STUDY ON SYSTEM OF RICE INTENSIFICATION IN TRANSPLANTED AND DIRECT-SEEDED VERSIONS COMPARED WITH STANDARD FARMER PRACTICE IN CHITWAN, NEPAL

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CERTIFICATE

This is to certify that the thesis entitled **“STUDY ON SYSTEM OF RICE INTENSIFICATION IN TRANSPLANTED AND DIRECT-SEEDED VERSIONS COMPARED WITH STANDARD FARMER PRACTICE IN CHITWAN, NEPAL”** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** with major in **Agronomy** of the Postgraduate Program, Institute of Agriculture and Animal Science, Rampur, is a record of original research carried out by **Mr. KRISHNA DHITAL, ID. No. R-2009-AGR-03 M,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

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1. INTRODUCTION

Rice (*Oryza sativa* L. var. *Indica*) is the important crop in the country's food security accounting about 44% of the total food grain production and holds about 20% share in national AGDP (MoAC, 2010). Thus the national economy depends heavily on rice cultivation. Rice is grown in about 1.48 million ha, producing 4.03 million tons with an average productivity of 2.71 ton/ha. Of the total rice area, more than 70% rice is grown under rainfed condition, 9% under upland and 21% under partially or fully irrigated conditions (NARC, 2007).

One fourth of the population in Nepal lives below poverty line (CBS, 2011) and have food security problems. There is vast regional variation in agriculture production and food balance. The Terai has food surplus while hill and mountain regions are in severely food deficit situation. Out of 75 districts, 40 suffer from are food deficiency and, once grain exporting country, Nepal imported 47323 mt milled rice from India in fiscal year 2008/09 (MoAC, 2010). Food grain production of the country compared to the total edible food requirement lagged behind by about 0.33 million tons for the fiscal year 2009/2010 (MoAC, 2010). Slow agricultural development, land shortage and population growth have been pushing more and more families into vulnerable situation regarding food security (Thapa, 2008). Land and water resources will become scarce for rice production in Asia in the next 30 years or so, mainly because of urbanization, industrialization, and increased population (Tran, 2005) and Nepal is no exception.

Agriculture worldwide faces two major challenges. First, it needs to enhance food production sustainably to feed a growing world population; at the same time, this increase needs to be accomplished under conditions of increasing scarcity of water resources (Bouman, 2007). Rice yield was reduced by 12.5% in 2006 and productivity reduced to 2.71 mt/ha in 2009 from 2.91 in 2008 at national basis due to drought (MoAC, 2010).

Rice (*Oryza sativa* L.) is the foremost staple food for more than 50% of the world's population. It is estimated that by the year 2025, the world's farmers should produce about 60% more rice than at present to meet the food demands of the expected world population at that time (Fageria, 2007). Irrigated rice production is the largest consumer of water in agricultural sector, and its sustainability is threatened by increasing water shortages. Such water scarcity necessitates the development of alternative system of irrigation in (irrigated) rice cultivation (systems) that require less water than traditional flooded rice (Bouman *et al.*, 2005).

Lots of efforts and new concepts are emerging to increase the productivity of rice (Uprety, 2006). So, more rice production can play vital role to overcome (by reducing) the problem of food grains. This additional rice will have to be produced on less land with less water, less labor and fewer chemicals. The traditional method of rice cultivation has no ability to explore natural potential of the rice plant because it's been transplanted with old seedlings, closely spaced and continual flooding which held back the plants natural potential (Tripathi *et al.*, 2004). The promising technologies generated by research can play a pivotal role in increasing productivity and thus food security of the nation. System of rice intensification can be a suitable methodology in this regard.

System of Rice Intensification (SRI), is based on some new insights into how rice can be grown best, translated into certain principles and practices, and was developed by Fr Henery de Laulani along with his farmer in 1982, in Madagascar. Its main objective is by planting very young seedlings which allows a greater realization of tillering potential of rice plants and wide spacing on a square pattern which gives the roots more space to grow and get more sunlight and air (Uphoff, 2002). System of Rice Intensification (SRI) is defined by Uphoff *et al.*, (2002) as a technique of agronomic manipulation. The practices are based on a number of sound agronomic principles. They work synergistically with others in order to achieve higher grain yield. It improves physiological activities of the plant and provides better environmental condition. The key to success with SRI is the early transplanting of seedlings (8 to 12 days seedling), single planting with wider space 25 to 35 cm plant to plant and row to row (NARC, 2005).

Two things were repeatedly reported by Morang district farmers (a) Their SRI crops, in addition to giving often doubled yield, are maturing 2, 3, even 4 weeks sooner than when the same variety is grown with 'normal' methods; this saves water, reduces the risks of crop loss, and makes land available for other crop production; and (b) once farmers have acquired experience and skill with SRI methods, the new system of crop management is labor-saving rather than labor-intensive; saving labor as well as seeds, water and costs of production makes SRI increasingly attractive to farmers (Uprety, 2006).

With SRI, seeding rates are drastically reduced to 5 to 10 kg/ha, about 5 to 10 times less than conventional rates. Especially for the poor farmers, this is a real benefit (Satyanarayana *et al*., 2004). Similarly Uprety (2005) also reported that seed requirement is 92,679.6 mt for 1545000 ha land (at the rate 60 kg/ha in conventional method) but by using SRI we can save 77,233 mt. of seed for consumption. If we introduce this technology only in 10% of land and increase yield by only 1mt/ha (SRI potential is 2 to 3 times more than the present productivity), and can produced 1, 54,466 mt. more rice.

Many parts of Nepal have suffered a reduction in rice production due to reduced water availability and a reduction in days of rainfall. In the present context of decreased water availability, System of rice intensification (SRI) can be a suitable method of cultivation. Many farmers are unable to plant their rice due to unavailability of water for puddling. Fields towards the end of irrigation channel (far from the source of water) had converted to the rainfed (unirrigated) lands due to reduced volume of water in the streams. If SRI methodology is adopted the same quantity of water is enough to cultivate larger areas. Thus more areas could be brought into rice cultivation, or at least the rice cultivated area can be maintained. To avoid the problem of water scarcity for puddling slight modification can be made in SRI like: Direct-seeded rice with other SRI management practices.

Uphoff (2006) suggested farmers in China, Cambodia, India and Sri Lanka who are making direct-seeding adaptations to SRI methodology to avoid the labor costs of transplanting. He suggested farmer with a very small area of rice land to transplant - to get the maximum benefits from SRI methodology. But to the larger farmer with more land, he suggested to direct-seed, trading off some possibly attainable yield in order to reduce labor costs. Direct-seeding also cuts off the large quantity of water required for puddling. This facilitates the on time planting of rice crop. Otherwise delayed transplanting (old aged seedlings) will highly reduce the yield.

SRI will become more attractive as water scarcity becomes a more pervasive agricultural constraint. Droughts are becoming more frequent and serious. As weather fluctuations are becoming greater, SRI methods by inducing rice plants to grow much larger and deeper root systems give SRI plants more resistance to impact of drought enabling farmers to reduce their irrigation requirements.

As a new method, its promoters have faced several difficulties, because it differs markedly from conventional farming methods. Rather it gives small farmers additional opportunities to raise the productivity of their land, while trying to meet their staple food requirements. In Nepal, SRI is becoming as the best solution for its food deficit problems and for enhancing food security in remote areas, where modern inputs are costly and difficult to obtain. The performance of SRI raises the hope among policy makers, development workers and farmers of solving this national problem (Uprety, 2006). It is repeatedly stated that SRI increases rice production and raises the productivity of land, labour, water and capital through different practices for management (Laulanié, 1993; Uphoff, 2001). But the principles always need to be tested in and adapted to varying environments, as there is no set formula for achieving the higher yields. Tripathi *et al*. (2004) have concluded from an on farm and on station trials that performance of SRI could vary from location to location. Thus a need of an field experiment was felt and a research was conducted during June-November to compare three different varieties (Sabitri, Loktantra, and Radha-4) under three different method of crop establishment; i) General farmers system of transplanted rice cultivation (TPR) ii) System of rice intensification (SRI), and iii) Direct seeded rice with other SRI management practice (DSR), with the following objectives:

- To determine the growth and productivity of rice varieties under different method of crop establishment; and
- To analyze the economics of rice cultivation under different crop establishment method and varieties.

2 LITERATURE REVIEW

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

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

In 1990, Laulaníe helped to establish a Malagasy NGO called Association Tefy Saina (ATS) and became its technical advisor. ATS began introducing SRI with farmers in a number of communities in the country. In 1994, Cornell International Institute for Food, Agriculture and Development (CIIFAD) started working with ATS to introduce SRI as an alternative to slash and burn cultivation. From 1998, CIIFAD has become increasingly active in drawing attention to the potential of SRI also in other major rice growing areas in Asia (Uphoff *et al*., 2002), leading to a serious controversy with scientists of some established rice research institutes (Stoop *et al*., 2006).

2.2 System of rice intensification

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

2.3 Principles of system of rice intensification (SRI)

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

2.3.1 Transplanting of single seedling per hill

Under SRI management it can be suggested that early transplanting provides a longer vegetative growth period, and single seedling per hill reduces the competition and helps minimize the shading effect of lower leaves. This helps lower leaves to remain photosyntheitcally active, for much longer, and in turn, root activity remains higher for a longer period due to the plant’s enhanced supply of oxygen and carbohydrates to the roots (Tanaka, 1958; Horie *et al*., 2005). Further, higher root activity, in turn, supplies cytokinin to the lower leaves, delaying senescence and helping to maintain photosynthetic efficiency of the plant at latter growth stages. This outcome has been confirmed by a finding where a single seedling per hill had higher yield compared to three seedlings per hill (San-oh *et al*., 2006).

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

2.3.2 Transplanting of young (8–12 days old) seedlings

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

Before proceeding any further, the term phyllochron needs to be introduced since it will be used very often in this thesis. Phyllochron, which has been used to characterize the growth dynamics of cereals, is defined as the interval of leaf emergence (Nemoto et al., 1995). It varies in a function of temperature, day length, nutrition, light intensity, planting density and humidity (Nemoto *et al.*, 1995). The modeling of the phyllochron was first published in 1951 when Katayama presented the growth rules he had worked out for leaf emergence on the main stem and tillers of rice, wheat and barley. This model was used by de Laulanié for explaining the success of the SRI system which he had already developed empirically.

As we can see from the Katayama table, the first tiller off the main stem appears at the fourth phyllochron. De Laulanié had already found that if the rice seedling is transplanted later than the third phyllochron, the resulting plant will lose all of the incoming tillers from this first row of tillers which represents about 40% of the total tillers, and that any further delay of transplantation leads to a bigger loss of tillers (Association Tefy Saina, 1992).

An alternative explanation focuses on changes in phyllochron length as affected by temperature, soil moisture, shading, etc. The impact of transplanting seedlings before the fourth phyllochron, in terms of tillering, root development and yield, is very dramatic as seen from our research and in factorial trials (Randriamiharisoa and Uphoff, 2002). Exactly what physiological processes are involved that produce such a result remains to be determined. Proponents of SRI recommend transplantation of the seedlings during the third phyllochron, at the stage when the plant has still only two leaves, in order to avoid reduction in subsequent tillering and root growth (Laulanié, 1993). Early transplantation in conjunction with the other practices allows a greater realization of the tillering potential of rice plants (Association Tefy Saina, 1992).

Table 1. Phyllochron table of Katayama as adapted by Laulanié indicating the number and location of tillers being initiated at each stage of development in *Oryza sativa*, provided that growing conditions are optimal

Phyllochron sequences	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Main stalk	0	1	0	0	0	0	0	0	0	0	0	0	0	1
First row of tillers	0	0	0	0	1	1	1	1	1	1	0	0	0	6
Second row of tillers	0	0	0	0	0	0	1	2	3	4	5	6	5	26
Third row of tillers	0	0	0	0	0	0	0	0	1	3	6	10	15	35
Fourth row of tillers	0	0	0	0	0	0	0	0	0	0	1	4	10	15
Fifth row of tillers	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total number per phyllochron	0	1	0	0	1	1	2	3	5	8	12	20	31	84
Cummulative total tillers	0	1	1	1	2	3	5	8	13	21	33	53	84	

Source: Association Tefy Saina, 1992

Transplanting rice seedlings at a younger stage has been supported by many researchers (Horie *et al.*, 2005). This practice captures the benefit of the early phyllochron stages (less than four leaves) having higher potential to produce more tillers per plant (Katayama, 1951).

SRI methods give the the highest yield when young seedlings are transplanted, less than 15 days old and preferably only 8–12 days, i.e., before the start of the fourth phyllochron (Stoop *et al*., 2002). This preserves plants' potential for tillering and root growth that is compromised by later transplanting (Uphoff, 2001).

