# Does the system of rice intensification a panacea to smallholder rice farmers A case of Mkindo village irrigation scheme in Tanzania

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# Does the system of rice intensification a panacea to smallholder rice farmers? A case of Mkindo village irrigation scheme in Tanzania

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**Abstract:** Rice production represents a way of life of the livelihood of majority of smallholder rice farmers constrained with inadequate water for irrigation. However, little information was available on the production pattern of rice for SRI and non-SRI participants. This study investigated whether the SRI practice is a panacea to smallholder farmers of rice at Mkindo village irrigation scheme. Experimental research design and expert sampling plan was employed in which structured interview schedule was used to collect cross sectional data of 100 SRI and non-SRI participants. Descriptive statistics information was obtained using SPSS package. Surveyed findings showed that SRI and non-SRI participants harvested 0.75 to 13.75 tons per ha and 0.5 to 8.0 tons per ha, respectively. It was therefore concluded that SRI technology in rice production is a panacea to smallholder farmers as it leads to high yield. The study recommends on the adopt SRI technology by non-SRI participants to maximise their earnings.

**Keywords:** system of rice intensification; SRI; optimal rice yield; conventional rice cultivation; smallholder farmers; SRI participants; non-SRI participants.

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## 1 Introduction

Rice production represents a way of life and a means to livelihood. Globally, 55% of the area under rice cultivation that is irrigated contributes 75% of the total rice production (Thiyagarajan and Gujja, 2013). Besides, Nakano et al. (2014) report that 100% of Near East and North Africa depends on irrigated rice followed by East Asia (71%), while Sub Saharan Africa is the least region (21%). In Tanzania, rice sector production is among the major sources of employment, income and food security for farming households and it ensures staple food supply for the urban population (CFC, 2012). That's why, 99% of rice produced in Tanzania is grown by smallholder farmers using traditional paddy growing practices and a variety of rice seeds are used and they depend on rain-fed while irrigated rice cultivation contributes 12% (Barreiro-Hurle, 2012). As a result, low yield is attributed to inadequate and unevenly distributed rainfall, periodic droughts, weed infestations and the prevalence of pests resulting into marginal use of the potential for irrigation (CFC, 2012; URT, 2009).

It is for this reason that irrigation is necessary for providing protection against drought as a means of stabilising rice production and assurance of household food security (URT, 2009). Yet, the demand of water for irrigation purposes in Tanzania outstrips the amount of water available for irrigation to feed the growing population (Katambara et al., 2013). Consequently, inadequate water for irrigation therefore calls for the new technologies and farming practices that ensure more food production while minimising water uses (Katambara et al., 2013; Namara et al., 2003). The system of rice intensification (SRI) therefore is an innovative agro-ecological methodology that aims to increase yields and farmer's profits by creating t suitable environment for the rice plant to grow (Dill et al., 2013). Furthermore, SRI principles focuses on timely seed preparation, seedling and nursery preparation, transplanting, fertilisation and irrigation scheduling (Dill et al., 2013; Katambara et al., 2013; Namara et al., 2003). Thus, SRI substantially changes traditional and conventional cultivation practices that rice farmers have used for centuries into profitable, mixed scales and commercial operations to reduce both income and non-income poverty (URT, 2009).

Smallholder rice farmers face a series of unprecedented, intersecting challenges, often originating at global levels: increasing competition for land and water; increased influence of and changing markets; rising fertiliser prices; and climate change (IFAD, 2013). Tanzania's rice productivity is low and varies from 1.2 M tons to 2.4 M tons/Ha under rain-fed (CFC, 2012; URT, 2009). With improved irrigation infrastructure and water management, paddy yields on an average can increase from 1.8 tons per hectare to 4.5 tons per hectare. Subsequently, reliable irrigation service delivery can also persuade risk conscious farmers to invest in better production practices and to diversify into higher value farming systems by generating higher incomes; increases food security and stimulates economic growth (URT, 2009). Similarly, Namara et al. (2003) observed higher returns to crop budgets; yet, the cost of production per hectare was not lowered with the SRI methods. The estimated average profits for SRI was almost double that of the conventional practice, but not all farmers registered positive profit figures, some had net losses (Namara et al., 2003). Conversely, Nakano et al. (2014) found that SRI beneficiaries achieved as high average yield of 5.1 tons per hectare in their SRI plots contrary to 1.8 tons per hectare of non-SRI plots of rain-fed areas.

However, weeding, complicated water management and transplanting procedures were the downside of SRI farming (Ressurreccion et al., 2008). Furthermore, an intricate network of brokers, wholesalers, intermediaries and retailers ensured that rice gets to the final consumer even if farmers had no producer surplus (CFC, 2012). Consequently, small scale rice farmers in Tanzania are characterised by low cash, lacking either savings or access to credit as a result; distress sales made immediately after harvest are common (CFC, 2012). Therefore, sustainable irrigation development under SRI practices is a basis for improved food and livelihood security and reduction of poverty (URT, 2009). That's why Mkindo irrigation scheme was established to serve smallholder rice farmers where rice is grown in two major seasons, *vuli* and *masika* (Nation Soil Services, 1986). However, little information was available on the trend of rice production of SRI participants since its inception at Mkindo irrigation scheme. This study therefore, assessed rice production trend of smallholder farmers practicing SRI technology and conventional approach at Mkindo village irrigation scheme.

