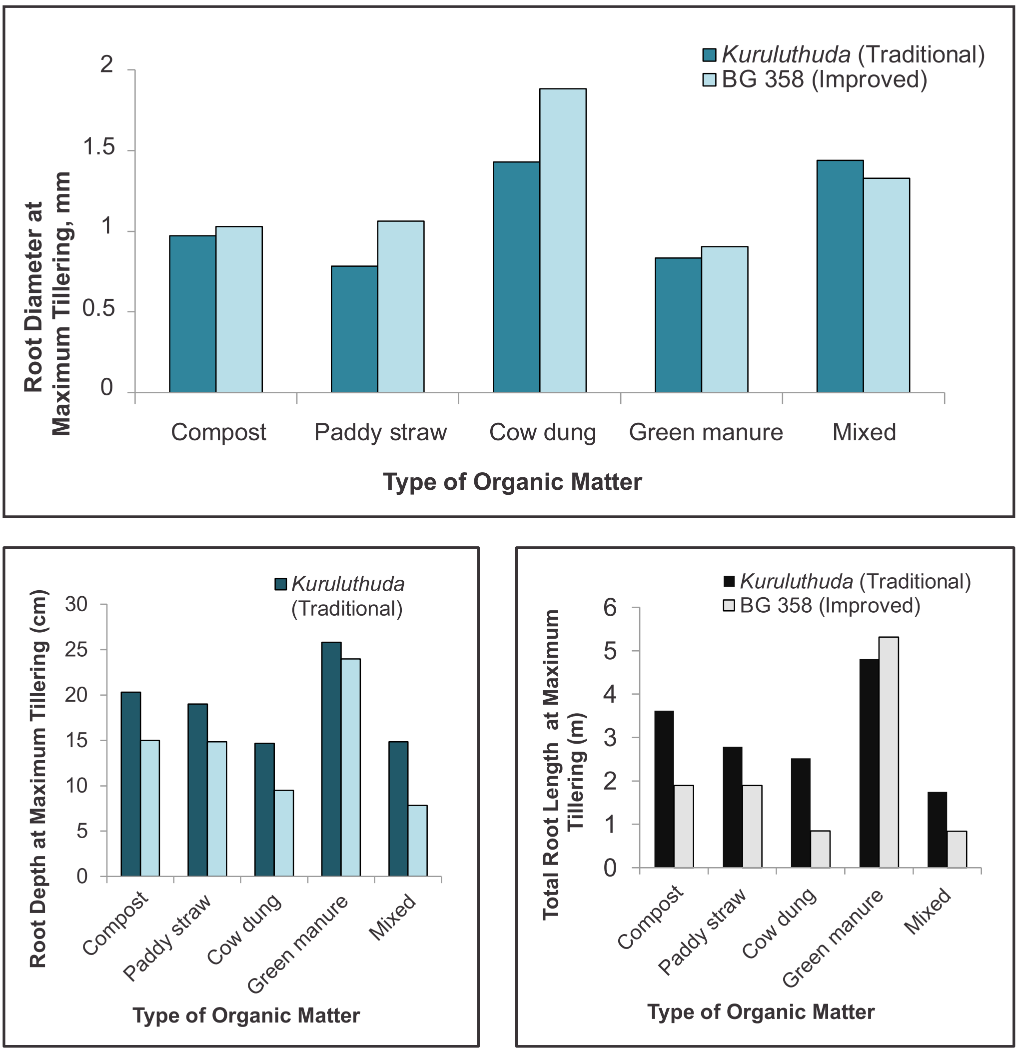


Figure 4.2. Root growth characteristics of rice with respect to organic matter

4.3.2 Weed growth of rice paddy with respect to organic matter

There were no significant differences (p=0.05) among either different rice varieties or type of organic matter on weed count or weed biomass (Figure 4.3). This indicated that a single type of organic matter or a mixture of organic matter does not affect the weed growth in SRI fields. However, weed biomass had increased from first weeding to the second in all the treatments. to that of the grain yield (Figure 4.4).

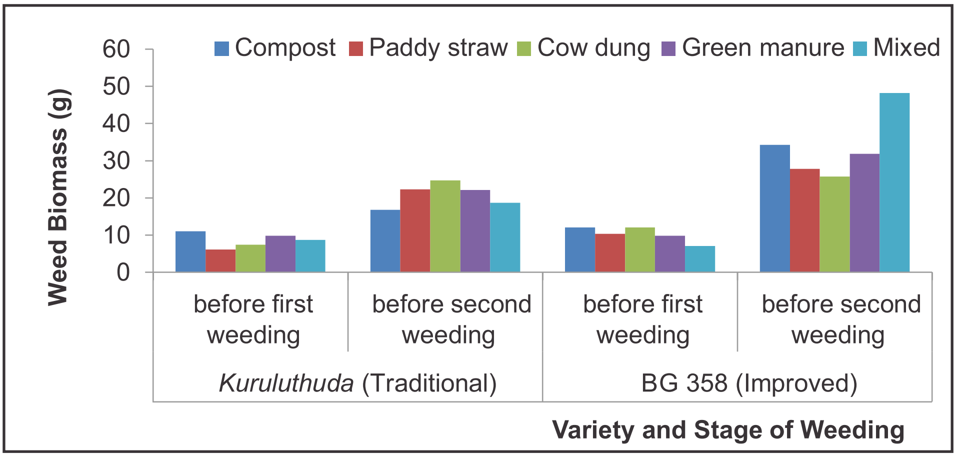


Figure 4.3. Weed biomass with respect to organic matter and variety

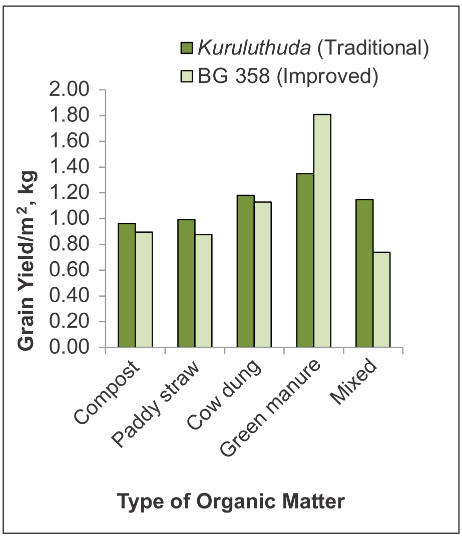
4.3.3 Grain yield

There were no significant differences in the yield and yield parameters of the two varieties of rice with respect to the type of organic matter (Table 4.3). The traditional variety produced comparably more grain yield than the improved variety with all types of organic matter except for green manure. Treatment with green manure shows a comparatively higher grain yield per square metre than treatments with other types of organic matter. However, more investigations are necessary to confirm this trend. Thousand grain weight also showed a more or less similar pattern of variation to that of the grain yield (Figure 4.4).