In general, uprooting causes stress to the seedling which could be minimized when the endosperm remains attached (Sakai and Yosida, 1957; Hoshikawa *et al*., 1995). In conventional management, it has been reported that around 40-60% of the roots remain in the soil during pulling up from the nursery. Pruning up to 60% of the root during transplanting significantly decreased subsequent root and shoot dry matter accumulation (Ros *et al*., 1998). Therefore, it may be suggested that SRI practices lead to increased shoot and root dry matter accumulation by protecting root system during transplanting.

2.3.3 Transplanting of seedlings into a muddy field

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

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

2.3.4 Wide spacing of 25×25 cm^2 or more depending upon soil fertility

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

Long duration varieties perform better with wider spacing than short duration varieties (Baloch *et al*., 2002). Stoop (2005) suggested that long-duration varieties perform better under SRI management.

2.3.5 Mechanical weeding

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

With SRI, weeds are controlled by the use of mechanical weeding with a rotary pushed weeder. The system relies on early and frequent weeding which varies from 3 to 4 times throughout the cultivation period. The first in the series of weedings is done about 10 days after transplantation and the others in a frequency of 10-20 days (Association Tefy Saina, 1992).

2.3.6 Intermittent irrigation during vegetative growth stage

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

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

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

2.3.7 Addition of organic manure instead of chemical fertilizer

The incorporation of organic manure into the soil can bring beneficial effect to root growth by improving the physical, chemical and biological environments in which root grow (Yang *et al.*, 2004). Under continuous water logging condition, there is significant decrease in root growth (Sahrawat, 2000), whereas under intermittent irrigation, the incorporation of organic matter improves root morphological characteristics and root activity of rice plant. It has the effect of increasing root density, active absorption area, root oxidation ability and nutrient uptake (Yang *et al.*, 2004).

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

2.4 The SRI methodology

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

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

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

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

2.5 Beneficial effect of SRI

SRI is showing that in many cases farmers’ income can be increased by using less rather than more external inputs. The fact that SRI can give higher yields with lower investment of capital make attractive and beneficial for poorer households. One of the benefited indentified in the GTZ Cambodia evaluation was that SRI farmers could make fewer cash outlay at the start of planting season, when their cash reserves were lower

(Anthofer *et al.,* 2004). SRI reduces farmers application of synthetic fertilizer and crop protection biocides, with beneficial effect on soil and water quality and health.

2.5.1 Water saving with SRI

The most direct benefit of SRI is through reductions in water requirements. Rice is the 'thirstiest' crop in the world, requiring several thousand liters of water to produce 1 kg of rice when using conventional rice-growing methods with continuous flooding. SRI alternative water management methods can reduce this by 25-50%, while raising yields 50-100% or more. This alone should be enough justification for using SRI methods wherever water is not an abundant and effectively free good. One social benefit, hard to quantify, is the advantage of reducing the amount of conflict over water (Uphoff, 2003). The realization that rice does not require or produce its best when in standing water comes as quite a surprise to many persons, who have accepted the conventional wisdom. However, that belief is wrong, as shown by research (Guerra *et al.,* 1998). Water productivity can be increased from two times to even six times (Ceesay *et al.,* 2007). Yuan (2002) reported that the research held on China National Hybrid Rice Research and Development Center, that the water applications could be reduced by as much as 65% on SRI plots compared with conventional irrigated ones and same time yield was 16 t/ha in trials with a Super-1 hybrid variety grown with SRI methods in 35.6% higher than the 11.8 t/ha achieved with the same hybrid in conventional, water intensive methods. Similarly, water saving with SRI was calculated as 40% in Indonesia, 67% in Philippines and 25% in Sri Lanka while conducting different trials comparing with that of conventional system (Sato, 2006; Lazora, 2004; Namara *et al*., 1995).

2.5.2 The relation of SRI and increase in grain yield of rice

There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by two to three fold compared to current yield levels

(Uphoff, 2007). Husain *et al*. (2004) documented a 30% yield advantage for SRI in Bangladesh and Namara *et al*. (2003) showed an even larger benefit of 44% in Sri Lanka.

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

2.5.3 Reduction in crop cycle

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

2.5.4 Less economic risk

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

2.5.5 Creating a better soil environment for rice

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

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

2.6 Rice varieties under SRI

With SRI, farmers do not need new rice varieties, because all cultivars respond positively. The best SRI yields have been achieved with high-yielding varieties or hybrids, but even traditional varieties can produce 6-8 mt/ha and as much as 10-12 mt/ha. Since SRI reduces seed requirements by 80-90%, it slashes otherwise significant hybrid seed costs (Uprety, 2005). Uphoff (2006) pointed out that varietal performance can be quite different between conventional practice and SRI practice; however, it should not be assumed that a variety which does not do well in their trials with standard cultivation methods will not perform well if grown under SRI. Genetic potential of variety will significantly contribute to difference in yield under SRI and other management practices. Uprety (2006) reported that among the varieties, Bansdhan, Mansuli, Suwarna, Bares 2014, Sugandha, Radha 12, Basmati and Hardinath (a recently released 120-day variety), Radha-12 ranked the first, followed by Suwarna and Bansdhan, respectively. But Suwarna and Bansdhan had the the highest recorded yields, up to 11 mt/ha and Radha-12 showed the the highest average yield.

2.7 Plant growth under SRI

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

2.8 Environmental benefits of SRI

SRI methods are not only beneficial for people but also for the natural habitat and biodiversity. Because SRI methods do not require chemical fertilizer, they enable farmers to reduce their fertilizer applications, or eliminate them altogether, producing yields as good or better by use of compost. This can contribute to both better soil and water quality and to improved soil health and human health. Not all farmers are willing to change to fully organic sources of fertilization, but SRI training and experience encourage reduced use of chemical fertilizer. An evaluation of 120 farmers in Cambodia who had used SRI methods for three years, with a doubling of yield, documented that farmers reduced their fertilizer use by 43% and their use of agrochemicals by 80% (Tech, 2004). When SRI was introduced to farmers in eastern Indonesia under a Japanese-funded project, farmers were advised to cut their applications of fertilizer (nitrogen, potassium and phosphorus) by 50% compared to what was recommended by the government. With this reduction in fertilizer use and a 40% reduction in water use, farmers' yields increased by 78% (3.3 mt/ha) on average. These data are from 12,133 on-farm comparison trials covering a total area of 9,429 hectares (Sato and Uphoff, 2007). Because SRI methods increase rice plants' resistance to pests and diseases, farmers find that they can reduce or even eliminate their use of agrochemicals, many of which have adverse effect on soil and water quality. An evaluation of SRI in Vietnam in 2005-06 by the Ministry of Agriculture's National Integrated Pest Management (IPM) Program found that with SRI methods, the prevalence of major pests and disease was reduced by 40 to 80%. The number of sprayings per crop was cut from 2.75 to 1.25 (Ngo, 2007). SRI thus makes it possible for farmers to grow more and better crops by reducing the application of chemical fertilizers and sprays. These environmental benefits can also contribute to better human health. SRI methods can also contribute to the conservation of biodiversity. This is most direct and obvious with respect to the biodiversity of rice species, making traditional local varieties more productive, profitable, and thus competitive with high-yielding varieties and hybrids. (Uphoff, 2006).

2.9 Impact of SRI on greenhouse gases

This has not been evaluated systematically, so no claims are made about SRI's net impact on the emission of greenhouse gases (GHG) that contribute to global warming. But there are reasons to expect that SRI will contribute to slowing the accumulation of GHG, and there is some initial scientific support for this. The flooding of rice paddies to grow irrigated rice is one of the major sources of methane within the agricultural sector (Neue, 1993). Flooded rice paddies apparently account for between 6 and 29% of the methane, for which human beings are responsible. A recently published article on this issue (Yan *et al.*, 2009) considered data and models generated for the Intergovernmental Panel on Climate Change (IPCC). There was no evaluation of SRI methods per se, but two of the key practices were assessed, at levels less divergent from conventional irrigated rice-growing practice than SRI recommends: not keeping paddy fields continuously flooded, and increasing the application of organic matter to the paddy soils. The article's abstract reported:

"We estimated that if all of the continuously flooded rice fields were drained at least once during the growing season, the CH_4 *emissions would be reduced by 4.1 Tg* a^{-1} *[giga tons per annum]. Furthermore, we estimated that applying rice straw off-season wherever and whenever possible would result in a further reduction in emissions of 4.1 Tg* a^{-1} *globally. If both of these mitigation options were adopted, the global* CH_4 *emission from rice paddies could be reduced by 7.6 Tg* a^{-1}*. Although draining continuously flooded rice fields may lead to an increase in nitrous oxide (*N_2O*) emission, the global warming potential resulting from this increase is negligible when compared to the reduction in global warming potential that would result from the* CH_4 *reduction associated with draining the fields."*

This would be almost a 30% reduction in methane, as global CH_4 emissions from rice fields in the year 2000 were estimated to be 25.6 Tg a^{-1}. Regarding the N_2O effect of altered practices, the authors write that

"the increased global warming potential resulting from this amount of N_2O *emissions [when converting flooded rice paddies to non-flooded paddies, as calculated from data used by the IPCC] is only approximately 2.7% of the reduced global warming potential that would result from the 4.1 Tg reduction in* CH_4 *emission [with the cessation of flooding]. Therefore, it is favorable to reduce* CH_4 *emissions from rice field by draining the fields" (Yan et al., 2009).*

2.10 SRI with direct seeding

Farmers who have labor shortages that make transplanting difficult to utilize, have been adapting SRI concepts and methods to direct-seeded crop establishment methods, coupled with the other SRI practices. Their main objective is to reduce labor requirements. They will try to achieve this goal even if it means that their paddy yield may be somewhat reduced because they are most concerned with favorable economics, not just agronomics.

Uphoff (2006) reported that a Sri Lankan farmer (Ariyaratne Subasinghe) developed a method and evaluated by a rice scientist at Tamil Nadu Agricultural University in India (S. Ramasamy), is based on broadcasting pregerminated seed on a muddy, leveled field. Ariyaratne uses about five times more seed if he established his SRI crop with transplanted seedlings, i.e. he broadcasts seed at a rate of about 25 kg per hectare instead of establishing a nursery with 5 kg of seed per hectare. When the young plants are 10-12 days old in the field Ariyaratne simply 'weeds' it as if he had transplanted it with spacing of 25x25 cm. This 'weeding' radically thins the stand of rice, eliminating about 80% of the young plants. It leaves them in a square geometrical pattern, with usually one plant at the intersections of the weeding passes, and sometimes two or even three. Occasionally there is no plant within this intersected space, but then adjoining plants grow larger to fill in any open space. The goal is to have a sparse, evenly and widely spaced plant population. This methodology can reduce labor requirements for SRI by 40%, according to Ramasamy at TNAU, because there is no need to construct and manage a nursery, and also it eliminates the task of transplanting. All the farmer has to do is broadcast seed and then 'weed' the field just as he would have been done anyway after transplanting the crop. Ariyaratne says that he is confident of getting a yield of 7.5 mt/ha. While this is perhaps less than from a more carefully managed field, he has many competing demands for his labor time, and this gives him a respectable harvest with a much reduced expenditure of labor.

2.11 Possible limitations or disadvantages of SRI

The most obvious drawback of SRI for most farmers is that when fields are not kept continuously flooded, weed control presents a problem. Use of herbicides is effective, but these do not have the positive effect of aerating the soil that is achieved when rotary hoes or cono-weeders, are used. Such implements not only remove weeds but create more favorable growing conditions for rice plant roots and for the majority of soil biota which are aerobic. This operation can be quite labor-demanding, but its timing is more flexible than for transplanting and farmers are inventing weeding tools that reduce the labor time required (Satyanarayana *et al.,* 2004).

SRI has been considered too labor-intensive for many farmers. This was given as a reason for disadoption of SRI by up to 40% of farmers, particularly poor ones, surveyed in one study done in Madagascar (Moser and Barrett, 2003). However, as farmers become more comfortable and skilled with the new methods, SRI is becoming labor-saving. In the Chinese study reported above, labor-saving was regarded by farmers as the main attraction of SRI, more than its water saving, and more than its yield and profitability increases (Li *et al.,* 2005) with making agreement Tech (2004) reported that in Cambodia, 55% of 120 farmers who have used SRI for three years evaluated it as 'easier' to practice, whereas only 18% considered it 'more difficult'; 27% said there was 'no difference'. Similar report can be found that an evaluation done of 108 farmers in Madagascar who were using both SRI and conventional methods determined that while first-year users required 20-30% more labor/ ha, by the fourth year, SRI required 4% less labor and by the fifth year, 10% less (Barrett *et al*., 2004).

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

One common constraint identified by farmers is that many of them do not have access to as much biomass as is recommended for enriching the soil for SRI practices. As noted already, the other SRI methods can be used beneficially with chemical fertilizer, while saving water, if organic sources of nutrients are insufficient. Once farmers come to appreciate the merits of organic soil fertilization, and see the returns they can get from SRI, they begin making more use of available biomass sources and start harvesting and even growing biomass on non arable areas (Satyanarayana *et al.,* 2004).