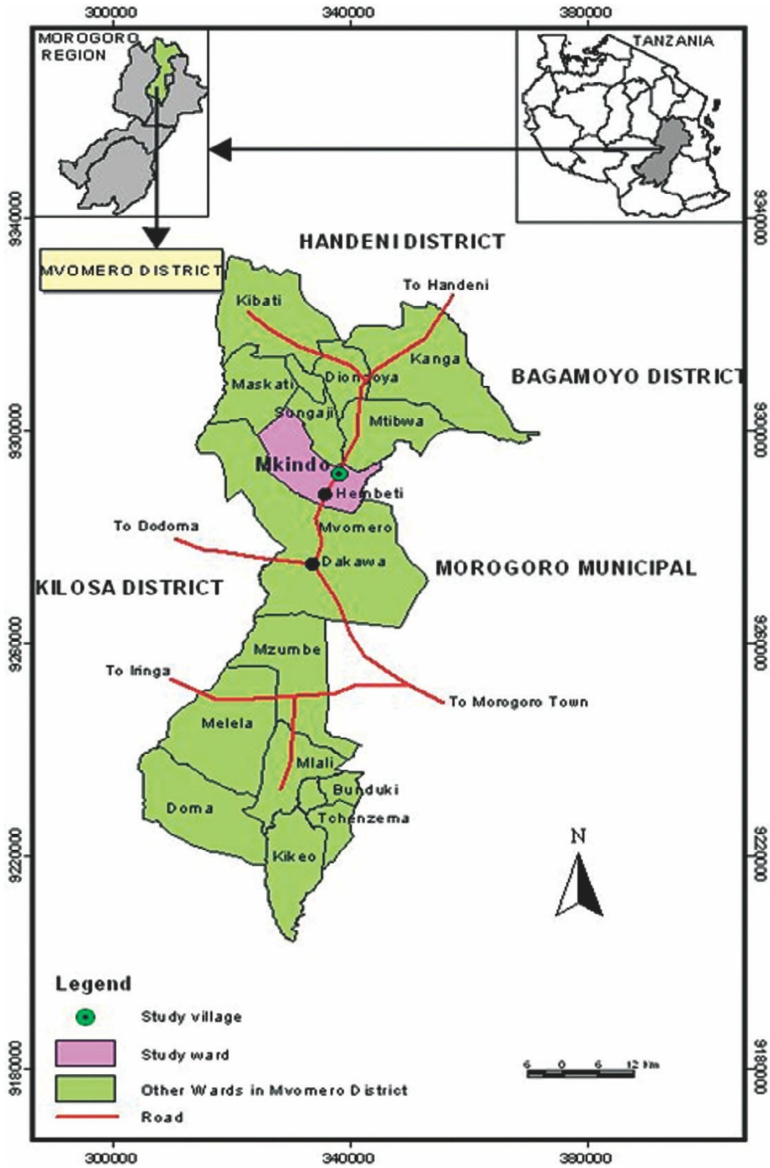
## 2 Methodology

### *2.1 Description of the study area*

Mkindo village irrigation scheme is located at Mvomero Dirstic, Morogoro Region Tanzania (Figure 1). The scheme forms part of the flat land of the Wami flats at the foot of the Nguru Mountains and covers an area of 115 ha divided into two blocks (Nation Soil Services, 1986). The irrigation water used is diverted form Dizingwi stream and the flows are adequate for irrigation throughout the year. The slope of the scheme ranges between 0.2%–2% and permits water to be distributed all over the land (Nation Soil Services, 1986). The soil texture vary from alluvial sediments which permeable to heavy texture with clay and cracking properties. However, the soil has natural fertility levels suitable for rice production. The variety of the planted rice was TXD 306 (SARO) (Kahimba et al., 2014) and is characterised by flavour and aroma (Katambara et al 2016).

This study was conducted at Mkindo village irrigation scheme where SRI interventions were practiced by rice farmers and is the subjects of interest. Both SRI and non-SRI practicing farmers were available and adequate to fulfil the research purpose and they were within the reach.

**Figure 1** Location of Mkindo village irrigation scheme (see online version for colours)




*Source:* Kahimba et al. (2014)

## 2.2 SRI practices

SRI practices involves the some underlying principles which include seed sorting, sowing, transplanting younger seedlings, weeding and water management (Stoop et al. 2002; Katambara et al., 2013, 2016). A brief description of the principles include:

a Sorting out of the seeds: A rice seed that sinks in salty water solution that is capable of floating an egg is a good seed and a bad seed is the one that floats.

b Raising seedlings in seedbeds: This ensures a careful management of seedlings and easy uprooting as well as transplanting.

c Uprooting and transplanting time: This process should take 15–30 minutes and the roots should be under moist during this time (Stoop et al., 2002).

d Early transplanting of age of 8 to 15 days-old seedlings: This create a buffer for the seedling from being damaged during transplanting, full tillering and optimal production occurs when the seedling are transplanted before entering the fourth phyllochron of growth (Stoop et al., 2002).

e Single, widely spaced transplants: This ensures that the plants have enough space for tillering as well as to allow the mechanical weeder to pass through without harming the plants.

f Early and regular weeding: This ensures that weeds do not compete with the rice plant. Also the mechanical weeder aerates the soil. The roots need oxygen so as to be strong and healthy for optimal tillering and development of healthy rice grains.

g Carefully controlled water management: Alternate wetting and drying makes the rice plant healthy since the roots are supplied with moisture as well as air. This allows the root to uptake adequate nutrients from various soil horizons..

h Application of compost manure: The compost manure are rich with nutrients as well as organisms whose activities favour the growth of rice. Above all, it is environmentally friendly to use compost than industrial fertilisers.

i No use of herbicides: The non-use of herbicides favours the sustainability of the ecosystem and the micro-organisms whose activities are suitable for the growth of rice plants.