Table 4.3 Source of variation, degrees of freedom and mean squares obtained from analysis of variance for yield parameters

Source of Variation	DF	Mean Squares					
		Total no of tillers	Productive tillers	Panicle length (cm)	No of filled seeds/panicle	Thousand grain weight at 13% (g)	Per pt yield (g)
OM	4	10.19	11.17	2.18	1358.95	3.64	172.87
VAR	1	0.06	0.14	34.53	1337.87	5.32	0.1514
OM x VAR	4	1.49	1.077	2.22	2154.25	4.81	60.89
CV %		23.74	21.95	6.33	25.42	14.13	45.01

OM – Type of organic matter; VAR – Variety



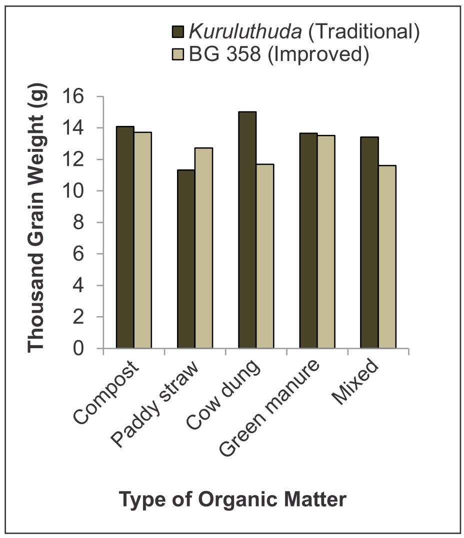


Figure 4.4. Grain yield of rice with respect to organic matter.

4.3.4 Soil nutrition status before and after cropping

Table 4.4 shows the results of the analysis of soil samples obtained from the research location after harvesting. Exchangeable potassium and soil organic matter, all other nutrients, soil pH and EC were not significantly different among different organic matter treatments.

Table 4.4 Source of variation, degrees of freedom and mean squares obtained from analysis of variance for soil nutrient parameters after harvesting

Source of Variation	Mean Squares						
	DF	pH	EC (μs/cm)	Available Phosphorous (mg/l)	Exchangeable Potassium value (ppm)	Organic Matter content (ml/mol)	Total Nitrogen %
OM	4	0.002	295.67	0.002	7.16**	0.064*	0.085
VAR	1	0.002	37.85	0.004*	6.16	0.054	0.013
OM x VAR	4	0.01	79.28	0.0035*	2.61	0.029	0.023
CV%		1.78	26.75	11.70	11.88	9.36	13.85

OM – Type of organic matter; VAR – Variety; EC- Electrical Conductivity; ** =0.01; *= 0.05

Exchangeable potassium, available phosphorous, total nitrogen, soil organic matter, soil pH and EC were measured before ploughing and after harvesting. Almost all the treatments have lower values of the parameters compared with the values before ploughing. The soil nutrient parameters before ploughing and after harvesting are presented in Figure 4.5.

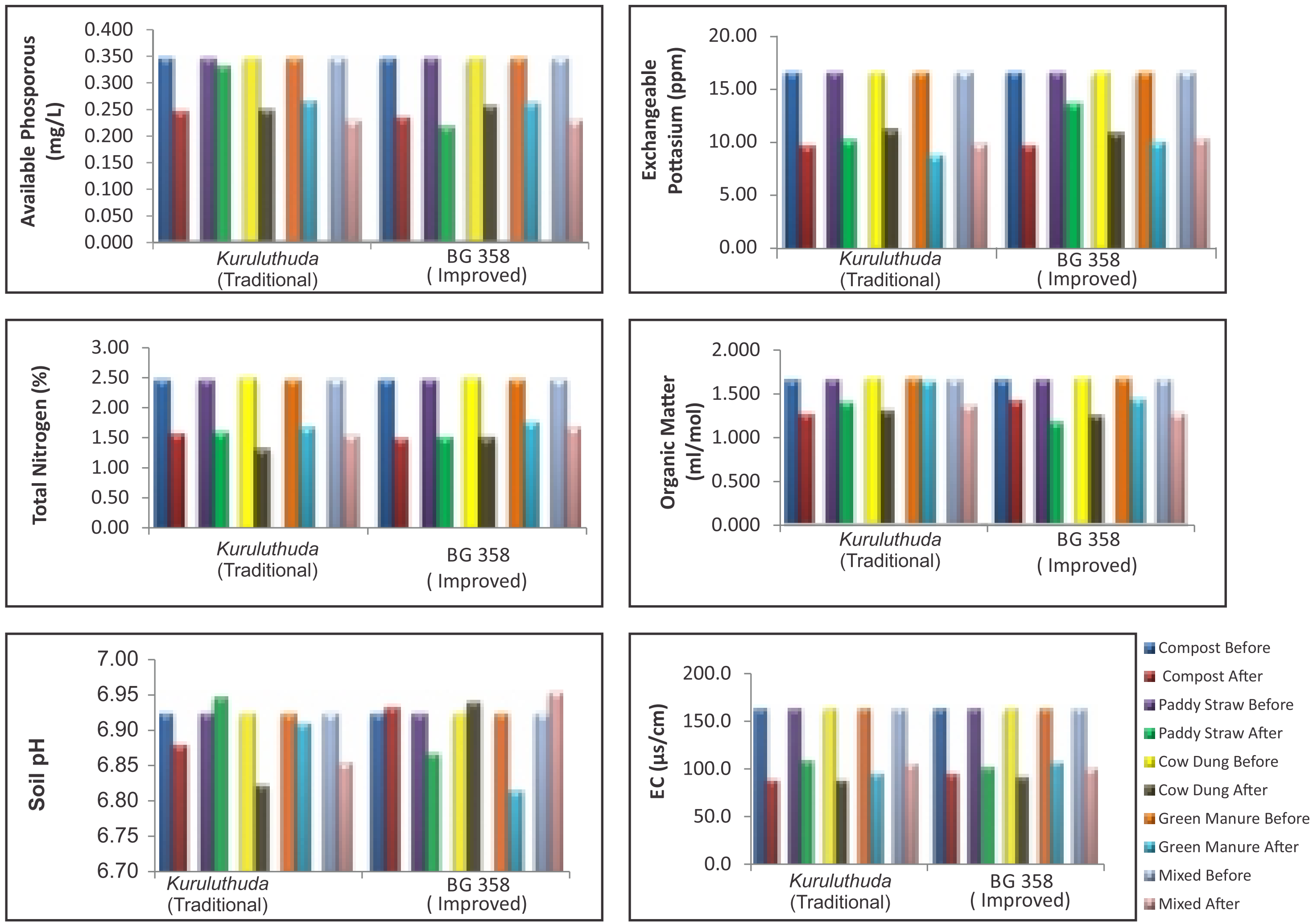


Figure 4.5. Soil nutrient properties, soil pH and EC of location before ploughing and after harvesting with respect to organic matter