This is the main objective constraint on SRI adoption, since the methodology hinge on the application of small but reliably available water to the rice crop. In their first few weeks, tiny transplanted seedlings are vulnerable to inundation. This limits their use in monsoon climates where little effort has been made to promote drainage, thinking that maintaining flooded fields is beneficial for the rice crop. Investments in drainage facilities, innovations like raised beds, and better organization among farmers to manage excess water are more profitable with, so they are likely to increase. While water control is important for success with SRI, most of the other methods -- wider spacing, more organic nutrients, and reduced water application after flooding subsides can be beneficial even without such control (Satyanarayana *et al.*, 2004).

2.12 SRI research and findings

In an experiment conducted in Bangladesh to evaluate the performance of hybrid rice under SRI in 2002 boro (dry season) and T. aman (wet season) at BRRI, transplanting and SRI treatments with 30cm x 30cm spacing produced identical grain yield but the later saved two thirds the amount of seedlings used by farmers (Islam *et al.*, 2005). In a ISIS press release (2005), it has been reported that for the past three years a dozen farmers in Morang District near the Nepal-Indian border 300 miles south of Kathmandu have been testing SRI, using only a fraction of the normal amount of local mansuli variety rice seed and far less water than usual, their yield has more than doubled. Initial trials were not very impressive, largely because of inadequate water management during monsoon season; trials through farmer field schools in 2002 and 2003 at Sunsari-Morang irrigation system established >8 mt/ha average for SRI vs. nearly 4 mt/ha with farmer methods and nearly 6 mt/ha with improved (high input) methods. More than doubling of yields in Morang district in 2004, with reduced time to maturity and lower costs led to national interest in SRI; dissemination now endorsed by Minister of Agriculture and supported by World Bank grant to extension service.

Mae Wan Ho (2005) reported an average SRI yield of 8.07 mt/ha, 37% higher than the average with improved practices, and 85% higher than the average with farmers' practices in Nepal in 2002. During monsoon season 2004, farmers got more than a doubling of yield (3.37 to 7.85 mt/ha) with a 15 day reduction in time to maturity. Being able to harvest sooner reduces farmers' risks of damage from pests or from typhoons, cyclones or other extreme weather that can come at the end of the season. Farmers compared SRI with their own usual practices and "improved" practice.

In a study conducted by Hossain *et al.* (2003) in Mymensingh, Bangladesh, SRI planting method produced higher number of total tillers /hill and higher number of effective tillers/hill, also regarding 1000-grain weight. This finding closely resembles to that of Uphoff (2001). Higher straw yield (5.48 mt/ha), biological yield (11.65 mt/ha) and harvest index (48.62%) were also observed.

Tripathi *et al.* (2004) reported that the yields obtained under SRI system from the variety Rampur masuli was higher than the variety Radha-4 and the spacing 20x20 cm^2 produced significantly higher grain yields (8.82 mt/ha), 30x30 cm^2 produce (7.63 mt/ha) and 40x40 cm^2 produce (5.75 mt/ha).

The yield obtained from Sabitri was significantly higher, whereas Radha-4 yielded lower compared with farmers' practice. Excluding weeding cost, there is a 28% yield advantage with 20x20 cm^2 spacing and 33 percent with 30x30 cm^2 spacing over farmers' practice with manual weeding treatment hills. Again 20x20 cm^2 spacing out-yielded the rest of the treatments with 49% higher (maximum grain yield of 9.6 mt/ha) grain yields compared to the farmers practice with the chemical fertilizer applied at 100:50:30 kg N, P_2O_5 and K_2O kg/ha. The national average rice yields are 2.7 t/ha. There is thus a great potential of SRI to increase rice production in the country. The only problem is the management of weeds on time (Bhatta *et al.*, 2005).

In a review of SRI presentation from 17 countries in Comell University, Fernandes (2002) concluded: Three fourth of studies confirms a significant yield advantage in SRI vs conventional rice. For yields below 8 t/ha, yield increases due to SRI were between 10 to 50%. SRI results in increased yields for both traditional and improved varieties, several studies reported that some varieties respond better to SRI than others. 120 to 140 day varieties may respond best to SRI. Very short or long duration varieties appear to respond less.

Suggested spacing for SRI varies from 25 cm x 25 cm to 35 cm x 35 cm. Most studies report that SRI is more labor demanding than conventional rice. It is hypothesized that soil biological factors are very important for SRI synergy. Flooding and draining of water requires good access to and control of water. In one study, soil drying and cracking yielded less than continuously moist soil. Most studies reported a significant saving in the amount of seed used to establish the rice field. Fewer chemical and pesticide inputs can translate into healthier food.

Alternate flooding and draining can reduce CH4 emissions but result in significant increases in NOx emissions. The effect of nitrous oxide is nearly 35 times greater than CH4. Though SRI requires less water than usually applied when growing rice; it does depend on having good water control. The potential benefits include production as well as economic and environmental aspects in particular for the situations under which resource poor, small farmers have to operate.

3 MATERIALS AND METHODS

The details of methods adopted and materials used during the course of study have been described in this chapter under following headings.

3.1 Description of the field experiment

3.1.1 Location

The experiment was conducted in the farmer's field at Phulbari V.D.C.-9, Gopaljung, Chitwan from June to November, 2010. This site is situated at 9.8 km south-west from Bharatpur, headquarter of Chitwan district. The altitude of the site is 256 meter above main sea level. Geographically, it is located at 27^0 37' North latitude and 84^0 25' East longitudes (Thapa and Dangol, 1998). The experimental plot was cropped with summer maize and was at 4- 5 leaf stage when the field ploughed.

3.1.2 Physico-chemical characteristics of experimental soil

Composite soil sample were randomly taken from different spots from 0-15 cm depth using tube auger to record the initial soil physico-chemical properties of the experimental site. Soil sample was air dried, grounded and sieved through 2 mm sieve and tested for their properties.

The total nitrogen was determined by Kjeldhal distillation unit (Jackwson, 1967), available phosphorus by spectrophotometer (Olsen *et al.*, 1954) and available potassium by Ammonium acetate method (Black, 1965). Organic matter was determined by Walkey and Black method (1934), pH (1:2 soil: water suspensions) by Beckman Glass Electrode pH meter (Wright, 1939) and soil texture by hydrometer method. Physico-chemical properties of the soil of the experimental site are presented in Table 2.

Table 2. Physico-chemical properties of the soil of the experimental site at Phulbari, Chitwan, 2010

S.N.	Properties	Average content	Scale
1.	Physical properties		
	Sand (%)	61.1	
	Silt (%)	25.2	
	Clay (%)	13.7	
2.	Chemical properties		
	Soil pH	5.4	Slightly acidic
	Soil organic matter (%)	1.9	Low
	Total nitrogen (%)	0.09	Low
	Available phosphorus (kg ha^{-1})	325.5	High
	Available potassium (kg ha^{-1})	326.2	High
3.	Texture/Rating	Sandy loam	

From the analysis, sand was found to be dominated in the physical properties of soil than silt and clay, possessing the sandy loam texture (Table 2).

On the chemical properties of soil, organic matter, total nitrogen, available phosphorus and potassium were observed. The average soil pH was found slightly acidic (pH 5.93) in the experimental field. The available nitrogen in the field represented medium (Khatri Chhetri, 1991), phosphorus in high and potassium in lower range where as organic matter of soil (Jaishy, 2000) indicated the low soil fertility status (Appendix 6).

3.1.3 Climatic condition during experimentation

The experiment site represents the subtropical humid climate of Nepal. Sub-humid type of weather condition with cool winter, hot summer and distinct rainy season with annual rainfall of about 1919.5 mm is the characteristics feature of the experimental area (NMRP, 2000). It is characterized by three distinct seasons: rainy season (June to October), cool winter (November to February) and hot spring (March to May). Thapa and Dangol (1988) reported that the minimum temperature never goes down to freezing point even during the coldest months (December-January), and the range of minimum temperature is 6 to 10^{0}C. The maximum winter temperature rises up to 27^{0}C. In the hottest months of the year (April, May and June), the maximum temperature goes as high as 42^{0}C. In general, the site receives ample rainfall during the rainy season, which starts from June and continues up to September. July 623.8 mm and August 641.2 mm received the the highest amount of rainfall, where as November received no rainfall. Relative humidity starts rising up from May (on an average 50%) and attains an extreme (100%) in some weeks of December and January. Monthly average data on different weather parameters, i.e., maximum and minimum temperatures, total rainfall, and relative humidity, recorded during rice season at National Maize Research Program, Rampur, Chitwan, are presented in Figure 1. Weekly average data on temperature, RH and rainfall are given in Appendix 1.

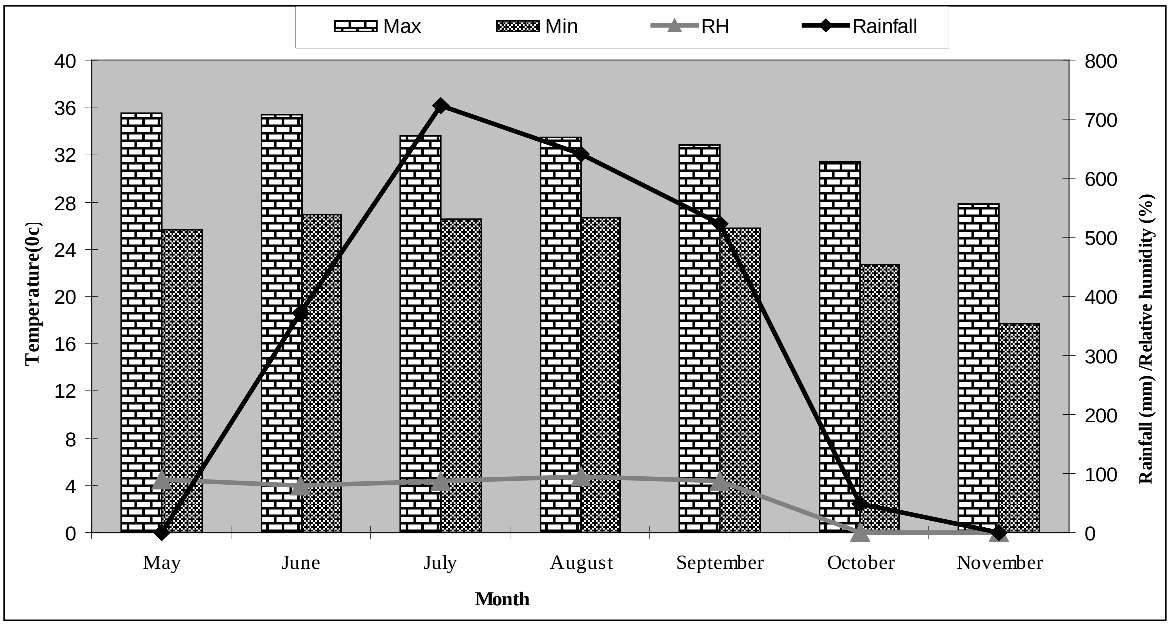

Figure 1. Weather condition during the course of experimentation at farmer's field, Phulbari, Chitwan, 2010 (Source: NMRP, 2010)

The average maximum temperature during the crop growth season ranged from 27.80^{0}C to 35.47^{0}C and it was maximum 35.47^{0}C in the month of May and minimum 27.80^{0}C in the month of November. The average minimum temperature ranged from 17.71^{0}C to 26.92^{0}C and it was maximum 26.92^{0}C in the month of June and minimum

17.71^{0}C in the month of November. The average relative humidity during the period of experimentation (May to September) was 90.83, 78.65, 87.74, 96.00, 87.90 respectively. Ustimesko-Bakumovsky (1983) reported normal vegetative growth of rice crop within the temperature range of 25-30^{0}C. The average temperature during the period of the booting to heading (September to October) and ripening (October to November) was 28.42 and 24.53^{0}C, respectively. Such level of temperature is significant for the rice crop because it requires temperature of 26.5 to 29.5^{0}C at booting and 20 to 25^{0}C at ripening stage (Singh, 2004). The total rainfall received during the growth period of rice, i.e., May to November, was 2308.60 mm, which was sufficient for the crop growth and development. Sharma *et al*. (1991) also recorded that rainfall of 1250 mm required for the vegetative growth of rice.

3.2 Experimental details

3.2.1 Field layout

The experiment was laid out in two factors split plot design with four replications having nine treatments combinations. The treatments consisted of combination of factor A (three methods of crop establishment that were general recommended method for transplanted rice –TPR, system of rice intensification – SRI, and direct seeded rice with other SRI management practices – DSR) and factor B (three rice varieties with different maturity periods that were Sabitri- 145 days, Loktantra- 135 days and Radha-4 of 125 days). The size of individual plot was 3 m × 4 m (12 m^2). There was a bund of 0.5 m width between two experimental plots and each replication was separated by bund of 1 m width.