## 2.3 Experiment set-up

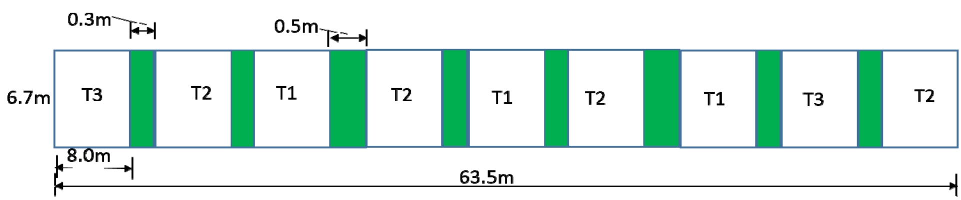
The experimental site for rice transplanting age was located within Mkindo village irrigation scheme and water was not a limiting factor during the growing season. This experiment was set in two dry seasons of September 2013/2014 and September 2014/2015 with three treatments, T1, T2 and T3 representing rice seedlings transplanted at 8, 12 and 15 days old, respectively (Figure 2). In this experiment, all other agronomical practices were kept uniform in all the three treatments.

The experiment was conducted using a field of 63.5 m × 6.7 m. Treatments were replicated 3 times each to form 9 sub plots of 8 m × 6.7 m, with buffer strips of 0.5 m.

The field trial experiments for each season were set in randomised complete block design (RCBD). The general field layout is as shown in the Figure 2.

The field preparation involved ploughing and pulverised by a power tiller and levelling. The rice variety used during the experiment was TXD 306 Super SARO which is recommended by the Ministry of Agriculture, Food Security and Cooperatives. All treatments were transplanted at a spacing of 25 cm × 25 cm. Transplanting was conducted using seedlings from one seedbed prepared following SRI principles in three different days. Treatments T1, T2 and T3 were transplanted using seedlings at age of 8, 12 and 15 days old. Spacing between rice hills were marked using a wooden space marker at 25 cm × 25 cm spacing and one seedling was transplanted per rice hill.

**Figure 2** Transplanting age experiment layout (see online version for colours)




### *2.3.1 Total number of tillers and productive tillers per hill*

The number of tillers per hill in different treatments was monitored throughout the growing season. Data was collected from the random set experiment with three treatments and three replicates for each treatment. From each replicate 5 hills were chosen randomly, marked with a thin stick pressed in the soil at early stages of plant growth. Tillers were manually counted in 2 weeks interval throughout the growing season and recorded in the data recording sheet for analysis. Number of productive tillers per hill was counted at crop maturity stage. This was considered to be an important factor to investigate the number of total tillers per hill against productive ones.

### *2.3.2 Yield*

Rice grain yield was estimated at the end of each cropping season (110–120 days after transplanting). In each subplot, a tape measure was used to measure 1 $m^2$ for harvesting samples for analysis. During harvesting rice panicles were cut and put into the labelled bag for further processing in the laboratory. At the laboratory rice seed was separated from straws, weighed using measuring balance and then recorded on data recording sheet as a fresh weight grains. The sub sample grains was taken from each bag, reweighed again, labelled and then put in the oven which was set at a temperature of 70°C and then oven dried for 3 consecutive days. Re-weighing of the dry grains was conducted after three to five days.

## *2.4 Research design*

The present study employed an experimental research design since the intervention was randomly allocated among eligible beneficiaries and the assignment itself created a comparable treatment (SRI participants) and control (non-SRI participants) groups which were statistically equivalent to one another (Baker, 2000; Newman, 2007). An experimental approach is a powerful outcome because, the control group generated through random assignment serves as a perfect counterfactual and free from the troublesome selection bias. Also, the main benefit of this technique is its simplicity in interpreting results that can be measured by the difference between the means of the samples of the SRI participants and non-SRI participants) (Baker, 2000).

### *2.5 Sampling plan*

The study employed expert sampling approach to pick cases that had the required information, possessed varied perspectives and common experiences on rice production based on SRI and conventional practices to meet research objectives (Saunders et al., 2009; Mugenda and Mugenda, 2003). This approach enabled researchers to use their judgmental to select cases that best enable them to answer research questions and to meet research objectives. On the other hand, the elements chosen were believed to be good sources of information, purposive sampling is sometimes referred to as expert sampling because individuals are chosen for their special knowledge and not necessarily for their formal training or education. The key to purposive or expert sampling is that selection is intentional and is consistent with the goal of the research. SRI and non-SRI rice growers therefore were intentionally chosen for their special knowledge on Mkindo village irrigation scheme for both *vuli* and *masika* rice production seasons (Krysik and Finn, 2007).

### *2.6 Sampling frame*

The present study used SRI and non-SRI participants' registry at Mkindo village irrigation scheme to randomise cases (Ghauri and Grønhaug, 2005; Saunders et al., 2009).

### *2.7 Data collection instruments*

The data for the study was collected using structured questionnaire interview schedule survey in which one-to one basis between interviewer and respondent was conducted at Mkindo village irrigation scheme whereby quantifiable information was collected (Saunders et al., 2009).

### *2.8 Data analysis*

Descriptive research pertained to the characteristics of the intervention and the characteristics of those participants and non-participants in the area. This involves questions such as: How many people participated, and with what consequences? How does the intervention differ by demographic characteristics? As a result, data generated at the household level were subjected to descriptive analyses using SPSS to characterise the sample of farmers' rice crop production practices using means, standard deviation and skewness distribution as way of comparing between treatment and control group of rice farmers at Mkindo village irrigation scheme.