5 FARM EXPERIMENT: METHODS OF ESTABLISHMENT AND LABOUR UTILISATION IN SRI

Many rice farmers in Sri Lanka have recognised labour utilisation in various stages as critical in the practice of SRI. In fact, it has been a decisive controlling factor on the number of adopters of the system (Ginigaddara et al. 2013). Moser and Barrett (2003) also reported that the labour intensity of SRI limits farmer adaptation of SRI. Uphoff (n.d.) has mentioned in his paper on "Farmer Innovations Improving the System of Rice Intensification" that transplanting is the most labour-intensive aspect of SRI operations. A survey undertaken in six districts covering all climatic zones of Sri Lanka in 2013 showed that crop establishment and weeding are considered major labour consuming activities in SRI (Ginigaddara et al. 2013). Therefore, "transplanting is more labour intensive in SRI" is a popular impression among farmers (Ginigaddara et al. 2013).

SRI farmers in different parts of the world are exploring different establishment techniques in their cultivations. Though the most prominent plant establishment method in SRI is manual transplanting with 8- to 12-day-old seedlings, direct manual seeding, seeding with seeders and parachute transplanting have also shown good results (Ginigaddara et al. 2013; Uphoff 2006).

5. Methodology

A three-factor factorial experiment was undertaken in farmers' fields in three selected locations. A split-split plot design was used with two replicates each. The treatment schedule is presented below (Table 5.1).

Table 5.1 Treatment schedule of the on-farm research trial

Location	Establishment method	Variety
Thalawa (Gurugama)	Manual SRI transplanting	BG 358 *Kuruluthuda*
	Parachute transplanting	BG 358 *Kuruluthuda*
	Machine row seeding	BG 358 *Kuruluthuda*
	Broadcasting	BG 358 *Kuruluthuda*
Thambuttegama (Kooratiyawa)	Manual SRI transplanting	BG 358 *Kuruluthuda*
	Parachute transplanting	BG 358 *Kuruluthuda*
	Machine row seeding	BG 358 *Kuruluthuda*
	Broadcasting	BG 358 *Kuruluthuda*
Eppawala (Katiyawa)	Manual SRI transplanting	BG 358 *Kuruluthuda*
	Parachute transplanting	BG 358 *Kuruluthuda*
	Machine row seeding	BG 358 *Kuruluthuda*
	Broadcasting	BG 358 *Kuruluthuda*

Plate 5.1. A farmer preparing the field in Thambuttegama

Plate 5.2. Nurseries laid on parachute trays in Thambuttegama

Plate 5.3. Transferring seedlings for transplanting from the nursery to the paddy field in Thambuttegama


Plate 5.4. Transplanting 8-day-old seedlings in Eppawala


Plate 5.5. Transplanting 8-day-old seedlings in Thalawa

Plate 5.6. Weeding by a farmer in Thambuttegama

Plate 5.7. Ecologically friendly farming under SRI in Eppawala

A mixture of organic matter was applied to farmers' paddies at the rate of 1kg m^{-2} two weeks before the land was prepared. Rice straw from the previous season, homemade compost, green leaves found in close proximity and cow dung from their own cattle sheds were the most common types of organic matter used. Two ploughings were done followed by puddling and the seedlings and seeds of the two varieties were established in the field using four different establishment methods following the treatment schedule. Pre-soaked pre-germinated seeds were used for broadcasting and machine row seeding in the field. The same lots of seeds on the day of seeding in relevant treatments were used to lay a parachute tray nursery and normal nursery in the field. In the parachute nursery, 2-3 seeds were laid in one hole in the tray. In the manual SRI transplanting method, 8-day-old seedlings were established manually with a spacing of 20cm x 20cm, where two seedlings were established in each hill. When seedlings reached 8 days in parachute nurseries, they were thrown to the puddled paddy fields in such a way to achieve approximately 20cm x 20cm spacing in the paddy field. In the direct seeding treatments, paddy fields were protected from bird damage. Ultimately, the seedlings of all the treatments were of the same age, irrespective of the transplanting method.

In the parachute and manual SRI transplanting treatments, water was applied to fields for one week for proper establishment of seedlings. Thereafter, water was applied at weekly intervals until plants started flowering. A thin water layer was maintained in the fields during the period of flowering. Paddy fields were drained out two weeks before harvesting to allow for the grains to dry. The basal dressing was omitted from the treatments and half dose of the top dressing was applied to all the fields. An integrated pest and disease management approach was adopted in the paddies. However, no significant pest or disease appeared in any treatment during the cropping period.

Manual weeding was done in the fields transplanted under the broadcasted and parachute methods, and a cono-weeder was used in row-seeded and manual transplantation.

5. 2 Measurements and Observations

Plant growth parameters, both above- and below-ground were measured. Number of tillers, plant height, leaf area, shoot biomass, root depth, total root length and root biomass were measured at the maximum tillering stage. LAI was calculated (Yoshida 1981). After harvesting, yield parameters such as total number of tillers, number of productive tillers, panicle length, number of filled and ill-filled seeds per panicle and 1000-grain weight were measured. A sample of plants in one square metre was harvested and grain yield at 13% moisture content was measured. Labour utilisation in each method of plant establishment was recorded per location and per treatment.

5.3 Results

5.3.1 Plant growth characteristics

Plant height and shoot dry weight were significantly different among different locations while number of tillers, LAI and shoot dry weight were significantly different with respect to different establishment methods (Table 5.2). The varieties didn't show any significant difference. None of the interactions were significant with respect to above-ground growth parameters (Table 5.2).

In root growth parameters, root depth and total root length were significantly different according to location. Almost all root parameters measured were significantly different (0.001) with respect to the method of establishment (Table 5.3). None of the interactions were significant with any of the above-ground growth parameters (Table 5.3).

Tables 5.4 and 5.5 present the means and the standard deviations of different shoot and root growth parameters and their level of significance in relation to location, method of establishment and variety. Although the plant height and LAI are apparently higher in the traditional variety than the new improved variety, they are not significantly different.