The crop geometry for general recommended TPR was maintained at 20 cm × 20 cm (hill to hill and row to row spacing) with three to four seeding per hill with 15 rows in each plot. In SRI and DSR plots, crop geometry was maintained at 25cm × 25cm (hill to hill and row to row spacing) with single seedling per hill, with 12 rows in each plot. The six central rows were treated as net plot rows for harvesting and remaining three rows in each side were used for biometrical and phenological observations.

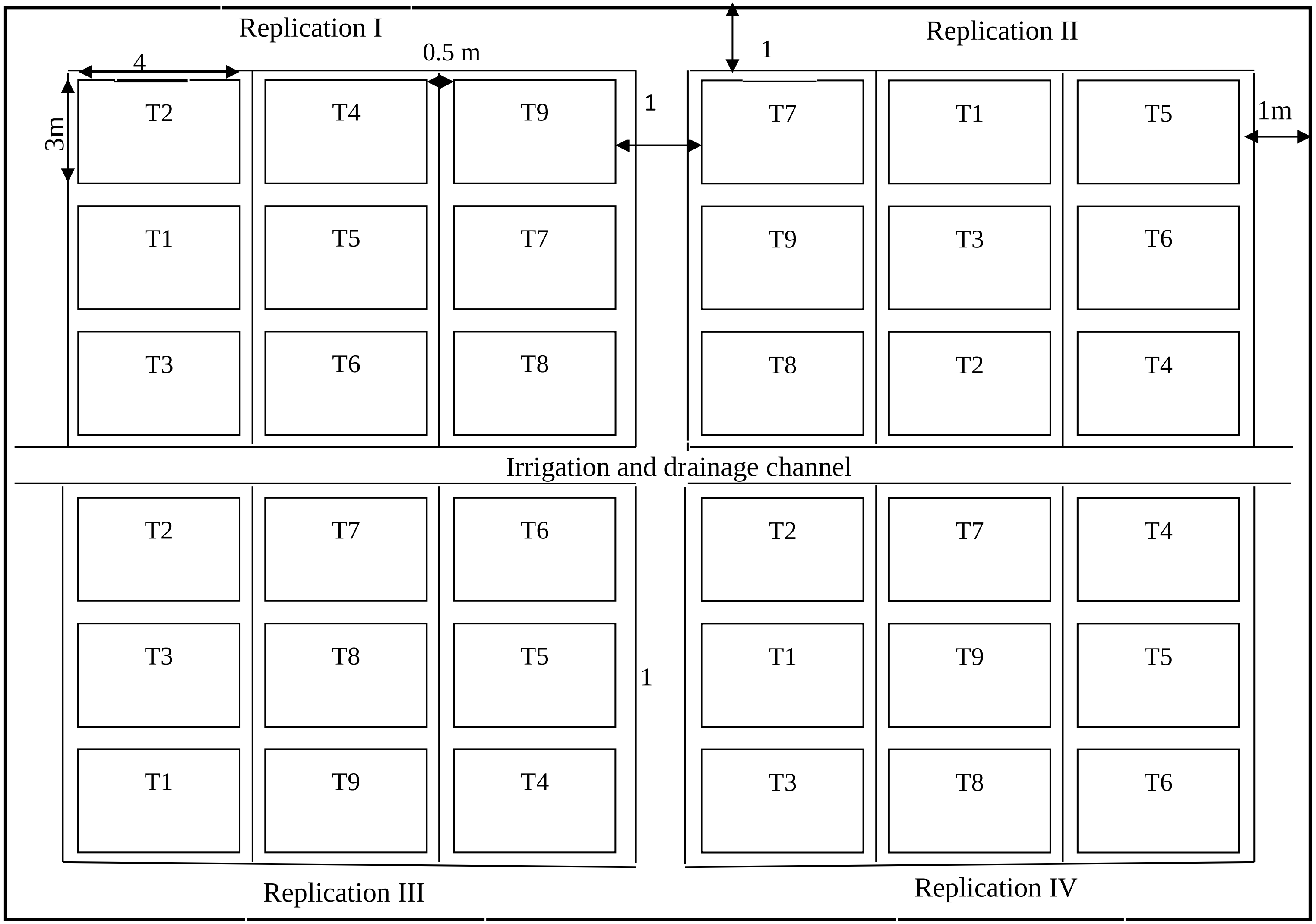

Figure 2. Layout of experimental plot

3.2.2 Treatment details

The treatments in main and sub-plots were as follows:

Main plot: Method of crop establishment

P1-General recommended method for transplanted rice (TPR)

P2- System of Rice Intensification (SRI)

P3- Direct seeded rice with SRI management practice (DSR)

Sub-plot: Varieties

V1- Sabitri (Long duration variety 140-145 days)

V2- Loktantra (Medium duration variety 130-135 days)

V3- Radha -4 (short duration variety about 121-125 days)

Table 3. Details of treatment combinations in an experiment during June to November 2010 at farmer's field Phulbari, Chitwan, Nepal

Treatment	Combination	Symbols
T1	Transplanted rice (TPR) + Sabitri	P1V1
T2	Transplanted rice (TPR) + Loktantra	P1V2
T3	Transplanted rice (TPR) + Radha-4	P1V3
T4	System of Rice Intensification (SRI) + Sabitri	P2V1
T5	System of Rice Intensification (SRI) + Loktantra	P2V2
T6	System of Rice Intensification (SRI) + Radha-4	P2V3
T7	Direct seeded rice with SRI management (DSR) + Sabitri	P3V1
T8	Direct seeded rice with SRI management (DSR) + Loktantra	P3V2
T9	Direct seeded rice with SRI management (DSR) + Radha-4	P3V3

3.3 Description of the tested rice varieties

3.3.1 Sabitri

It was released in 1972 and still becoming popular variety in central and western terai (Adhikari, 2006). It was derived from the cross of IR 1561-228-1/IR 1737//Cr 94-13 (Poudel, 2007). It has slender and medium size grain. The milling and cooking qualities are acceptable. It is resistant to bthe last and bacterial blight. In terai and similar environment, it is gradually replacing Masuli because of higher yield, resistant to bthe last and earlier maturity (140 -145 days after sowing) than Masuli. It is semi-dwarf in nature and produces about 4.0-5.0 mt/ha of the average grain yield (NRRP, 1997).

3.3.2 Loktantra

Loktantra is a rice variety released by National variety releasing committee in May 2006 after the establishment of Loktantra in April 2006 in Nepal. Its pedigree name is NR1487-2-1-2-2-1-1. It was developed by NRRP, Nepal from the six generations of selection from F2 bulk IR55072 (Mahsuri/IR4547-6-2-2), which was introduced from IRRI in 1986. It is high yielding and suitable for rainfed low land areas in terai, inner terai and foot hills below 500m altitude and for partially irrigated areas in mid hills 500-800m altitude. It matures in 130-135 days. The grain yield production ranges from 3.0-3.75 mt/ha. It is resistant to bthe last and moderately resistant to bacterial leaf blight. It is intermediate in height (120 cm) and straw yield is 10 mt/ha which is significantly higher to Radha 4, the old popular rain fed low land rice variety. It has superior grain quality like medium size grain, no cooking problem, good taste and acceptable appearance of cooked rice compared to Radha 4. Milling recovery is 68%. Its preference for the cooking and eating quality is similar to Masuli. It gives satisfactory yield in medium fertility condition. (Khatiwada and Chaudhary, 2006)

3.3.3 Radha-4

Radha-4 is a rice variety released by National variety releasing committee in 1995. Its pedigree name was IR 8423 and was derived from the cross of BG34 -8/IR2071-625-1. It was originated from IRRI Philippines. It is high yielding and recommended for the terai region of mid-western and far-western development region of Nepal i.e. Kapilvastu, Dang, Banke, Bardiya, Kailai and Kanchanpur. Days to flowering was reported to 88 DAS and physiological maturity to 120-125 days. The average grain yield production recorded in on farm and on station trials was 3.5 mt/ha with thousand grain weight of 25.5 g. It is short in height (91 cm) and numbers of effective tillers per square meter was 212. It had got vigorous growth habit, panicle exertion is well and seeds are awnless with intermediate threshability. . It has medium grain quality like medium size bold grain, no cooking problem, acceptable taste and appearance of cooked rice. It gives satisfactory yield in medium fertility rainfed condition.

3.4 Cultivation practice

Date-wise details of the various cultural practices recorded for comparative study of TPR, SRI and DSR method of crop establishment from seedbed preparation and sowing to harvesting are presented in Appendix 2.

3.4.1 Layout of field

The field was ploughed two times using a disc harrow through tractor. The layout of the field was done by making 36 plots manually by digging, weeding and pulverizing soils. Bunds and water channels were well maintained.

3.4.2 Raising of seedlings

Three nursery beds, one each for Sabitri, Loktantra and Radha-4 variety, of 1.5m length, 1.5 m breadth, and 15 cm height were prepared for raising seedlings. Rice seeds were sown on 18th June 2010 (4th Ashad 2067) with a seed rate of 10 kg per hectare. The nursery bed was fertilized using FYM (10 mt/ha), NPK at the rate of 100:30:30 kg/ha through urea, diammonium phosphate (DAP) and murate 0f potash (MOP), respectively and zinc sulphate (20 $ZnSO_4$ kg/ha through Sanjewani, 21% $ZnSO_4$). The seed was treated with Bavistin @ 2 g/kg of seed. Seeds were soaked in water for 36 hours and dried in shed for 6 hours and then sown in nursery beds. The nursery bed was irrigated through electric water pump and was made saturated with water.

Similarly, the plots with the direct seeding treatments were sown on the same day of seed bed establishment. FYM, basal dose of fertilizers, were incorporated into soil, weeds were removed and the plots were pulverized and then two to three seeds per hill were dibbled by maintaining the spacing of 25cm × 25cm (row to row and plant to plant). Thinning out of the seedlings and removal of weeds was performed on the 12th day of sowing so that single seedling per hill was maintained and seedling gets favorable condition for growth.

3.4.3 Land preparation

Each experimental plot was prepared for transplanting after incorporation of FYM and basal dose of chemical fertilizer, puddling and leveling. FYM was incorporated in each plot on the day of nursery bed establishment. The amount of chemical fertilizers was applied as mentioned on fertilizer management. The plots were puddle two days before transplanting so that weeds population can be reduced. Plots were well leveled so that uniformed wetting of the soil is achieved with less water.

3.4.4 Transplanting and gap filling

In SRI main plots, eleven day-old seedlings were transplanted in leveled muddy field with one seedling per hill, maintaining 25 cm×25 cm row to row and plant to plant distance (16 plants per m^2) within 30 min after removal of seedlings from the nursery on 29th June 2010. Seedlings were taken out of the nursery very carefully, lifted with a trowel, so that the seed sac was attached to the root and roots were less disturbed. Seedlings were transplanted in the soil very shallow, just 1-2 cm deep without knocking off the attached soil. Spacing was maintained by crossing with 25 cm spaced toothed wooden rake. Gap filling was done two days after transplanting of rice seedlings to maintain the plant population in the experimental field. Remaining seedlings were left for transplanting in TPR plots.

In TPR plots, 28 days old seedlings (left out from the same seed bed after transplanting of SRI) were transplanted in 4-5 cm deep water puddled field with 3-4 seedlings per hill, maintaining 20cm×20cm row to row and plant to plant distance (25 hills per m^2) on 16th July 2010. Gap filling was done four days after transplanting to maintain the plant population in experimental plots.

3.4.5 Fertilizer management

The fertilizer recommendation used in this experiment was 15 mt/ha of well-decomposed FYM, 100:30:30 NPK kg/ha, and $ZnS0_4$ @ 20 kg/ha. In this practice (total of 100 kg N/ha), 50 kg N/ha was applied before puddling, and the remaining half dose of nitrogen was split into two equal halves and top-dressed at tillering and panicle initiation stages, respectively. Whole doses of phosphorus @ 30 kg/ha, potash @ 30 kg/ha, and zinc sulphate @ 20 kg/ha were applied as basal fertilizer. The available source of fertilizers were urea (46% N), DAP (18% N and 46% P_2O_5), MOP (60% K_2O), and Sanjewani (21% $ZnSO_4$).

3.4.6 Weed management

The SRI and DSR plots were weeded by soil aerating rotary weeder at 13 and 26 days after transplanting (DAT) of SRI. The plots were irrigated on 12th day and water level was maintained 3-4 cm to make the soil loose and weeding easier. Water was drained after weeding. Third weeding was performed by manual hand weeding to remove the weeds adjoined to rice plant on 35 DAT. TPR plots were twice hand weeded at 22 and 45 DAT.