## 3 Results and discussion

### *3.1 Characteristics of SRI and non-SRI participants*

#### *3.1.1 Respondents interviewed and marital status*

Findings (Table 1) showed that 44%, followed by 35% of respondents interviwed were Non –SRI and SRI participants, respectively, while 21% of them practiced both SRI and conventional modes of rice production at Mkindo village irrigation scheme and were statistically significant at $p < 0.001$ levels. Meaning that majority of rice farmers (56%) had a likelihood of adopting SRI technology in rice production. Results suggest that as SRI technology practiced at village irrigation scheme, ceteris paribus, majority of rice farmers will adopt the technology because of its felt benefits by participants. Results, agree with observation made by Gatto et al. (2020) that sustainable intensification has a huge potential and positive welfare effects.

Also, results showed that 65% of interviewed respondents were the household heads while 12% were grown up children.This proposes that majority of households engaged in rice production were more likely to practice SRI technology which also had odds of influencing grown up children to participate. This could be attributed to the likelihood of learning and adotpion sustainability of SRI technology by rice farmers.This was evidenced by 78% of interviewed respondents who were married and statistically significant at $p < 0.05$ levels, suggesting that married ones had a felt need to practice SRI technology to meet family binding commitments such as food security in comparison to others. Equally, Nakano et al. (2014) observed that SRI trainees achieved as high average yield as a result non-participants were attracted to practice it.

**Table 1** Respondents interviewed and marital status

| *Participants ($t = 25.17$***)* | *Frequency* | *Percent, %* |
|---|---|---|
| SRI | 35 | 35.0 |
| Non-SRI | 44 | 44.0 |
| Both | 21 | 21.0 |
| Total | 100 | 100.0 |
| *Category of respondents* | | |
| Household head | 65 | 65.0 |
| Spouse of household head | 23 | 23.0 |
| Grown up child | 12 | 12.0 |
| Total | 100 | 100.0 |
| *Marital status of respondents ($t = 13.12$**)* | | |
| Married | 78 | 78.0 |
| Single | 9 | 9.0 |
| Separated | 3 | 3.0 |
| Divorced | 3 | 3.0 |
| Widowed/widower | 7 | 7.0 |
| Total | 100 | 100.0 |

Notes: ***significant at $p < 0.001$ and **significant at $p < 0.05$.

### 3.1.2 Sex of and age of respondents

Findings (Table 2) showed that 68% and 32% of respondents were male and female, and statistically significant at $p < 0.001$ levels, respectively. Meaning that majority of rice farmers interviewed were male, suggesting that male respondents were more likely to participate in SRI technology in rice production than their counter parts female. This could be attributed to the observed benefits acrued to SRI participants which attracted more male than female. Also, results showed that 35% followed by 29% of respondents were under the age categories 35–45 and 46–58 of years, respectively compared to 3% which were 72–84 years and statistically significant at $p < 0.001$ levels. Results suggest that majority of the repondents were in the productive economic age indicating that they were more likely toadopt SRI technology in rice production activties at village irrigation scheme. The current findings agree with observation made Taylor and Bhasme (2018) who found that age influenced the adoption behavior of rice farmers due to uneven access to key assets.

**Table 2** Gender and age of respondents

| *Category of respondents (t = 20.91***)* | *Frequency* | *Percent, %* |
|---|---|---|
| Female | 32 | 32.0 |
| Male | 68 | 68.0 |
| Total | 100 | 100.0 |
| *Age category (t = 12.89***)* | | |
| 20–32 | 23 | 23.0 |
| 33–45 | 35 | 35.0 |
| 46–58 | 29 | 29.0 |
| 59–71 | 10 | 10.0 |
| 72–84 | 3 | 3.0 |
| Total | 100 | 100.0 |

Notes: ***significant at $p < 0.001$.

### 3.1.3 Education level, main occupation and household size of respondents

Observed findings showed that 68% followed by 21% of participants had non formal education and had no education, respectively, while 10% and 1% of the rest rice farmers had attained primary school and ordinary level secondary education and statistically different at $p < 0.001$ levels. This proposes that the majority of particpants were knowledgeable and they participated in both SRI technology and conventional rice production for easy training and skills acquisition (Mwidege and Katambara, 2020). Furthermore, all of the interviewed respondents were rice farmers, suggesting that their entire livelihood depend on rice production activities.

Also, findings indicated that 52% and 45% of interviewed rice producers had a household size of 5–8 and 1–4, respectively, while 3% had a household size of 9–12 and were different at $p < 0.001$ levels. Results suggest that household size of rice farmers was a key push factor for SRI technology adoption to meet income and non-income family requirements. Results obtained concur with observation made by Namara et al. (2003) that rich and the poor farmers were equally likely to practice SRI technology for different reasons that the rich were more educated and more inclined to experiment with new methods while the poor had more urgent need to raise the productivity of their limited land and their relatively more abundant family labour (Taylor and Bhasme, 2018; Namara et al., 2003).

**Table 3** Education level, main occupation and household size of respondents

| *Education levels (t = 15.48***)* | *Frequency* | *Percent, %* |
|---|---|---|
| No education | 21 | 21.0 |
| Non formal education | 68 | 68.0 |
| Standard seven | 10 | 10.0 |
| Form four | 1 | 1.0 |
| Total | 100 | 100.0 |
| *Main occupation* | | |
| Rice farmer | 100 | 100 |
| Total | 100 | 100.0 |
| *Household size (t = 25.38***)* | | |
| 1–4 | 45 | 45.0 |
| 5–8 | 52 | 52.0 |
| 9–12 | 3 | 3.0 |
| Total | 100 | 100.0 |

Notes: ***significant at $p < 0.001$.