Plate 5.8. A farmer holds a SRI rice plant in Thambuttegama

Table 5.2 Source of variation, degrees of freedom and mean squares obtained from analysis of variance for shoot growth parameters at maximum tillering

Source of Variation	DF	Mean Squares			
		Plant height (cm)	Number of tillers	LAI	Shoot Dry weight (g)
Location (L)	2	1925.67 ***	81.68	4.33	415.99*
Method of establishment (E)	3	542.77	668.51***	39.71***	975.42***
Variety (V)	1	319.25	12.48	0.61	8.68
L x E	6	118.39	22.75	1.54	67.36
L x V	2	28.37	27.89	1.15	19.09
E x V	3	144.74	12.28	0.60	1.88
L x E x V	5	140.95	14.91	0.46	5.95
CV%		16.32	50.85	61.42	47.27

LAI- Leaf area index; *Significant at p=0.05; ***Significant at p=0.001

Plate 5.9. Single broadcasted rice plant (left) and single SRI transplanted rice plant (right) at maximum tillering in Eppawala

Plate 5.10. Parachute transplanted rice in Eppawala

Plate 5.11. Measuring grain moisture using the grain moisture meter
Photo: Nilantha Sanjeewa

Plate 5.11. Manual weeding in fields transplanted with the parachute method in Eppawala

Table 5.3 Source of variation, degrees of freedom and mean squares obtained from analysis of variance for root growth parameters at maximum tillering

Source of Variation	DF	Mean Squares			
		Root depth (m)	Total Root length (m)	Root Dry Weight (g)	S:R
Location (L)	2	181.08*	340.40*	102.27	0.13
Method of establishment (E)	3	249.89 ***	823.43***	198.82***	5.07
Variety (V)	1	15.77	11.76	1.60	11.79*
L x E	6	17.51	71.28*	26.43	2.26
L x V	2	34.94	51.65	3.11	2.85
E x V	3	1.67	4.69	5.82	7.12
L x E x V	5	6.64	27.65	6.85	2.10
CV%		15.63	37.75	65.18	33.05

S:R – Shoot to root ratio; *Significant at p=0.05; ***Significant at p=0.001

Table 5.4 Mean shoot growth parameters of two rice varieties with respect to location and method of establishment

Location	Method of establishment	Variety	Plant height,cm	Tiller number	LAI	Shoot dry weight, g
Thalawa (Gurugama)	Manual SRI transplanting	BG 358	72.07± 0.80 BaA*	21.5± 14.8 AaA	5.22± 4.08 AaA	18.20±4.67 BaA
		Kuruluthuda	78.80± 9.05 BaA	17.50±0.70 AaA	4.25± 1.34 AaA	12.82±11.20 BaA
	Parachute transplanting	BG 358	64.24±10.62 BabA	27.00±1.41 AaA	5.59±0.79 AaA	17.68±3.21 BaA
		Kuruluthuda	-	-	-	-
	Machine Row seeding	BG 358	-	-	-	-
		Kuruluthuda	-	-	-	-
	Broadcasting	BG 358	55.55± 6.15 BbA	2.50± 0.71 AbA	0.20± 0.05 AbA	1.54± 0.68 BbA
		Kuruluthuda	55.95±13.08 BbA	4.50±2.12 AbA	0.44± 0.09 AbA	1.31± 0.32 BbA
Thambuttegama (Kooratiyawa)	Manual SRI transplanting	BG 358	68.70±10.6 BaA	11.00±4.24 AaA	2.91 ±2.33 AaA	20.80±7.21 BaA
		Kuruluthuda	95.2 ±33.7 BaA	10.00±4.24 AaA	2.57± 0.32 AaA	18.90±0.99 BaA
	Parachute transplanting	BG 358	72.75± 1.06 BabA	21.0±15.6 AaA	4.11 ± 3.18 AaA	19.20± 1.13 BbA
		Kuruluthuda	63.40±0.70 BabA	12.0 ±1.41 AaA	2.27±0.35	13.35±3.32 BbA
	Machine Row seeding	BG 358	61.15± 5.16 BabA	6.50±4.95 AbA	0.86± 0.49 AbA	14.40±1.70 BcA
		Kuruluthuda	-	-	-	-
	Broadcasting	BG 358	66.7± 14.2 BbA	3.50±0.70 AbA	0.80±0.49 AbA	14.15± 1.63 BcA
		Kuruluthuda	62.65±5.87 BbA	3.00± 1.41 AbA	0.50±0.11 AbA	10.90± 0.42 BcA
Eppawala (Katiyawa)	Manual SRI transplanting	BG 358	83.10±2.83 AaA	16.50±2.12 AaA	3.82±0.6 AaA	28.10±2.26 AaA
		Kuruluthuda	90.0±15.9 AaA	18.50±2.12 AaA	4.51±1.08 AaA	31.55±4.45 AaA
	Parachute transplanting	BG 358	85.90±2.55 AabA	18.0±5.66 AaA	4.59± 1.26 AaA	23.30±0.84 AbA
		Kuruluthuda	106.2± 21.8 AabA	22.50±7.78 AaA	5.03±2.34 AaA	22.95±0.21 AbA
	Machine Row seeding	BG 358	86.97± 7.46 AabA	5.00± 2.83 AbA	1.04± 0.78 AbA	16.65± 2.47 AcA
		Kuruluthuda	81.35 ± 2.33 AabA	6.00 ± 1.41 AbA	1.26± 0.51 AbA	19.25±2.62 AcA
	Broadcasting	BG 358	74.15 ± 4.88 AbA	2.00±0.00 AbA	0.347±0.17 AbA	13.15±0.49 AcA
		Kuruluthuda	-	-	-	-
	LSD		6.59	4.57	1.25	2.07

*First capital letter/s denote the mean variation with respect to the location, second simple letter/s denote the mean variation with respect to the establishment method; Third capital letter/s denote the mean variation with respect to the variety.

Table 5.5 Mean root growth parameters of two rice varieties with respect to location and method of establishment