3.4.7 Irrigation management

General recommended method of transplanted rice (TPR) plots were kept continuously flooded, to maintain a 5-8 cm depth of water during the entire growth period. In SRI plots, the first irrigation was applied 5 days after transplanting to moisten the field without ponding. A second irrigation was given to the SRI and DSR plots on the evening of the 12th day after transplanting at a ponding depth of 4-5 cm, and the next morning a weeding was performed by rotary weeder. Thereafter, the alternate wetting and drying method of irrigation was followed, and irrigation water was applied when cracks appeared in the field. After panicle initiation, all plots were kept flooded with a thin layer of water 1–2 cm on the paddies, and all were drained 15 days before harvest. Irrigation water was applied through pipe from electricity operated pump. The detail of irrigation schedule is given in Appendix 2.

3.4.8 Insect-pest management

Rice earhead bug was observed problematic at milking stage and was managed by spraying of Endosulfan 35 EC @ 2 ml/liter of water.

3.4.9 Harvesting and threshing

The crop from the net plot area was harvested manually with the help of sickle. Harvested plants were left in-situ in the field for 3 days for sun drying. Threshing was done manually, and grains were obtained by winnowing and were weighed.

3.5 Observation recorded in rice

3.5.1 Phenological observations

It was taken from fixed 15 hills (7 hills in the 5th and 8 hills in the 11th rows of each plot). The phenological observation was recorded at panicle initiation, booting, heading, milking, soft and hard dough, and physiological maturity. Approximately 75% development of each of the stage was treated as completion of that particular stage and the data was expressed as days after sowing (DAS).

Based on the observed phenological stages at DAS and recorded temperature from the Meteorological station various measurements of heat unit concept was calculated according to the formulae given by Rao *et al.* (2000), Singh *et al.* (1998) and Rajput (1980). GDD were calculated using the base temperature of 10^0C from daily mean temperature.

$$\text{Growing Degree Days (GDD)} = \sum_{i=1}^{n} \left\{ \frac{(Tmax + Tmin)}{2} - Tb \right\}$$

Where, Tmax is maximum temperature of the day, Tmin minimum temperature and Tb is the the lowest temperature at which there is no growth which is also called base temperature.

3.5.2 Biometrical observations

3.5.2.1 Plant height (cm)

A single plant from each row except border row, i.e. 10 plants were tagged from each plots and height was recorded at an interval of 15 days beginning on the 35th days after sowing (DAS) and was continued up to 95 DAS. It was measured from the base to the top of the longest leaf of main tiller.

3.5.2.2 Leaf area index (LAI)

Three hills were taken from 9th row and all leaves will be used for measurement. Automatic leaf area meter was used to measure at 15 days interval beginning on the 35th days after sowing (DAS). The leaf area so obtained was then used to calculate the leaf area index. Leaf area index (LAI) = Leaf area/ground area

3.5.2.3 Number of leaves per tiller

The leaves detached from the plant samples taken for leaf area index were counted and was used to calculate the number of leaves per tiller.

3.5.2.4 Number of tillers per square meter

In case of SRI and DSR, number of tillers per square meter was counted from 16 hills from 3rd row of each plot and 25 hills (15 from 3rd row and 10 from 4th row) in case of TPR at 15 days interval beginning from 35 DAS up to 95 DAS.

3.5.2.5 Growth analysis

Three rice hills samples were taken from 9th row of each plot at an interval of 15 days. At the time of sampling, plants were taken by digging to the depth of 25 cm so that almost almost all the root mass was collected. The taken samples were further separated into roots, leaves and stems. The leaf sheath and the developing inflorescence before onset of heading or panicle after heading were retained as part of the stem. Dry matter deposition was determined by drying plant organs at a temperature of 70°C in hot oven for ten days.

3.5.2.5.1 Crop growth rate

The dry matter accumulation of the crop per unit land area in unit of time is referred to crop growth rate (CGR), expressed as g m^{-2} d^{-1}. The mean CGR values for the crop during the sampling intervals were computed using the formula of Brown (1984). For calculating the CGR, above ground biomass, i.e. total dry matter of leaves and stem from the $0.25m^2$ area of destructive sampling at an interval of 15 days from 35th DAS to 95th DAS were used.

$$Crop\ Growth\ Rate(CGR) = \frac{W2 - W1}{SA\ (T2 - T1)}$$

Where, SA is ground area occupied by the plant at each sampling. W1 and W2 are the total dry matter production in grams at the time T1 and T2, respectively.

3.5.2.5.2 Relative growth rate

The relative growth rate at which a plant incorporates new material into its sink was measured by Relative Growth Rate of dry matter accumulation and was expressed as g of dry matter produced by a g of existing dry matter in a day, i.e. g $g^{-1}day^{-1}$. Relative growth rate was worked out by using the above ground biomass as in the case of CGR by following the formula of Radford (1967).

$$Relative\ Growth\ Rate(RGR) = \frac{LnW2 - LnW1}{T2 - T1}$$

Where, W1 and W2 is initial and final dry matter weight at the time T1 and T2, respectively. Ln refers to Natural Logarithm.

3.5.3 Yield attributing characters of rice

3.5.3.1 Number of effective tiller per square meter

Observation regarding the effective tillers per square meter was recorded within each net plot from two randomly selected areas with the help of a quadrate (1 m × 1m) just before harvesting the crop and the average value was used to obtain effective panicles per square meter.

3.5.3.2 Length and weight of panicle

The length and weight of panicle were taken from the 20 randomly selected panicles from net plot just before harvesting and mean was calculated.

3.5.3.3 Number of grains per panicle

Numbers of filled and unfilled grains were counted to determine the number of grains per panicle of the sampled 20 panicles. The numbers of unfilled grains per panicle were used to determine the sterility percentage.

3.5.3.4 Thousand grain weight (TGW)

Thousand grains were counted from the randomly separated grain yield of net plot and weighed with the help of portable automatic electronic balance.

3.5.3.5 Sterility percentage

Total unfilled grains per panicle were obtained from 20 panicles and were used to calculate sterility percentage as per the following formula:

$$Sterility\ \% = \frac{No.of\ unfillied\ grain}{Total\ no.of\ grain} \times 100$$

3.5.3.6 Biomass yield and grain yield

Biomass (straw) yield and grain yield were taken at harvest from net plot consisting of each plot which was 5.52 m^2 (4.6m×1.2m) from the net plot area. The crop was dried, threshed, sun dried, cleaned and again dried to maintain 12% moisture and final weight taken. The grain yield per hectare was computed for each treatment from the net plot yields. The straw yield per hectare was obtained by deducting the grain yield from the total biomass yield. Oven dry method was used to record the moisture percentage of the grain. Finally, grain yield was adjusted at 12% moisture using the formula as suggested by Paudel (1995).

$$\text{Gain yield (kg ha}^{-1}\text{) at 12\% moisture} = \frac{(100 - \mathbf{MC}) \times \mathbf{plot\ yield\ (kg)} \times \mathbf{10000\ (m^2)}}{(\mathbf{100 - 12}) \times \mathbf{net\ plot\ area\ (m^2)}}$$

Where, MC is the moisture content in percentage of the grains. Straw yield was also recorded from the rows of net plot area and then translated into hectare.

3.5.3.7 Harvest index

Harvest index (HI) was computed by dividing grain yield with the total straw yield as per the following formula:

$$Harvest\ Index\ \% = \frac{Grain\ yield}{(Grain\ yield + straw\ yield)} x\ 100$$

3.5.4 Water requirement

3.5.4.1 Irrigation water and water productivity

The data on amount of rainfall received during the cropping period was collected from the meteorological station at NMRP Rampur, Chitwan. The amount of water discharge per minute from the pump was recorded and time elapsed for irrigation per plot was also recorded accordingly. The data on time elapsed for irrigation was used to compute the quantity of water supplied per plot in litre, later it was computed to m^3/ha. Mark was made at five places per plot at 5cm and allowed the water upto the level of mark and the quantity of water was calculated. The water productivity was calculated for treatment and expressed in kg m^{-3}. The formula used to calculate the water productivity is as follows:

$$\text{Water productivity} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Total water consumed in m}^{3}\text{ ha}^{-1}}$$

$$\text{including effective rainfall}$$

3.5.4.2 Effective rainfall

Total rainfall received during the crop period from June 18 to November 7, 2010 was 2234mm, and the effective rainfall was computed from it. There are several empirical methods of estimating effective rainfall in different countries. They are based on long experience and have been found to work quite satisfactorily in the specific conditions under which they are developed. Rice thrives under conditions of abundant water supply, hence the practice of land submergence is preferred. Depth of flooding is governed by the variety grown and its height, the height of field bunds and availability of water. The water requirements of rice include evapotranspiration and percolation. Measuring effective rainfall is thus more complicated. Different empirical methods used in different countries have been outlined below (Kung, 1971). In this experiment, the empirical method derived for measurement in rice in India is used, given by Dastane, 1972 which is as follows:

In this method, rainfall less than 0.25 in (6.25 mm) on any day is considered as ineffective. Similarly, any amount over 3 in (75 mm) per day, and rainfall in excess of 5 in (125 mm) in 10 days is treated as ineffective. In addition to above procedure, two times drainage of ponded water due to rainfall (120mm) in SRI and three times drainage in DSR (180mm) in DSR was reduced from rainfall quantity to compute effective rainfall.

3.6 Economic analysis

3.6.1 Cost of cultivation

Cost of cultivation was calculated on the basis of local charges for different agro-inputs, i.e. labor, fertilizer, compost, and other necessary materials. Cost of cultivation for three different methods was calculated separately. (Appendix 3, 4, 5).

3.6.2 Gross return

Economic yield (grain + straw) of rice was converted into gross return (Rs. ha^{-1}) on the basis of local market price.

3.65.3 Net return

It was calculated by subtracting the cost of cultivation from the gross return.

3.6.4 B:C ratio

It was calculated by the formula, B: C ratio = Gross return / Cost of cultivation.

4 RESULTS AND DISCUSSION

The results obtained during the experiment were analyzed and are presented in this chapter with the help of the tables and figures wherever necessary. The results obtained are discussed with possible reasons and literature support.

4.1 Rice phenology

Plant phenology is the study of the time period like events, dissimilar events, or the duration of a process. Like events include the time intervals between main stem leaves or branch leaves on a plant. Unlike events include the intervals between the plant emergence and formation of flower bud, flower, or mature fruit (Reddy *et al.*, 1997). In this experiment, unlike events, i.e. the interval between rice sowing and panicle initiation, booting, heading, dough and maturity stages were observed under different method of crop establishment and rice varieties. Different method of crop establishment and rice varieties significantly influenced on the phonological stages (Figures 3, 4).

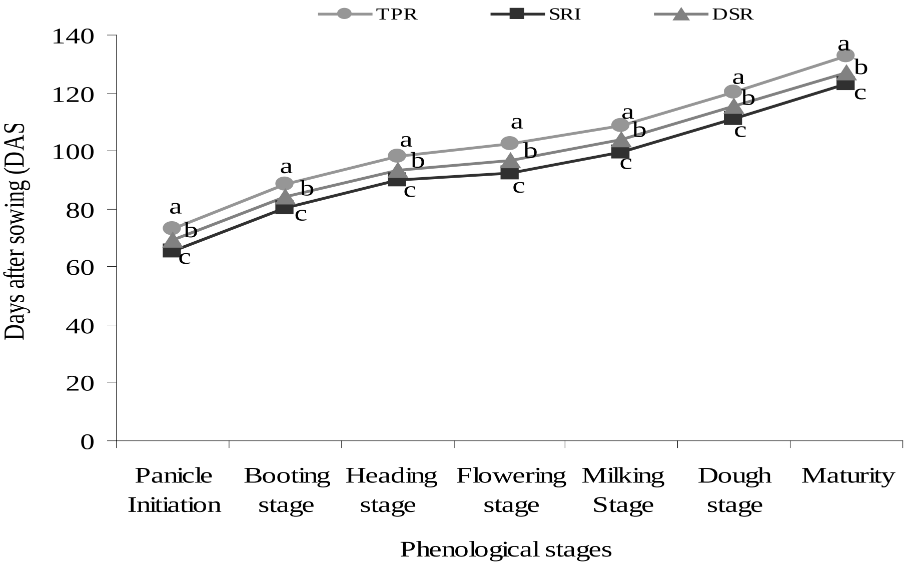

Figure 3. Phenological stages as affected by method of crop establishment of rice in days after sowing at Phulbari V.D.C., Chitwan, 2010. Treatments means followed by common letter (s) in each phenological stage are not significantly different among each other by DMRT at 5% level of significance