### *3.1.4 Household experience, mode of rice farm ownership and source of income*

Findings (Table 4) showed that 46% followed by 25% of both SRI and non-SRI respondents interviwed had experience of 2–11 and 12–21 years, respectively, while 5% of them had experience of 42–51 years in rice production. Results proposed that rice farmers had practiced conventional mode of rice production for a number of decades followed by SRI technology at village irrigation scheme. According to their experience acquired in rice production and significant at $p < 0.001$ levels; therefore, it was a breeding ground for rational farmers to adopt SRI technology based on marginal benefits and costs in comparison to conventional mode of rice production. Results agree with Mishra and Mohanty (2019) who found that SRI was more resource use efficient than conventional system.

Experience in rice production reported by interviewed rice farmers was evidenced by their mode of rice farm ownership whereby the majority (51%) purchased land followed by inherited (31%) and rented (18%) rice farms and were significantly different at $p < 0.001$. Results suggested that, rice farmers willingness to purchase and rent rice farms was their driving force to achieve optimal food self sufficiency and income. This, therefore, indicates their likelihood to adopt SRI technology in rice production as their main primary source of income depend on sale of harvested rice (99%). Equally, Noltze et al. (2013) found that training on new technology, experience and share of rice acreage under SRI had a positive influence on adoption.

**Table 4** Household experience, mode of rice farm ownership and source of income

| Years of experience (t = 12.89***) | Frequency | Percent, % |
|---|---|---|
| 2–11 | 46 | 46.0 |
| 12–21 | 25 | 25.0 |
| 22–31 | 13 | 13.0 |
| 32–41 | 11 | 11.0 |
| 42–51 | 5 | 5.0 |
| Total | 100 | 100.0 |
| *Mode of farmland ownership for rice production* | | |
| Purchased | 51 | 51.0 |
| Inherited | 31 | 31.0 |
| Rented | 18 | 18.0 |
| Total | 100 | 100.0 |
| *Source of income* | | |
| Sale of rice | 99 | 99.0 |
| Sale of maize | 1 | 1.0 |
| Total | 100 | 100.0 |

Notes: ***significant at $p < 0.001$.

## 3.2 Sorting rice seeds, raising seedlings in a garden and age of transplanting

Study findings (Table 5) show that majority of rice farmers (69%) sorted out rice seeds in *vuli* 2013 before raising seedlings contrary to the rest participants (31%). Furthermore, seedlings were raised in a garden by participants (95%). Findings suggest that rice seeds were sorted out to get healthier and viable seeds which when planted in the garden produced healthier seedlings. Results agree with observations made by Katambara et al. (2016) that rice grains grown under SRI practices are suitable for seeds. Moreover, findings showed that most rice farmers (49%) followed by 38% transplanted seedlings during the eighth and above fifteenth day of age were statistically significant at $p < 0.001$ levels, accordingly. This could be attributed to easy handling during transplantation process. Results comply with Too et al. (2020) who found that transplanting rice seedling at the age of 8 to 11 days recorded highest seed yield. Also, findings (Table 6) showed that most of seedlings (40%) were transplanted at a space of 25 cm × 25 cm followed by 20 cm × 20 cm (37%) and statistically significant at $p < 0.001$ levels. Results proposed that seedlings were transplanted in appropriate space between seedlings in order to facilitate weeding activities and consequently had optimal rice yields. Results are in accordance with Too et al. (2020) who observed that transplanting rice seedling at 20 cm by 20 cm spacing recorded highest seed yield/ha as compared to traditional flooding.

**Table 5** Sorting rice seeds, raising seedlings in a garden and age of transplanting

| *Aspects* | *Response* | *Frequency* | *Percent, %* |
|---|---|---|---|
| Did you sort out rice seeds in *vuli* 2013 before raising seedlings? | Yes | 69 | 69 |
| | No | 31 | 31 |
| Did you raise seedlings in a garden? | Yes | 95 | 95 |
| | No | 5 | 5 |
| Total | 100 | 100 | 100.0 |

| *Age of seedlings transplanted in vuli 2013 (t = 13.81***)* | *Frequency* | *Percent, %* |
|---|---|---|
| 8 days | 49 | 49.0 |
| 9 days | 1 | 1.0 |
| 10 days | 5 | 5.0 |
| 12 days | 3 | 3.0 |
| 14 days | 4 | 4.0 |
| Above 15 days | 38 | 38.0 |
| Total | 100 | 100.0 |

Notes: ***significant at $p < 0.001$.

**Table 6** Spacing between seedlings transplanted in *vuli* 2013

| *Space (t = 26.19***)* | *Frequency* | *Percent, %* |
|---|---|---|
| 10 cm × 10 cm | 21 | 21.0 |
| 10 cm × 20 cm | 1 | 1.0 |
| 20 cm × 20 cm | 37 | 37.0 |
| 25 cm × 25 cm | 40 | 40.0 |
| 30 cm × 30 cm | 1 | 1.0 |
| Total | 100 | 100.0 |

Notes: ***significant at $p < 0.001$.

### *3.3 Acreage planted under SRI technology and conventional in different production seasons*

Findings (Table 7) showed that SRI participants cultivated a minimum of 0.25 acres and a maximum of 2.5 acres of rice farm contrary to non-SRI participants who cultivated the same minimum acreage of rice farm with a maximum of eight acres and were statistically different at $p < 0.001$ levels. Results suggested that majority of both SRI and non-SRI cultivated rice farm below the average acreage shown by positively skewed distribution. Moreover, findings showed that SRI participants practiced more SRI technology during *vuli* production season contrary to non-SRI participants. This could be attributed to the easy water schedule management during *vuli* in comparison to *masika* rice production season where the practice is interfered with rains, thus difficult to control water flowing into the rice farm. Similarly, Dill et al. (2013) argue that SRI is based on a set of rice cultivation principles and therefore is not a cultivation technology in the conventional sense. Results are in line with observations made by Mwidege and Katambara (2020), Sharma et al. (2019) and Gbenou et al. (2016) that high grain yield and increased return to labour influenced rice farmers to adopt SRI practices.