Location	Method of establishment	Variety	Root depth, cm	Total Root length, m	Root dry weight (g)	S:R
Thalawa Gurugama)	Manual SRI transplanting	BG 358	19.90± 0.70 BaA*	18.50±4.37 BaA	5.78±1.75 BaA	3.12 ± 0.16
		Kuruluthuda	18.75± 5.44 BaA	20.2±16.1 BaA	4.71± 4.14 BaA	2.73 ± 0.03
	Parachute transplanting	BG 358	15.98± 0.88 BbA	10.21±1.89 BaA	5.30 ±3.53 BaA	4.02 ± 2.07
		Kuruluthuda	-	-		-
	Machine Row seeding	BG 358	-	-	-	-
		Kuruluthuda	-	-		-
	Broadcasting	BG 358	8.55± 1.77 BcA	2.158 ± 0.72 BbA	0.29±0.20 BbA	5.84 ± 1.73
		Kuruluthuda	12.90 ± 2.26 BcA	3.16± 0.74 BbA	0.58± 0.11 BbA	2.25± 0.12
Thambuttegama (Kooratiyawa)	Manual SRI transplanting	BG 358	17.21 ±5.48 BaA	18.54± 5.85 BaA	5.32±0.24 BaA	3.51 ± 1.26
		Kuruluthuda	16.14 ±3.31 BaA	17.88±9.45 BaA	6.33 ± 4.38 BaA	3.51± 1.26
	Parachute transplanting	BG 358	16.82 ±5.44 BaA	14.06±1.50 BaA	9.13 ±8.99 BaA	3.15 ± 3.27
		Kuruluthuda	6.57± 0.60 BaA	11.52±10.32 BaA	3.39±3.15 BaA	3.50 ± 0.20
	Machine Row seeding	BG 358	5.17± 1.74 BbA	3.95±2.76 BbA	1.01±0.45 BbA	5.03 ± 4.98
		Kuruluthuda	-	-	-	-
	Broadcasting	BG 358	5.32±1.37 BbA	4.34 ± 3.44 BbA	2.29±2.26 BbA	2.23 ± 0.70
		Kuruluthuda	4.05±0.53 BbA	2.37±0.36 BbA	0.62±0.04 BbA	3.79 ± 0.28
Eppawala (Katiyawa)	Manual SRI transplanting	BG 358	27.67±4.08 AaA	29.68±4.31 AaA	12.56± 1.23 AaA	2.36 ± 0.11
		Kuruluthuda	30.47±0.30 AaA	29.25±0.95 AaA	9.48±5.28 AaA	3.69 ± 2.16
	Parachute transplanting	BG 358	24.07± 1.54 AaA	28.97±4.17 AaA	16.15±5.47 AaA	1.86 ± 0.37
		Kuruluthuda	33.91±6.67 AaA	32.8± 14.2 AaA	17.12±4.12 AaA	1.87 ± 0.38
	Machine Row seeding	BG 358	6.50± 3.76 AbA	8.49±6.66 AbA	1.28 ± 0.88 AbA	6.33 ± 0.85
		Kuruluthuda	10.82±3.60 AbA	10.12±6.08 AbA	4.08±1.28 AbA	2.36 ± 0.75
	Broadcasting	BG 358	5.21± 0.00 AbA	3.04±0.95 AbA	0.85±0.85 AbA	6.01 ± 4.90
		Kuruluthuda	-	-	-	
LSD			4.28	4.75	2.66	NS

*First capital letter/s denote the mean variation with respect to the location, second simple letter/s denote the mean variation with respect to the establishment method; Third capital letter/s denote the mean variation with respect to the variety.

An analysis that ignored the location and variety effects showed a significant difference in the shoot and root growth parameters of rice with respect to four methods of establishment. Rice in manual SRI transplanting and row seeding reported the highest plant height, root depth, total root length and shoot dry weight while the highest number of tillers per plant and root dry weight were reported by rice transplanted with the parachute method (Figure 5.1). The highest overall shoot growth was prominent in rice established with manual SRI transplanting, while the lowest was of rice established with broadcasting. The lower competition of rice transplanted in SRI due to two plants per hill and 20cm x 20cm spacing might be the reason for the highest performance of rice in manual SRI transplanting. Higher competition of rice established with broadcasting for resources might have caused the poor growth performance.

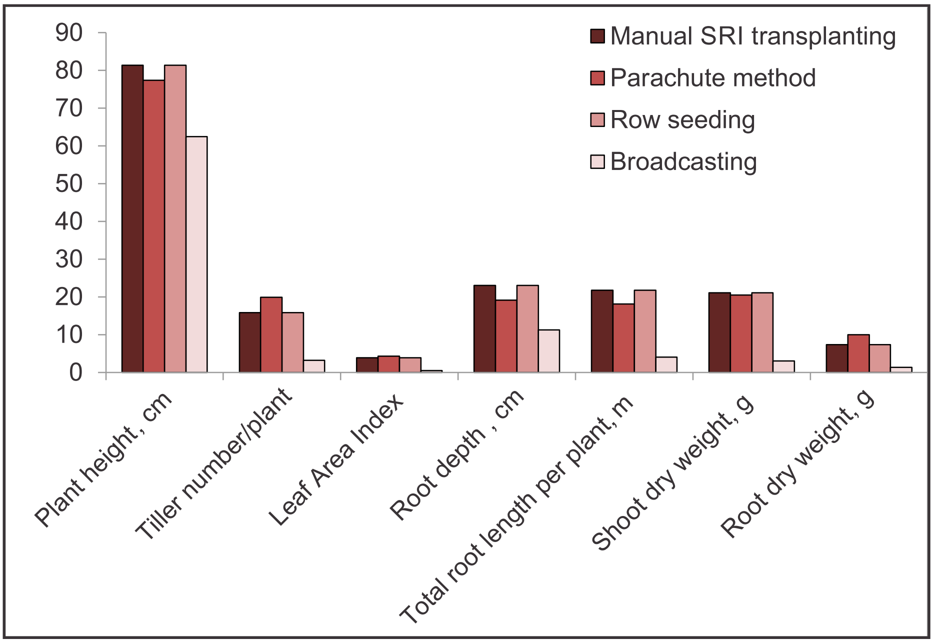


Figure 5.1. Shoot and root growth parameters of rice at maximum tillering with respect to four establishment methods

5.3.2 Yield parameters

Table 5.6 presents the source of variation, degrees of freedom and mean squares obtained from an analysis of variance for yield and yield parameters. Almost all yield parameters other than 1000-grain weight were significantly different with respect to the method of establishment. The panicle length and the filled seeds per panicle had significant differences between the two varieties. The variety *Kuruluthuda* had the longest panicles compared with BG 358 while the filled seeds per panicle were higher in variety BG 358 compared with *Kuruluthuda* (Table 5.7). Traditional rice varieties of the same age have longer panicles and a lower number of seeds/panicle characteristically, while new improved rice varieties have shorter panicles with more seeds/panicle. Per plant seed weight has significant differences with respect to the method of establishment (Table 5.6). The grain yield was higher in the manual SRI transplanting method followed by parachute transplanting method. The broadcasting method has the lowest grain yield per hectare and the second lowest was with machine row seeding (Table 5.7).