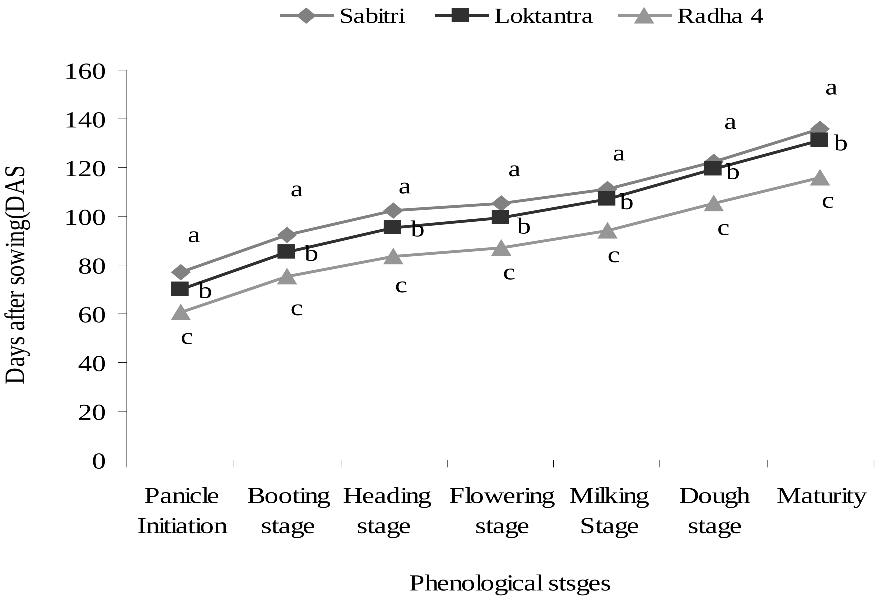

Figure 4. Phenological stages as affected by varieties of rice in days after sowing at Phulbari V.D.C., Chitwan, 2010. Treatments means followed by common letter (s) in each phenological stage are not significantly different among each other by DMRT at 5% level of significance

4.1.1 Panicle initiation (PI)

The panicle initiation stage begins when the primordium of the panicle is differentiated and becomes visible. In a short duration variety (105 days from seed to maturity), the panicle primordium starts to differentiate at about 40 days after seeding and becomes visible 11 days later (visual panicle initiation) as a white feathery cone 1.0-1.5 mm in length (De Datta, 1981). If water is limiting, panicle initiation may be delayed. This often occurs in rice direct-seeded in a non-puddled soil. The average PI stage was observed at 69.36 DAS (Table 4) and it ranged from 60.58 DAS to 77.25 DAS among varieties and fertility management practices. The period of PI was found significantly different among the three different methods of cultivation, TPR required the longest period of 73.33 DAS, followed by DSR with 69.33 DAS and SRI with the shortest period of 65.42 DAS. There was also significant difference for panicle initiation period among varieties, Sabitri (77.25

DAS), Loktantra (70.25 DAT) and Radha-4 (60.58 DAS). The longest duration for PI was observed in Sabitri and the shortest duration was observed in Radha-4 variety.

The interaction between method of crop establishment and varieties also influence days to panicle initiation from sowing (Appendix 19). Panicle initiation depends upon the duration of varieties, soil fertility management, age of seedling, water availability. The combination of TPR method of crop establishment and Sabitri (81.75 DAS) took significantly longer duration for Panicle initiation and the duration for the combination of SRI and Radha-4 was significantly lower, i.e. 55.25 DAS (Figure 5). In all the methods of crop establishment PI was observed earlier in Radha-4 variety and later in Sabitri. In general, longer duration variety took long time to come PI stage as compared to short duration variety.

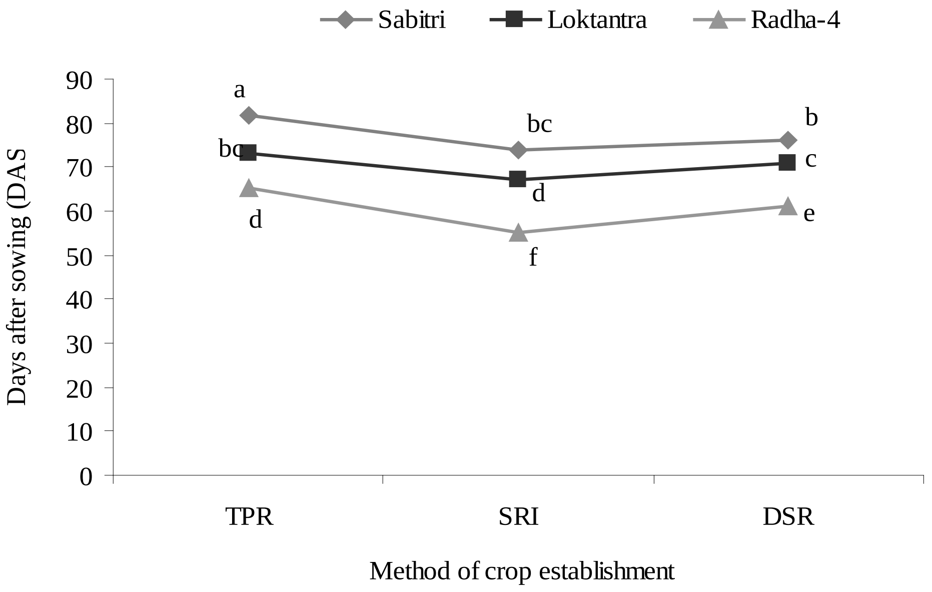

Figure 5. Interaction effect of method of crop establishment and varieties on panicle initiation stage of rice in days after sowing at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

4.1.2 Booting stage

This is the stage at which the sheath of the flag leaf shows some swelling and it generally occurs two weeks (12-18 days) after panicle initiation stage. The average booting stage was recorded at 84.39 DAS and it ranged from 75.25 DAS to 92.42 DAS (Table 4). Significantly earlier booting was recorded in SRI method (80.33 DAS) than DSR (84 DAS) significantly earlier than TPR 88.75 DAS. Similarly, Sabitri took significantly longer duration (92.42 DAS) to come at booting stage as compared to Loktantra (85.5 DAS) and Radha-4 (75.25 DAS) took significantly the shortest duration.

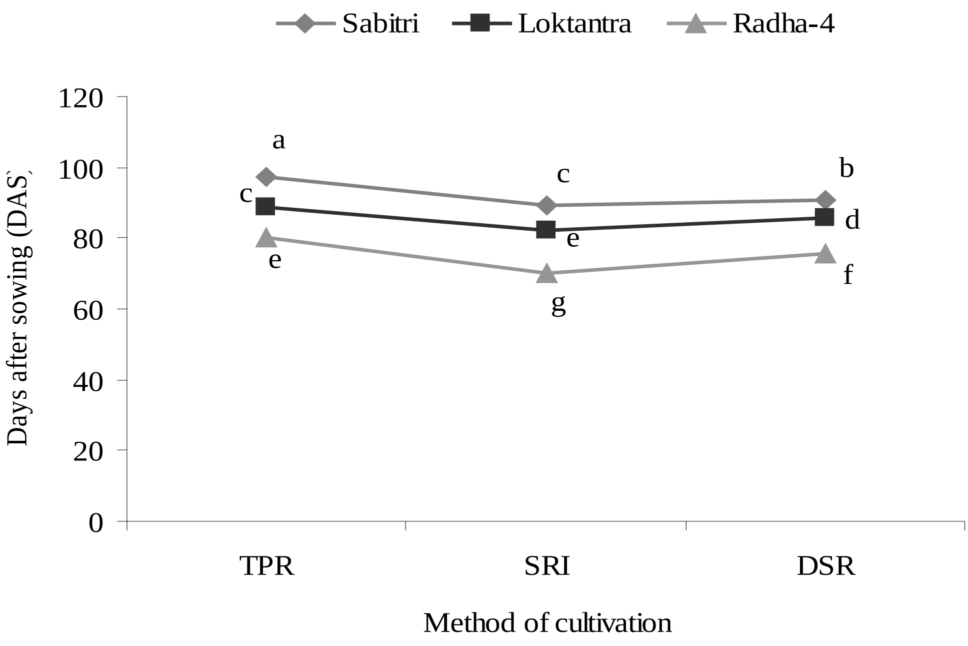

Figure 6. Interaction effect of method of crop establishment and varieties on booting stage of rice in days after sowing at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

The interaction effect of method of crop establishment and variety influenced the duration from sowing to booting stage (Appendix 19). The combination of TPR and Sabitri (97.25DAS) took statistically longer duration for booting and the duration for the combination of SRI and Radha-4 was significantly shorter, i.e. 70 DAS. The combination of TPR with Loktantra (88.75 DAS) and SRI with Sabitri (89 DAS) were statistically at par duration. In all the methods of cultivation booting was observed earlier in Radha-4 variety and later in Sabitri. In general, longer duration variety took long time to booting stage as compared to short duration variety.

Table 4. Phenological stages of rice as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Phenological stages (DAS)						
	Panicle Initiation	Booting stage	Heading stage	Flowering stage	Milking Stage	Dough stage	Maturity
Method of crop establishment							
Farmer Practice (TPR)	73.33^{a}	88.75^{a}	98.00^{a}	102.3^{a}	108.9^{a}	120.4^{a}	132.9^{a}
SRI	65.42^{c}	80.33^{c}	89.83^{c}	92.58^{c}	99.50^{c}	111.2^{c}	123.2^{c}
DSR	69.33^{b}	84.08^{b}	93.25^{b}	96.83^{b}	103.8^{b}	115.3^{b}	126.8^{b}
LSD (P = 0.05)	2.11	2.23	1.28	1.66	0.99	1.125	1.56
SEM ±	0.61	0.64	0.37	0.48	0.29	0.3252	0.45
Varieties							
Sabitri (V1)	77.25^{a}	92.42^{a}	102.5^{a}	105.2^{a}	111.3^{a}	122.3^{a}	135.6^{a}
Loktantra (V2)	70.25 ^{b}	85.50^{b}	95.17^{b}	99.50^{b}	106.8^{b}	119.4^{b}	131.3^{b}
Radha 4 (V3)	60.58 ^{c}	75.25^{c}	83.42^{c}	87.08^{c}	94.17^{c}	105.3^{c}	116.0^{c}
LSD (P = 0.05)	1.18	1.14	1.43	1.27	1.07	1.13	1.10
SEM ±	0.40	0.38	0.48	0.43	0.36	0.38	0.37
CV %	1.99	1.57	1.78	1.52	1.19	1.14	1.01
Grand Mean	69.36	84.39	93.69	97.25	104.08	115.64	127.64

DAS, Days after sowing ; Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

4.1.3 Heading stage

Booting stage is followed by the emergence of panicle tip (heading) out of the flag leaf sheath. Generally, heading starts 3 weeks after panicle initiation (Prasad, 1999). The

Data (Table 4) showed that on an average heading stage in the experiment was recorded at 93.69 DAS and it ranged from 83.42 DAS to 102.5 DAS among method of crop establishment and varieties. The duration for booting stage was significantly longer for TPR (98 DAS), followed by DSR (93 DAS) and the shortest for SRI (89.93 DAS). Variety also significantly influenced the period from sowing to heading stage. Sabitri had significantly longer duration (102.5 DAS) to come at heading stage whereas Radha-4 had comparatively shorter duration (83.42 DAS) to come at heading stage. There was no interaction between different method of crop establishment and varieties on days to heading from sowing. The similar research at Punjab Agriculture University by Mahajan and Sarao. (2009) revealed the similar findings that early heading on SRI (72 DAT +10 days old seedlings) then DSR (84 DAS) and for conventional TPR (62DAT + 35 days old seedling).

4.1.4 Flowering

Anthesis or flowering refers to a series of events between the opening and closing of the spikelet, the lasting about 1-2.5 hours. It takes 7-10 days for all the spikelets within the same panicle to complete anthesis; most of the spikelets complete anthesis within 5 days. Within the same field, it takes 10-14 days to complete heading because panicle exertion varies within tillers of the same plant and between plants in the same field. Hence, it takes about 15-20 days for all the spikelets of a crop to complete anthesis (Yoshida, 1981).

The average duration for the flowering stage was 97.25 DAS and it varied from 87 DAS to 105 DAS among different dates of sowing and varieties (Table 4). Significantly earlier flowering stage (92.58 DAS) was recorded in SRI method whereas TPR (102 DAS) had taken statistically longer duration for flowering. Varieties also significantly influenced on the days to come at flowering. The variety (Sabitri) had significantly longer days, i.e.

105 DAS for flowering followed by Loktantra and significantly shorter duration, i.e. 87 days was taken by variety Radha-4. There was no significant interaction between different method of crop establishment and varieties on days to flowering stage from sowing.