**Table 7** Acreage planted under SRI technology in different production seasons

| *Acreage planted under SRI rice production* | | | | | | |
|---|---|---|---|---|---|---|
| *Production season* | *N = 56 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* | *Skewness* |
| *Vuli* 2011 (t = 9.36***) | 27 (48.2) | 0.25 | 2 | 0.79 | 0.437 | 1.530 |
| *Masika* 2012 (t = 8.11***) | 28 (50.0) | 0.25 | 2 | 0.79 | 0.512 | 1.322 |
| *Vuli* 2012 (t = 9.53***) | 33 (58.9) | 0.25 | 2 | 0.82 | 0.493 | 1.128 |
| *Masika* 2013 (t = 12.74***) | 42 (75) | 0.25 | 2 | 0.84 | 0.427 | 1.289 |
| *Vuli* 2013 (t = 13.57***) | 52 (92.9) | 0.25 | 2 | 0.86 | 0.455 | 1.288 |
| *Masika* 2014 (t = 12.40***) | 50 (89.3) | 0.25 | 2.5 | 0.86 | 0.459 | 1.616 |
| *Acreage planted under conventional rice production* | | | | | | |
| *Production season* | *N = 65 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* | *Skewness* |
| *Vuli* 2011 (t = 7.70***) | 35 (53.85) | 0.25 | 4 | 1.04 | 0.8 | 2.30 |
| *Masika* 2012 (t = 7.50***) | 50 (76.92) | 0.25 | 6 | 1.09 | 1.03 | 3.0 |
| *Vuli* 2012 (t = 8.11***) | 44 (67.69) | 0.25 | 4 | 0.94 | 0.8 | 2.40 |
| *Masika* 2013 (t = 6.71***) | 55 (84.61) | 0.25 | 8 | 1.10 | 1.2 | 3.90 |
| *Vuli* 2013 (t =8.28***) | 48 (73.85) | 0.25 | 4 | 0.90 | 0.74 | 2.60 |
| *Masika* 2014 (t = 8.99***) | 48 (73.85) | 0.25 | 4 | 0.97 | 0.77 | 2.10 |

Notes: ***significant at $p < 0.001$.

**Table 8** Use of fertiliser in rice production by both SRI and non-SRI participants

| *Response* | *Response* | *Frequency* | *Percent, %* |
|---|---|---|---|
| Did you used fertiliser in SRI production practices | Yes | 56 | 100.0 |
| | No | 0 | 0 |
| Type of fertiliser used during SRI practices | In-organic | 55 | 98.2 |
| | Manure | 1 | 1.8 |
| Total | | 56 | 100 |
| Did you use fertiliser in conventional rice production practices? | Yes | 44 | 100.0 |
| | No | 0 | 0.0 |
| Type of fertiliser used during conventional practices | In-organic | 44 | 100.0 |
| Total | | 44 | 100.0 |
| *Type of in-organic fertiliser* | | *Frequency* | *Percent, %* |
| UREA | | 70 | 70.0 |
| DAP | | 2 | 2.0 |
| MINJINGU | | 2 | 2.0 |
| Both DAP and UREA | | 2 | 2.0 |
| Both UREA and MINJINGU | | 6 | 6.0 |
| Not used | | 18 | 18.0 |
| Total | | 100 | 100.0 |

### *3.3.1 Application of fertiliser under SRI and conventional rice production*

Findings (Table 8) showed that both SRI participants and non-SRI participants (100%) used fertiliser in their rice farms during rice production seasons, and the majority applied inorganic fertiliser. Results suggested that both rice farmers were aware with fertiliser application in rice production so as to enhance rice yields in which 70% of them used UREA contrary to other types of inorganic fertilisers as a top dressing in rice farms. Also, this could have been attributed by differences in market prices and expected rice harvest after its application, since smallholder rice farmers were output oriented.

### *3.3.2 Average fertiliser applied per acre by SRI and non-SRI participants*

Survey findings (Table 9) showed that an average of 1.38 to 1.54 bags of 50 kg of fertiliser were used by SRI participants per acre during rice production seasons contrary to non-SRI participants who used 1.63 to 1.78 bags per acre and were significantly different at $p < 0.001$ levels. However, majority of rice farmers used less than the average quantity of fertiliser as shown by positively skewed distribution. Findings suggest that SRI participants applied less fertiliser per acre in comparison to their counter parts, non-SRI participants. Differences in quantity of fertiliser used could be attributed to water schedule management done by SRI participants that reduced leaching effect of fertiliser applied and enhanced up take by rice plants thus less fertiliser input contrary to conventional rice production practice. Equally, Ressurreccion et al. (2008) observed that savings from purchase fertilisers input was a chief benefit derived from SRI farming. Furthermore, Sato and Uphoff (2007) proposed to SRI farmers a standard chemical fertiliser application rate of 150 kg/ha of urea and 100 kg/ha of super-phosphate (SP36).