Table 5.6 Source of variation, degrees of freedom and mean squares obtained from analysis of variance for yield and yield parameters

		Mean Squares							
Source of Variation	DF	Total tillers. no	Productive Tillers, no	Panicle length (cm)	Total seeds /panicles, no	Filled seeds /panicle, no	1000-grain Weight (g)	Per plant yield (g)	Yield, tons/ha
Location (L)	2	1.17	1.25	2.93	5195.82	5070.90	1.02	88.24	18.43
Method of establishment (E)	3	88.59***	78.64***	36.36***	6066.11**	5722.11**	2.91	1499.50***	21.63**
Variety (V)	1	0.19	0.00	67.54***	941.57**	906.96**	2.24	17.17	0.94
L x E	6	0.91	0.85	2.27	1874.00***	1589.92***	1.21	38.71	3.33*
L x V	2	0.27	0.03	3.92	7.59	6.26	2.65	24.78	0.68
E x V	3	3.06	2.26	2.23	64.32	78.27	1.89	15.58	0.49
L x E x V	5	2.99	2.13	0.81	56.07	77.20	0.91	6.88	1.91
CV%		18.81	20.54	4.56	4.90	5.06	4.69	16.94	30.02

*Significant at p=0.05; ** Significant at p=0.01; ***Significant at p=0.001

Table 5.7 Mean yield and yield parameters of two rice varieties with respect to location and method of establishment

Location	Method of establishment	Variety	Total tillers, no	Productive tillers, no	Panicle length, cm	Filled seeds/panicle	1000-grain weight, g	Grain yield, t/ha
Thalawa (Gurugama)	Manual SRI transplanting	BG 358	11.33±1.89AaA	10.00± 2.36AaA	22.16± 0.04 AaB	178.9±11.1 AaA	17.00±1.41	2.76 ± 0.77 AaA
		Kurluluthuda	9.33± 0.47AaA*	8.50±0.23 AaA	26.32±0.26 AaA	174.0± 0.0 AaA	18.00 ±1.41	3.17 ± 0.01 AbA
	Parachute transplanting	BG 358	7.17± 2.59 AbA	6.50± 2.12 AbA	22.16± 0.11 AbB	172.1±10.5 AbA	19.00±0.00	2.87 ± 0.27 AaA
		Kurluluthuda	-	-	-	-	-	-
	Machine Row seeding	BG 358	-	-	-	-	-	-
		Kurluluthuda	-	-	-	-	-	-
	Broadcasting	BG 358	2.83± 0.23 AdA	2.16±0.23 AdA	19.55±0.46 AcB	142.2±37.0 AbA	16.50±2.12	1.36 ± 1.03 AcA
		Kurluluthuda	2.50± 0.70 AdA	2.16±0.23 AdA	23.49±3.24 AcA	130.7±52.9 AbA	18.00 ±2.83	1.67 ± 1.26 AcA
Thambuttegama (Kooratiyawa)	Manual SRI transplanting	BG 358	10.33±1.41 AaA	9.33 ± 1.41 AaA	22.67± 0.22 AaB	204.3±10.3 BaA	19.00±0.00	4.41 ± 1.61 AaA
		Kurluluthuda	7.17 ± 1.65 AaA	6.67±1.41 AaA	25.79±0.22 AaA	177.7 ±22.9 BaA	18.50± 0.70	5.50 ± 1.15 AaA
	Parachute transplanting	BG 358	7.50±1.65 AbA	6.67 ±1.41 AbA	21.26± 1.10 AbB	121.1 ±9.7 BbA	17.50± 0.70	4.60 ± 0.31 AaA
		Kurluluthuda	7.83±0.23 AbA	7.33±0.47 AbA	22.92±0.96 AbA	117.4±0.5 BbA	17.50±0.70	5.54 ± 0.44 AaA
	Machine Row seeding	BG 358	4.00±1.89 AcA	3.33 ± 1.41 AcA	19.65±0.49 AbcB	119.8±12.9 BbA	18.00± 1.41	3.78 ± 0.09 AbA
		Kurluluthuda	-	-	-	-	-	1.76 ± 2.48 AbA
	Broadcasting	BG 358	3.00±0.94 AdA	2.50±0.70 AdA	20.74±0.20 AcB	96.9±5.50 BbA	17.50± 2.12	1.20 ± 0.02 AcA
		Kurluluthuda	2.66±0.00 AdA	2.33±0.00 AdA	20.37±0.81 AcA	89.71±2.6 BbA	17.50±0.70	1.44 ± 0.10 AcA
Eppawala (Katiyawa)	Manual SRI transplanting	BG 358	8.33±0.47 AaA	7.50± 1.17 AaA	24.13±1.56 AaB	181.0±2.4 AaA	19.50±0.70	5.06 ± 2.20 AaA
		Kurluluthuda	9.17± 1.65 AaA	8.33±0.94 AaA	26.49±0.71 AaA	169.3±4.1 AaA	17.50±0.70	4.04 ± 0.89 AaA
	Parachute transplanting	BG 358	7.33±0.47 AbA	6.00± 0.94 AbA	22.19 ±1.59 AbB	173.4 ±7.9 AbA	17.00± 1.41	3.87 ± 0.71 AaA
		Kurluluthuda	6.50± 2.12 AbA	6.00 ±2.36 AbA	24.74±2.69 AbA	169.2 ±6.4 AbA	18.00 ± 1.41	3.71 ± 0.47 AbA
	Machine Row seeding	BG 358	5.66± 0.00 AcA	5.16± 0.70 AcA	20.67± 1.04 AbcB	163.1 ±9.7 AbA	16.00±0.00	3.91 ± 1.13 AbA
		Kurluluthuda	5.67±1.89 AcA	4.83 ± 1.65 AcA	23.30±0.28 AbcA	157.2 ±6.2 AbA	17.00±0.00	2.12 ± 0.20 AcA
	Broadcasting	BG 358	2.50± 0.23 AdA	2.16± 0.23 AdA	18.66±0.45 AcB	167.9± 8.5 AbA	17.00±0.00	1.05 ± 1.48 AcA
		Kurluluthuda	-	-	-	-	-	-
LSD (p=0.05)			0.85	0.82	0.73	5.48	ns	0.81

*First capital letter/s denote the mean variation with respect to the location, second simple letter/s denote the mean variation with respect to the establishment method; Third capital letter/s denote the mean variation with respect to the variety.

The results of the analysis of the data ignoring the location and variety effect, the final grain yield and yield parameters except 1000-grain weight were significantly different among different establishment methods. The number of productive tillers per hill, number of filled seeds per panicle, 1000-grain weight and grain yield were higher in rice established with manual SRI transplanting and row seeding methods (Figure 5.2). Rice established by broadcasting accounted for the lowest grain yield and yield parameters among all the establishment methods. The poor growth of shoots and roots under broadcasted rice may have ultimately contributed to the lower grain yield (Figure 5.2).