4.1.5 Dough stage

When ripening advances, milky liquid in grains becomes thicker and finally attains dough stage (Prasad, 1999). The appraisal of data in the Table 4 showed that the average duration for the soft dough stage was 104 DAS and it varied from 94 DAS to 111 DAS depending up on the different method of crop establishment and varieties. From the analysis, it was observed that soft dough was significantly later in TPR (109 DAS), followed by DSR (104 DAS) and significantly earlier in SRI (100 DAS). Similarly, variety also significantly influenced on soft dough stage. Sabitri had longer duration (111DAS) for soft dough duration whereas the time taken for Radha-4 to come at soft dough stage was significantly shorter, i.e. 94 DAS. The appearance of hard dough stage in the experiment took 105 DAS to 122 DAS depending up on the method of crop establishment and varieties, and the average duration taken by the rice crop for this stage was 115 DAS. SRI method took significantly shorter duration (111 DAS) for hard dough stage than other methods. The period from sowing to hard dough stage was significantly higher for Sabitri (122 DAS) followed by Loktantra (119 DAS) and the shortest for Radha-4 (105 DAS)

The interaction between method of crop establishment and variety significantly influenced days to soft dough and hard dough stage from sowing (Appendix 19 and 20). The combination of TPR and Sabitri had significantly longer duration for soft dough and hard dough stage whereas the combination of SRI and Radha-4 had significantly shorter duration for Soft dough and hard dough stage. For all varieties, soft dough and hard dough stages were attained significantly earlier in SRI followed by DSR and at the last by TPR method of crop establishment (Figure 7).

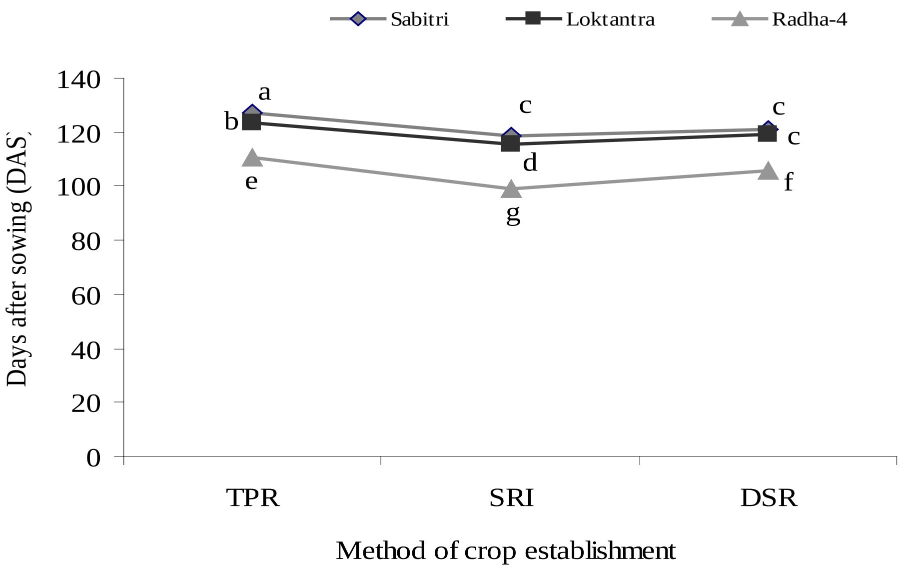

Figure 7. Interaction effect of method of crop establishment and varieties on hard dough stage of rice in days after sowing at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance.

4.1.6 Physiological maturity stage

The grain is said to be matured when grain color in the panicles begins to change from green to yellow. The individual grain is mature, fully developed, and is hard and free from green tint. The mature grain stage is complete when 90-100% of the filled spikelets have turned yellow. At this time, senescence of the upper leaves including the flag leaves is noticeable (De Datta, 1981).

The average physiological maturity stage was observed at 128 DAS (Table 4) and varied from 116 DAS to 136 DAS in response to different date of sowing and variety. Statistical analysis of the data recorded at this stage showed that physiological maturity was significantly earlier in SRI (123 DAS) method of crop establishment followed by DSR (126 DAS) and at the last TPR (132DAS). Variety also significantly influenced the period from sowing to physiological maturity. Variety Sabitri had significantly longer duration i.e. 136 DAS to fully ripen the crop, whereas the time taken to come at fully ripen stage for Radha-4 was observed to be significantly shorter, i.e. 116 DAS.

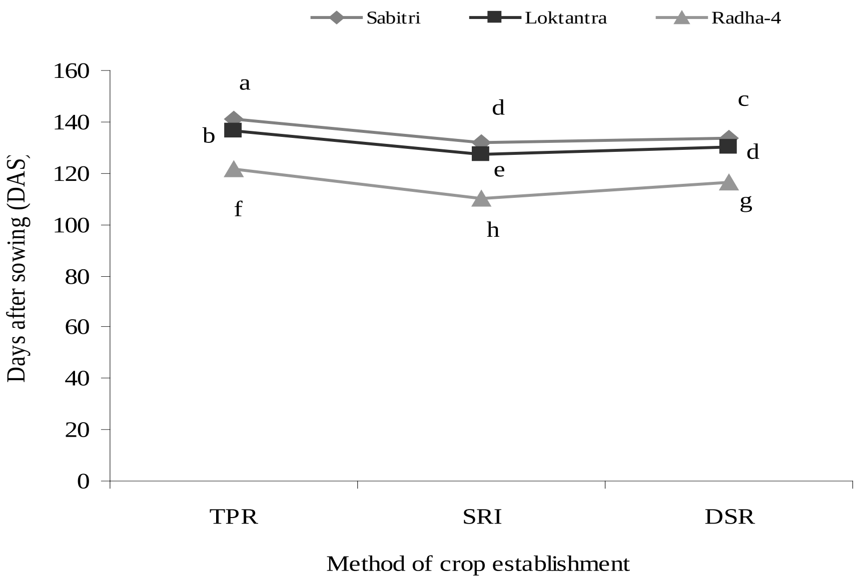

Figure 8. Interaction effect of method of crop establishment and varieties on physiological maturity stage of rice in days after sowing at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

The interaction effect of different method of crop establishment and varieties were observed on days to physiological maturity stage was significant (Appendix 20, Figure 8). The combination of TPR and Sabitri had significantly longer duration i.e. 141 DAS for physiological maturity followed by variety Loktantra under TPR (136 DAS), Sabitri under DSR (134 DAS), Sabitri under SRI (131.8 DAS) and Loktantra under DSR (130.3 DAS) are statistically at par, Loktantra under SRI (128 DAS), Radha-4 under TPR (121 DAS), Radha-4 under DSR (117 DAS) and finally the shortest duration for physiological maturity was observed in combination of SRI and variety Radha-4 (110 DAS). In general, in different varieties, the time taken for physiological maturity for TPR method has significantly longer duration where as it was the shortest in case of SRI method in the experiment.

Similar research in Thailand by Sanjeewane *et al.* (2009) reported that flowering commenced earlier in DSR than TPR, and also phonological stages was earlier in alternate wetting and drying than in continuous flooding method. The same difference existed even up to 50% flowering and maturity. The differences could have been associated with time required to establish the root system of transplanted seedlings as suggested by McDonald *et al.* (2006). Water stress leads to growth pthe lasticity, and shortening the time interval between phenological stages (Puckridge and O'Toole, 1980; Turner *et al.*, 1986; Inthapan and Fukai, 1988).

4.2 Biometrical observation of rice

4.2.1 Plant height

The plant height varied from 44.86 cm (35 DAS) to 123.5 cm (95 DAS) and increasing up to 95 DAS (Table 5, Figure 9). The increment in plant height was prominent (42.33 %) between 35 DAS and 50 DAS, which represents the rapid vegetative growth stage of plant coinciding with the stage of maximum tillering. Plant heights were significantly influenced by method of crop establishment at all observation. Similarly, plant heights of varieties were also significantly different among each other at all dates of observation. Maximum plant height was observed at 95 DAS of SRI method (128.9 cm) which is significantly higher than DSR (123.3cm) and the shortest height was of TPR (118cm). At 35 DAS, significantly tall plant height (54.87 cm) was observed in SRI method and significantly short plant height (31.52cm) was observed in TPR which could be due to late transplantation in TPR and higher competition in nursery bed. In case of 50 DAS significantly tall plant height (72.01 cm) was observed in SRI method and significantly short plant height (59.33 cm) was observed in TPR, which was at par with DSR (60.22 cm). Significantly tall plant height (92.53 cm) was observed in SRI method in case of 65 DAS and at the same observation short plant height (79.88 cm) was observed in TPR which was at par with DSR (82.33 cm). At 80 DAS, significantly tall plant height

(111.6 cm) was observed in SRI method followed by DSR (104.5 cm) and the shortest plant height was observed in TPR (97.28 cm). At 95 DAS taller plant height was observed in SRI method (128.9cm which was statistically at par with DSR (123.3cm) and significantly short plant height (118.3 cm) was observed in TPR which was also at par with DSR. At harvest maximum plant height was observed in SRI method (115.1 cm) followed by DSR method (110.1 cm) and the shortest was observed in TPR (104.7 cm) Mahajan and Sarao. (2009) on the similar research at Ludhiana India found similar result on i.e. SRI (10 days old seedling transplanted) 109.7 cm, DSR with other SRI management (101.4 cm) and TPR conventional (100.6cm). It is obvious that the reduction in plant height was attributed to the senescence of leaves and bending down of panicle and the height was measured up to the bend.

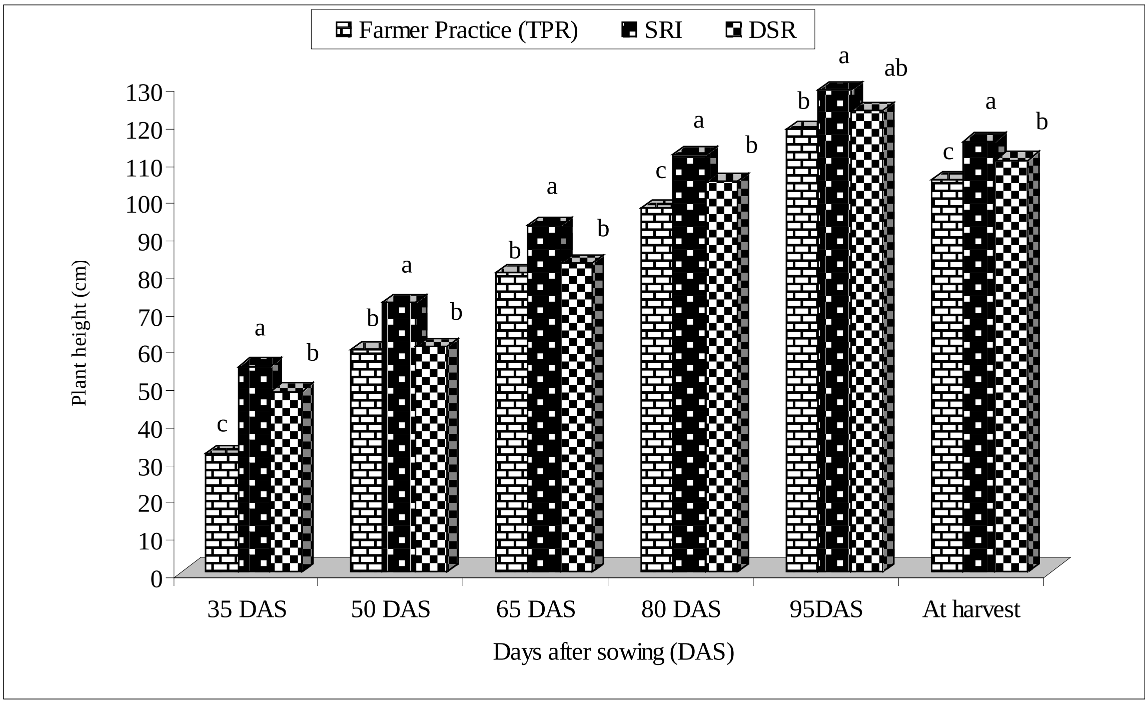

Figure 9. Plant height (cm) of rice as influenced by method of crop establishment at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

Table 5. Plant height of rice as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Plant height (cm)					
	35 DAS	50 DAS	65 DAS	80 DAS	95DAS	At harvest
Method of crop establishment						
Farmer Practice (TPR)	31.52^{c}	59.33^{b}	79.88^{b}	97.28^{c}	118.3^{b}	104.7^{c}
SRI	54.87^{a}	72.01^{a}	92.53^{a}	111.6^{a}	128.9^{a}	115.1^{a}
DSR	48.20^{b}	60.22^{b}	82.33^{b}	104.5^{b}	123.3^{ab}	110.1^{b}
LSD(P = 0.05)	3.71	3.98	5.18	5.57	6.25	4.49
SEM ±	1.07	1.15	1.50	1.61	1.81	1.30
Varieties						
Sabitri (V1)	41.74^{b}	60.80^{b}	79.36^{b}	96.57^{b}	115.2^{c}	104.1^{b}
Loktantra (V2)	47.75^{a}	66.53^{a}	89.18^{a}	107.3^{a}	132.5^{a}	122.9^{a}
Radha 4 (V3)	45.10^{a}	64.22^{a}	86.21^{a}	109.4^{a}	122.8^{b}	102.9^{b}
LSD (P = 0.05)	2.669	3.271	3.548	4.553	4.497	4.807
SEM ±	0.8982	1.101	1.194	1.532	1.514	1.618
CV %	6.94	5.97	4.88	5.08	4.25	5.10
Grand Mean	44.864	63.850	84.914	104.436	123.506	109.969

DAS, Days after sowing ; Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

At 35 DAS, Loktantra (47.75 cm) and Radha-4 (45.1 cm) were statistically at par in height and are significantly taller as compared to variety Sabitri (41.74 cm). In 50 DAS, Loktantra (66.53 cm) was statistically at par with Radha-4 (64.22 cm) but are significantly taller than variety Sabitri (60.80 cm). At 65 DAS, Loktantra (89.18 cm) and Radha-4 (86.21 cm) had higher plant height and are statistically at par at the same time significantly taller than Sabitri (79.36 cm). At 80 DAS, Sabitri (96.57 cm) reported significantly shorter plant height as compared to Loktantra (107.3 cm) and Radha-4 (109.4 cm) which were at par to each other. Significantly higher plant height (132.5 cm) was recorded in Loktantra at 95 DAS followed by Radha-4 (122.8 cm) and the shortest was Sabitri (115.2 cm). At harvest Loktantra reported significantly higher plant height (122.9 cm) than Radha-4 (102.9 cm) and Sabitri (104.1) which were at par with each other.