**Table 9** Average fertiliser applied per acre by SRI and non-SRI participants during rice production

| *Average fertiliser applied by SRI participants (50 kg of fertiliser)* | | | | | | |
|---|---|---|---|---|---|---|
| *Production season* | *N = 56 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* | *Skewness* |
| *Vuli* 2011 (t = 12.40***) | 31 (55.35) | 0.2 | 3.0 | 1.38 | 0.62 | 0.6 |
| *Masika* 2012 (t = 11.30***) | 28 (50.0) | 0.5 | 3.0 | 1.43 | 0.67 | 0.90 |
| *Vuli* 2012 (t = 14.65***) | 35 (62.5) | 1.0 | 3.0 | 1.50 | 0.60 | 0.92 |
| *Masika* 2013 (t = 13.76***) | 42 (75.0) | 0.5 | 3.0 | 1.54 | 0.72 | 0.54 |
| *Vuli* 2013 (t = 16.30***) | 53 (94.64) | 0.4 | 3.0 | 1.53 | 0.68 | 0.55 |
| *Masika* 2014 (t = 14.49***) | 43 (76.78) | 0.5 | 3.0 | 1.46 | 0.66 | 0.52 |
| *Average fertiliser applied by Non-SRI participants (50 kg of fertiliser)* | | | | | | |
| *Production season* | *N = 65 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* | *Skewness* |
| *Vuli* 2011 (t = 14.12***) | 38 (58.46) | 1.0 | 4.0 | 1.78 | 0.80 | 0.80 |
| *Masika* 2012 (t = 13.82***) | 44 (67.69) | 0.5 | 4.0 | 1.65 | 0.80 | 0.90 |
| *Vuli* 2012 (t = 13.06***) | 41 (63.07) | 0.5 | 4.0 | 1.72 | 0.84 | 1.05 |
| *Masika* 2013 (t = 14.06***) | 46 (70.77) | 0.4 | 4.0 | 1.67 | 0.80 | 0.70 |
| *Vuli* 2013 (t = 13.86***) | 44 (67.69) | 0.4 | 4.0 | 1.68 | 0.80 | 0.74 |
| *Masika* 2014 (t = 13.99***) | 46 (70.77) | 0.0 | 4.0 | 1.63 | 0.79 | 0.45 |

Notes: ***significant at $p < 0.001$.

### 3.3.3 Price of fertiliser in different rice production seasons

Study results (Table 10) showed that majority of rice farmers (72%), both SRI and non-SRI participants applied fertiliser in a rice farms at a minimum cost of TZS 35 000 and a maximum of TZS 80,000 per 50 kg with a great variation in cost of fertiliser applied among rice farmers and were statistically significant at $p < 0.001$ levels. Results propose that majority of rice farmers bought fertiliser at a higher price than the average price of fertiliser as evidenced by negatively skewed distribution. Probably, this had been contributed by differences in purchasing power among rice farmers and fertiliser availability, subsidised and non-subsidised fertiliser during production seasons. Present findings agree with IFAD (2013) who observed that farmers face a challenge of rising fertiliser prices which embodies environmental costs due to the use of environment-unfriendly inputs (Mishra and Mohanty, 2019).

**Table 10** Average price of fertiliser (TZS) in different rice production seasons

| *Production season* | *N = 100 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* | *Skewness* |
|---|---|---|---|---|---|---|
| *Vuli* 2011 (t = 72.26***) | 58 (58) | 45,000 | 75,000 | 66,400 | 6,995.8 | –1.47 |
| *Masika* 2012 (t = 56.47***) | 62 (62) | 35,000 | 75,000 | 64,800 | 9,040.8 | –1.78 |
| *Vuli* 2012 (t = 62.71***) | 68 (68) | 35,000 | 75,000 | 65,800 | 8,654.2 | –2.10 |
| *Masika* 2013 (t = 72.72***) | 74 (74) | 37,500 | 75,000 | 66,100 | 7,16.25 | –1.81 |
| *Vuli* 2013 (t = 78.40***) | 82 (82) | 37,500 | 75,000 | 66,500 | 7,682.9 | –2.00 |
| *Masika* 2014 (t = 80.08***) | 72 (72) | 35,000 | 80,000 | 67,200 | 7,221.6 | –2.09 |

Notes: ***significant at $p < 0.001$.

**Table 11** Did you apply herbicides in SRI and conventional practices?

| *Response* | *Response* | *Frequency* | *Percent, %* |
|---|---|---|---|
| Did you applied herbicides in SRI practices? (N = 56) | Yes | 42 | 75.0 |
| | No | 14 | 25.0 |
| Did you apply herbicides in conventional practices? (N = 44) | Yes | 34 | 77.3 |
| | No | 10 | 22.7 |
| Total | | 100 | 100.0 |
| How many times did you weed your rice farm under SRI and conventional | | | |
| | *Response* | *Frequency* | *Percent, %* |
| SRI practices (N = 56) | Once | 6 | 10.71 |
| | Twice | 33 | 58.94 |
| | Three times | 11 | 19.64 |
| | Four times or more | 6 | 10.71 |
| Conventional practices (N = 44) | Once | 8 | 18.20 |
| | Twice | 30 | 68.20 |
| | Three times | 6 | 13.60 |
| Total | | 100 | 100.0 |

### *3.3.4 Herbicides application under SRI and conventional and weeding frequency*

Both SRI and non-SRI respondents were asked whether they applied herbicide in their rice farms so as to control weeds. Findings showed that 75% and 52.3% of SRI participants and non-participants accordingly applied herbicides in their rice farms to control weeds. Results, propose that majority of both participants and non-participants were aware with herbicide application and its advantage. As a result, SRI participants (58.94%) and non-participants (68.2%) had to weed their rice farms twice in a production season. Less frequency of weeding their rice farms therefore could have been contributed by the application of herbicides that result in cost deduction.