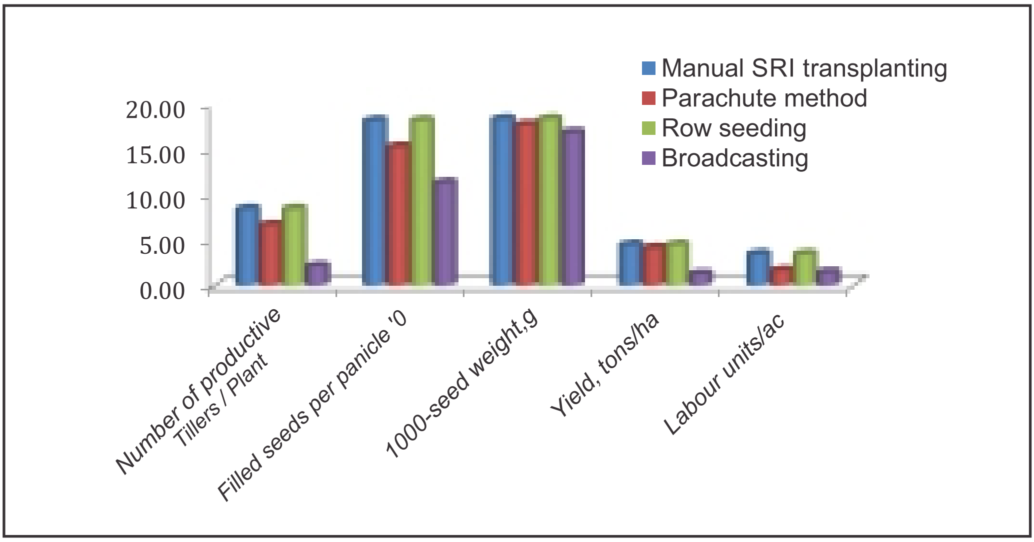


Figure 5.2. Grain yield and yield parameters of rice and labour units utilised per acre under different establishment methods

5.3.3 Relationship between labour utilisation and method of establishment

There was a significant relationship among labour utilisation, location and the method of establishment (Table 5.8). The broadcasting method reported the lowest labour use in establishment while manual SRI transplanting used more labour units Ac^{-1}. The parachute method reported the second lowest number of labour units used per acre for transplanting (Table 5.9).

Table 5.8 Source of variation, degrees of freedom and mean squares obtained from analysis of labour units used in each establishment method

Source of Variation	DF	Mean Squares of the Labour units used for establishment, units/ac
Location (L)	2	24.66
Method of establishment (E)	3	235.89***
Variety (V)	1	1.64***
L x E	6	5.39***
L x V	2	2.78***
E x V	3	1.39***
L x E x V	5	1.91***
CV%		2.19
***Significant at p=0.001		

Table 5.9 Mean labour units used for establishing two rice varieties with respect to location

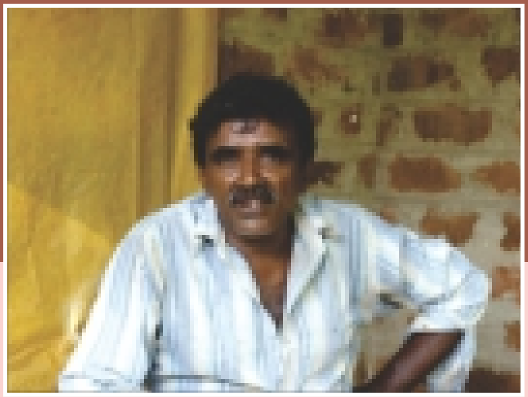
Location	Method of establishment	Variety	Labour units used for establishment/Ac
Thalawa (Gurugama)	Manual SRI transplanting	BG 358	12.00±0.00 BaA
		Kurluluthuda	7.50 ±0.70 BbA
	Parachute transplanting	BG 358	4.00 ±0.00 BaB
		Kurluluthuda	-
	Machine row seeding	BG 358	-
		Kurluluthuda	-
	Broadcasting	BG 358	4.00 ±0.00 BaA
		Kurluluthuda	4.00 ±0.00 BaB
Thambuttegama (Kooratiyawa)	Manual SRI transplanting	BG 358	14.00 ±0.00 AaA
		Kurluluthuda	14.00 ±0.00 AaB
	Parachute transplanting	BG 358	4.50 ±0.70 AbA
		Kurluluthuda	4.50 ±0.70 AbB
	Machine rowseeding	BG 358	12.00 ±0.00 AaA
		Kurluluthuda	-
	Broadcasting	BG 358	4.00 ±0.00 AbA
		Kurluluthuda	4.00 ±0.00 AbB
Eppawala (Katiyawa)	Manual SRI transplanting	BG 358	14.00 ±2.83 AaA
		Kurluluthuda	14.00 ±2.83 AaB
	Parachute tansplanting	BG 358	4.00 ±0.00 AbA
		Kurluluthuda	4.00 ±0.00 AbB
	Machine row seeding	BG 358	13.00 ±1.41 AaA
		Kurluluthuda	13.00 ±1.41 AaB
	Broadcasting	BG 358	4.00 ±0.00 AbA
		Kurluluthuda	-
LSD			0.13

*First capital letter/s denote the mean variation with respect to the location, second simple letter/s denote the mean variation with respect to the establishment method; Third capital letter/s denote the mean variation with respect to the variety.

5.4 Farmer Perceptions of SRI

Ten farmers participated in the on-farm research and they tested different establishment methods with respect to each variety at three locations. At the end of the season researchers interviewed them to find out their observations about the experiment.

NG Muthubanda,
88, Gurugama, Thambuttegama.



SRI is an excellent solution for some burning issues in the Anuradhapura area. Kidney failure among paddy farmers, other non-communicable diseases and cancer problems can be solved through the consumption of rice grown with SRI, which uses less chemicals.

We have to be aware of the consumption of rice with chemical residues, especially in the Anuradhapura area where kidney failure is frequently reported.

I experimented with machine row seeding, manual SRI transplanting and parachute transplanting, with both *Kuruluthuda* and BG 358. My yield is satisfactorily high this time. Because I didn't receive sufficient water either from rainfall or supplementary irrigation during weeding, I had difficulties.

Empowerment of SRI farmers is very necessary in our area. We don't have the necessary facilities for SRI farming. If we have a SRI farmers' organisation where cono-weeders, row seeders or transplanters, which are used in SRI farming, can be hired when needed, it will be convenient to the farmers. As a farmer organisation, we will have bargaining power and as a result we will be able to sell our products at a higher price.

Mrs. Devika Sumithra,
Kooratiyawa, Kalankuttiya, Thambuttegama.

I like the eco-friendly nature of SRI. I experimented this time with manual SRI transplanting using *Kuruluthuda* and BG 358.

I obtained comparably lower yields this time compared with the last season, where I broadcasted and applied the recommended full dose of chemical fertilisers, using weedicides and sometimes pesticides in my paddy field.

But this time, I applied only a quarter dose of chemical fertilisers and absolutely no pesticides and weedicides. Instead, I applied a large amount of organic matter and adopted manual weeding using the cono-weeder.

As my paddy field is shaded by big trees I experienced a low tillering rate, ultimately resulting in lower yield. But I'll be able to sell my paddy at a higher price to be used as seed paddy in the coming season. When compared with the cost of inputs used this time, and the selling price, I am happy about my yield since it is still cheaper than the last season.

I observed the parachute method of establishment, labour use and plant growth characteristics practised by my neighbouring farmer. I think it will be a successful method for my paddy field as well. I hope to test plant establishment with the parachute method in the coming season.

TA Sumanapala,
Wiharamahadevi Road,
No. 45, Track 09, Katiyawa, Eppawala.

I experimented with all four methods of plant establishment: broadcasting, manual SRI transplanting, machine row seeding and the parachute method with both rice varieties, *Kuruluthuda* and BG 358, in my paddy field.

I applied a lot of homemade compost in all the plots. I didn't use any weedicide or pesticide in my paddy field since there were no observed pest occurrences. Weeds were controlled using the cono-weeder and by hand weeding. I basically used family labour for weeding, which had to be supplemented with a few units of hired labour as and when necessary.

I had a yield increase of about 25% with this organic method of cultivation. I keep rice of both varieties for home consumption. My wife is suffering from diabetes, hypertension and high cholesterol. Organically grown *Kuruluthuda* is good medication for her. Other farmers who engage in conventional rice cultivation are impressed with my paddy fields and are enthusiastic about adopting this organic method of cultivation in the coming season. I can sell a part of the paddy harvested as seed paddy to the neighbouring farmers in my *yaya* [whole tract of paddy fields] in the coming season.

Organically grown traditional rice has more demand in the market than organically grown NIVs and can be sold at double the price. Establishing a better market for organically grown NIVs of rice would be helpful to interested farmers in the area.

I shall definitely practise the organic method of paddy farming in the coming season using traditional rice. I prefer the parachute method of establishment to the others.

TA Rathna Siril
No. 48, Track 9, Katiyawa, Eppawala.

This is the first time I adopted this system of paddy cultivation. I experimented with manual SRI transplanting and the parachute method of transplanting using both *Kuruluthuda* and BG 358.

I used a quarter dose of the chemical fertilisers recommended by the Department of Agriculture and did not use any weedicide or pesticide. I have applied plenty of homemade compost to my paddies and did manual weeding with the cono-weeder.

I am happy about my yield this time and particularly the healthy nature of the rice that we are going to consume. I don't intend on selling any paddy harvested from the plots cultivated under SRI this season. I would like to keep part of that as seed paddy for the next season and the rest will be used for my consumption.

I am determined to practise the parachute method of transplanting in the coming season as well. Because my paddy field has a deep layer of soft mud, I have experienced difficulty in weeding with the cono-weeder. So I might not use the manual SRI transplanting method next season.

WW Jayarathna,
212, Gurugama, Thambuttegama.

I experimented with machine row establishment and the broadcasting method with both *Kuruluthuda* and BG 358 this season. Due to a problem in the machine, I could not continue with machine row seeding.

I applied plenty of cow dung, straw and green manure before the first ploughing. I didn't apply any pesticide or weedicide. I applied the recommended chemical fertilisers in a quarter dose. Hand weeding was practised when necessary.

I am happy with my yield this time and there was a yield increase as well. Most of all, the healthy nature of the rice is very important so I kept my harvest for family consumption.

I wish to practise the broadcasting method of establishment with organic inputs in the coming seasons as well.

SM Gunasekera
30, Kooratiyawa, Kalankuttiya, Thambuttegama.

I am a SRI practitioner for over two years. This time I experimented with all treatments of four methods of establishment with two varieties of rice. I practised manual SRI transplanting, broadcasting, direct seeding with seeder and broadcasting with both *Kuruluthuda* and BG 358.

I applied plenty of organic matter in the form of paddy straw, green manure, compost, cow dung and so on to my paddy field. The real nutritional effect of organic matter can be seen 2-3 seasons after the application. It is a little difficult to observe any quick effect of organic matter in the applied season itself.

This time I obtained a satisfactory yield from my paddy filed. I had a soft and fertile soil in my paddy field compared to the neighbouring paddy fields in which conventional paddy cultivation was practised in the same *yaya*.

If I compare the different methods of establishment, I obtained a higher yield from the broadcasting method with both rice varieties this season. The fertile soil in the paddy field might be the reason for this difference. I faced difficulties in weeding with the cono-weeder due to the lower rainfall and lower supplementary irrigation at the time of weeding. With the low water availability, transplanted rice showed a better tolerance than the broadcasted rice.

The unit price of traditional rice varieties is becoming attractive these days and organically grown traditional rice gets special consideration. Therefore, farmers in my *yaya* are enthusiastic about growing traditional rice under an eco-friendly method in the coming season.

6 CONCLUDING REMARKS AND RECOMMENDATIONS

Rice is the staple diet of more than half the world population. In meeting the current demand, rice is being cultivated in different parts of the world following different systems. The system of rice intensification is prominent among them.

The initial SRI was improved over time in Madagascar and was eventually disseminated to other countries as well. As a result, after the year 2000, this system was introduced to Sri Lanka. Scientists recognised SRI as a package of practices and introduced it to certain locations that had different soil and climatic characteristics to the place from where it originated. In many locations, failure in adoption threatened its sustainability and reportedly threatened its acceptance. Sri Lanka stands out in this respect.

Even today, SRI research is focused more on yield enhancement. Only a few researches focus on the effective use of farmers' resources including land, labour and water. The need of the day is a more holistic approach to SRI research. Integration of various features of SRI such as ecological friendliness, sustainability, farm mechanisation, health-safe products, resistance to climate change and water saving is timely. Increasing more location specific research with a thorough focus on farmers' actual constraints and interventions during policy formulation must be considered crucial approaches for SRI to be more acceptable taking into consideration the country's specific needs.

Though Sri Lanka is a small country with a total area of 65,610km^2, it has 24 agro-ecological regions based on rainfall, temperature, soil type and etc. Soil types in different locations contain different chemical, physico-chemical and physical properties. As a result, farmers in different rice growing districts in Sri

Lanka have different constraints. Location specific SRI research could produce the necessary modifications and convince farmers of its sustainability.

The participatory approach in SRI research is as important as research station experiments. Participatory research helps in understanding the actual farmer situation better than research station experiments. It addresses real farmer problems more easily and modifies SRI, thus making it an effective approach.

Several countries engage in policy formulation on SRI while Sri Lanka lags behind. Changing the policy in Sri Lanka towards facilitating a more sustainable and eco-friendly rice cultivation that encourages the rice farmer to be a potential adopter is timely. This study recommends redirecting the paddy fertiliser subsidy to a fund that provides access to labour-saving devices like mechanical weeders or a subsidy for labour rather than fertiliser input.

Empowerment of SRI farmers in different farming locations is recommended as a step to enhance SRI adaptations. Farmers could then share knowledge, experience and skills related to SRI. It is important for farmers to share their resources and gain bargaining power in marketing their products at a premium price.

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