## *3.4 Labour in rice farms and average rice harvested per acre*

Accordingly, respondents were asked the type of labour employed in their rice farms during weeding and harvesting period. Both, SRI participants (76.79%) and non-participants (52.27%) reported that they hired labour for weeding and harvesting rice as its evidenced that majority of rice farmers harvested and threshed their rice by hand (Table 12). Survey findings suggest that rice production involved more labour beyond family labour due to the tedious nature of activities and that modern technology is less preferred due to its costs required in rice harvesting using combine harvester or being unfamiliar to rice producers. Equally, Namara et al. (2003) found that major obstacle to the adoption of SRI by non-adopters was the high labour demand and the tedious nature of practices involved. Similarly, Arsil et al. (2019) observed that price of rice which are similar to those of SRI and conventional system as a barrier.

**Table 12** Labour used in weeding and harvesting rice farm under SRI and conventional production

| | *SRI (N = 56)* | | *Conventional (N = 44)* | |
|---|---|---|---|---|
| *Type of labour* | *Frequency* | *Percent, %* | *Frequency* | *Percent, %* |
| Family labour | 13 | 23.21 | 21 | 47.73 |
| Hired labour | 43 | 76.79 | 23 | 52.27 |
| Total | 56 | 100.0 | 44 | 100.0 |
| How rice was harvested and threshed? | | | | |
| *Harvesting ways* | *Frequency* | | *Percent, %* | |
| By hand | 97 | | 97.0 | |
| By combine harvester | 3 | | 3.0 | |
| Total | 100 | | 100.0 | |

## *3.5 Rice harvested per acre under SRI and conventional practices*

Study findings (Table 13) showed that the minimum and maximum quantity of rice harvested per acre under SRI was 0.3 to 5.5 tons while under conventional practices was 0.2 to 3.2 tons per acre which was statistically significant at $p < 0.001$ levels, respectively. The difference in quantity of rice harvested between SRI participants and non-SRI participants could have been attributed to differences in knowledge, experience and skills on SRI technology in rice production, therefore, study findings concur with Nakano et al. (2014). The difference is therefore associated with SRI adoption. Furthermore, quantity of rice harvested had a slight difference between production seasons but more variation within production seasons as it is indicated by standard deviation. Results suggest that the differences within the production season could be attributed by inter-differences in knowledge, experience, skills on SRI technology and purchasing power accrued to rice farmers. Similarly, Namara et al. (2003) and Ressurreccion et al. (2008) observed that the average profits for SRI was almost double that of the conventional practice. Equally, Too et al. (2020) found that seed yield/plant was highly significant in SRI as compared to a traditional paddy system.

**Table 13** Average rice harvested per acre under SRI and conventional in different production seasons

| *Rice harvested per acre under SRI practices (100 kg)* | | | | | |
|---|---|---|---|---|---|
| *Production season* | *N = 56 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* |
| *Vuli* 2011 (t = 11.68***) | 25 (44.64) | 5.00 | 32.00 | 15.0600 | 6.45 |
| *Masika* 2012 (t =8.5***) | 27 (48.21) | 6.00 | 55.00 | 16.8519 | 10.29 |
| *Vuli* 2012 (t = 14.0*** | 32 (57.14) | 5.00 | 38.00 | 17.8750 | 7.22 |
| *Masika* 2013 (t = 13.3***) | 39 (69.64) | 4.00 | 35.00 | 15.6667 | 7.36 |
| *Vuli* 2013 (t = 16.2***) | 51 (91.07) | 3.00 | 35.00 | 17.3725 | 7.65 |
| *Masika* 2014 (t = 13.03***) | 42 (75.0) | 4.00 | 42.00 | 15.5238 | 7.72 |
| *Rice harvested per acre under conventional practices (100 kg)* | | | | | |
| *Production season* | *N = 44 (%)* | *Minimum* | *Maximum* | *Average* | *St. dev.* |
| *Vuli* 2011 (t = 17.30***) | 29 (65.91) | 4.00 | 28.00 | 16.4828 | 5.13128 |
| *Masika* 2012 (t = 17.28***) | 43 (97.73) | 3.00 | 28.00 | 14.7093 | 5.57976 |
| *Vuli* 2012 (t = 19.67***) | 42 (95.45) | 4.00 | 28.00 | 16.8095 | 5.53586 |
| *Masika* 2013(t = 18.10***) | 44 (100.0) | 2.00 | 32.00 | 14.5714 | 5.63471 |
| *Vuli* 2013 (t = 20.27***) | 44 (100.0) | 4.00 | 28.00 | 16.4783 | 5.51257 |
| *Masika* 2014 (t= 18.56***) | 44 (100.0) | 4.00 | 26.00 | 13.9778 | 5.05195 |

Notes: ***significant at $p < 0.001$.

## 4 Conclusions and recommendation

Based on the observation that smallholder farmers, both SRI and non-SRI sorted rice seeds (69%), raised seedlings (95%) and transplanted seedlings at the age of eighth day (40%) at a space of 25 cm × 25 cm (49%) and were significant at $p < 0.001$ levels. It was therefore concluded that most of SRI and non-SRI participants followed SRI technology principles in rice production, probably due to SRI information spill overs (Baker, 2000). Also, based on the findings that SRI beneficiaries applied 1.38 to 1.54 bags in comparison to 1.63 to 1.78 bags of fertiliser per acre. It was also concluded that SRI technology require less fertiliser input than conventional. Moreover, in support of the findings that SRI participants harvested 0.3 to 5.5 tons per acre in comparison to 0.2 to 3.2 tons per acre. It was therefore, concluded that practicing SRI technology in rice production is a panacea to participants as it leads to high grain yield than the conventional approach. It is therefore, recommended that both SRI and non-SRI participants in rice production should adopt SRI technology principles to maximise their livelihood earnings.

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