4.2.1.1 Interaction effect of sowing date and varieties on plant height

There was significant interaction between method of crop establishment and varieties at 80 DAS and 95 DAS on plant height (Appendix 21). At 80 DAS interaction effect of SRI method and Radha-4 variety recorded the maximum height (126.9 cm) followed by the combination of Loktantra in all three methods, Sabitri under SRI, Radha-4 under DSR, which were statistically at par, i e. statistically non different (Figure 10).

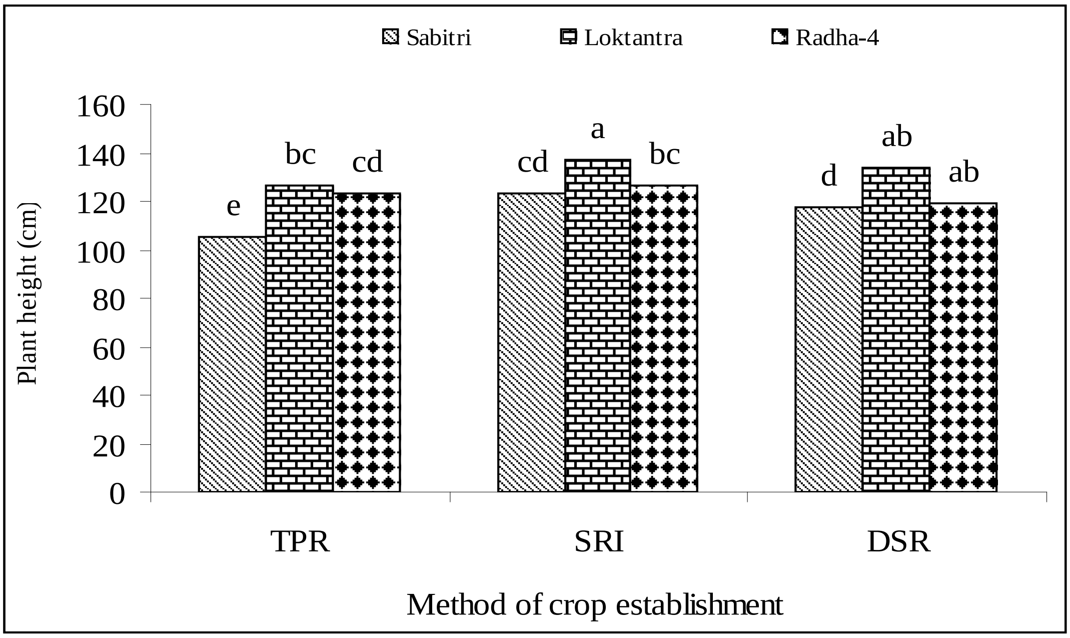

Figure 10. Interaction effect of method of crop establishment and varieties on plant height of rice at 95 DAS at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

The shortest plant height was observed in the combination of TPR and Sabitri (90.38 cm) variety which was statistically similar to Radha-4 under TPR. It was observed that the highest plant height was recorded with interaction of Radha-4 variety under SRI due to favorable growing condition for its earlier phonological stages completion. At 95

DAS, maximum plant height was recorded in combination of Loktantra under SRI (137.3 cm) and was statistically at par with Loktantra under DSR. The lowest plant height was observed in combination of TPR and Sabitri (105.20 cm). The interaction effect was mainly due to different maturity period for different varieties and method of crop establishment that created different growing condition.

4.2.2 Numbers of tillers per square meter

The number of tillers per square meter was significantly influenced by different method of crop establishment and varieties (Table 6). Different method of crop establishment influenced tillers per square meter in all the observation taken. The highest number of tillers per square meter (262.0) was observed in SRI method at 35 DAS. It was significantly higher than DSR (132.3) and TPR (127.9), which were statistically at par with each other. At 50 DAS, the highest number of tillers per square meter was in SRI (406.3) method and was statistically at par with TPR (389.8) but were significantly higher than DSR (309.5). Similarly, higher number of tillers at 65 DAS was observed in SRI (408.8) method which was statistically at par with TPR (385.1) but significantly higher than DSR (350.3). At the same time, TPR and DSR were also statistically at par. No significant effect was observed at 85 DAS. Higher number of tillers at 95 DAS was observed in SRI (265.5) method, which was statistically at par with DSR (245.2), but significantly higher than TPR (216.7). At the same time, TPR and DSR were also statistically at par. At harvest significantly higher number of tiller per square meter (256.9) was observed in SRI, followed by DSR (234.4) and significantly lower tiller number recorded from TPR (208.9). Significantly higher tillers per square meter were observed with SRI method in all the observations. This may be due to the optimum time of transplantation to utilize the potential tillering capacity, better growing condition, less competition for nutrients and sunlight. According to Gupta *et al.* (1976) and Hossain *et al*. (2002), intermittently irrigated rice produced more adventitious tillers. Tillering ability in rice has a close relationship with the number of phyllochrons completed before entering the reproductive stage (Nemoto *et al*., 1995; Stoop *et al*., 2002). The duration of phyllochrons is influenced by a number of environmental factors and biophysical growing conditions for the plant: soil and ambient temperature, exposure to sunlight, spacing, nutrient availability, soil friability vs. compaction, soil moisture vs. desiccation, and soil aeration vs. hypoxia (Nemoto *et al*., 1995). Thus higher number of tillers produced in SRI method is due to early transplanting of seedling and providing favorable condition to exploit maximum phyllochrons.

Varieties had also significant influence on tillers per square meter. No significant difference was observed in tiller number per square meter at 35 DAS due to varietal difference. Significantly higher tillers per square meter were observed in Radha-4 at 50, 65, 80 and 95 DAS whereas lower tiller per square meter was observed in Loktantra. At 50, 65 and 80 DAS Radha-4 and Sabitri were statistically at par in tiller number per square meter. Similarly, Sabitri and Loktantra were at par at 65 and 95 DAS. Significantly the highest tiller numbers per square meter at harvest was recorded in Radha-4 (259.0) followed by and Sabitri (232.8) and the lowest numbers in Loktantra (208.4).

The difference in tiller production among cultivars may be attributed to varietal characters (Chandrashekhar *et al.*, 2001). Higher numbers of tiller per square meter causes the higher numbers of leaves per unit area. The higher numbers of leaves produced high LAI ultimately the more photosynthesis. This indicates the highly significant relationship between the number of tillers per square meter at harvest and grain yield (r = 0.712**) (Appendix 35).

Tillers decrease from 65 DAS to till harvesting was due to tiller mortality. The highest number of tillers mortality was observed in SRI (48.14%), which was at par with

TPR (47.42%) method, whereas DSR method reported the significantly lower tiller mortality (37.65%). There was no significant effect of variety on tiller mortality percentage. Singh and Jain (2000) observed that tiller production increased sharply from active tillering to panicle initiation stage and declined gradually toward flowering and remained almost constant during ripening phase.

Table 6. Number of tillers per square meter of rice as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Number of tillers per m^2						
	35 DAS	50 DAS	65 DAS	80 DAS	95DAS	At harvest	Mortality%
Method of crop establishment							
Farmer Practice (TPR)	127.9^{b}	389.8^{a}	385.1^{ab}	321.65	216.7^{b}	208.9^{c}	47.42^{a}
SRI	262.0^{a}	406.3^{a}	408.8^{a}	276.60	265.5^{a}	256.9^{a}	48.14^{a}
DSR	132.3^{b}	309.2^{b}	350.3^{b}	312.77	245.2^{ab}	234.4^{b}	37.65^{b}
LSD(P = 0.05)	48.64	43.89	39.16	NS	31.24	13.33	4.88
SEM ±	14.06	12.68	11.32	8.47	9.03	3.85	1.41
Varieties							
Sabitri (V1)	178.25	405.7^{a}	389.9^{ab}	321.7^{a}	236.5^{b}	232.8^{b}	45.17
Loktantra (V2)	152.49	317.8^{b}	348.5^{b}	276.6^{b}	230.5^{b}	208.4^{c}	43.37
Radha 4 (V3)	191.46	381.9^{a}	405.7^{a}	312.8^{a}	260.5^{a}	259.0^{a}	44.67
LSD (P = 0.05)	NS	49.72	43.57	26.43	20.50	9.40	NS
SEM ±	12.02	16.73	14.66	8.89	6.900	3.16	1.60
CV %	23.93	15.73	13.32	15.41	9.86	4.69	12.45
Grand Mean	174.07	368.45	381.39	303.68	242.46	233.41	44.40

DAS, Days after sowing ; Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

4.2.2.1 Interaction effect of method of crop establishment and varieties on tillers per square meter

There was significant interaction between rice varieties and date of sowing on tillers per square meter at harvest (Appendix 21). Radh-4 produced the significantly the highest number of tillers under SRI method (295.4) followed by the interaction of Radha-4 and DSR (255.8) and Sabitri under SRI (251.4) but later two were statistically not different, whereas significantly lesser numbers of tiller (191.1) at harvest was observed in the interaction of Loktantra under TPR (Figure 11).

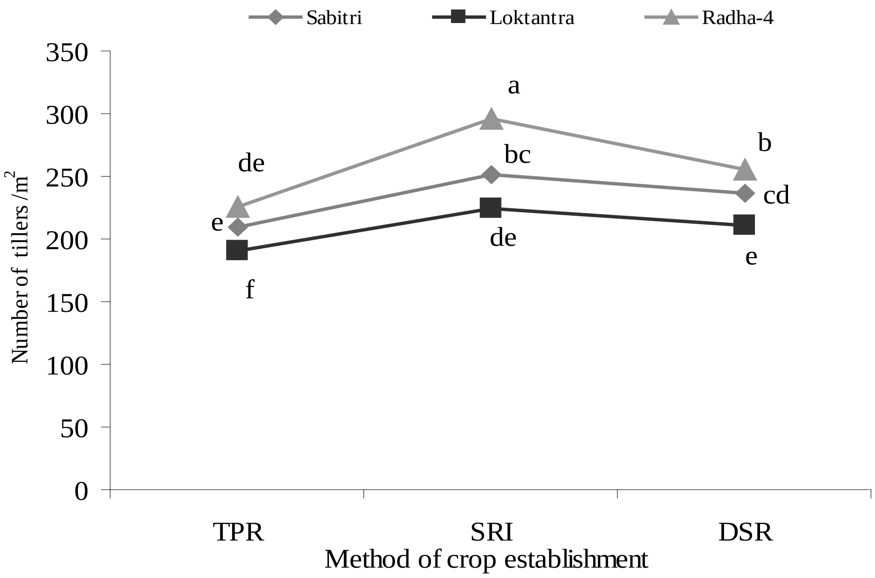

Figure 11. Interaction effect of method of crop establishment and varieties on tiller number per square meter of rice at harvest at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

4.2.3 Leaf area index (LAI)

The leaves of a plant are normally its main organ of photosynthesis and the total area of leaves per unit ground area, called leaf area index (LAI), has therefore been proposed by Watson (1947) as the best measure of the capacity of a crop producing dry matter and called it as productive capital. LAI values steadily increased and reached maximum at 80 DAS on an average and declines in most of the cases. But leaf area index increased in case of DSR method and variety Loktanta. The peak LAI reached a value of 4.01 at 95 DAS in treatment combination of TPR with Sabitri variety.

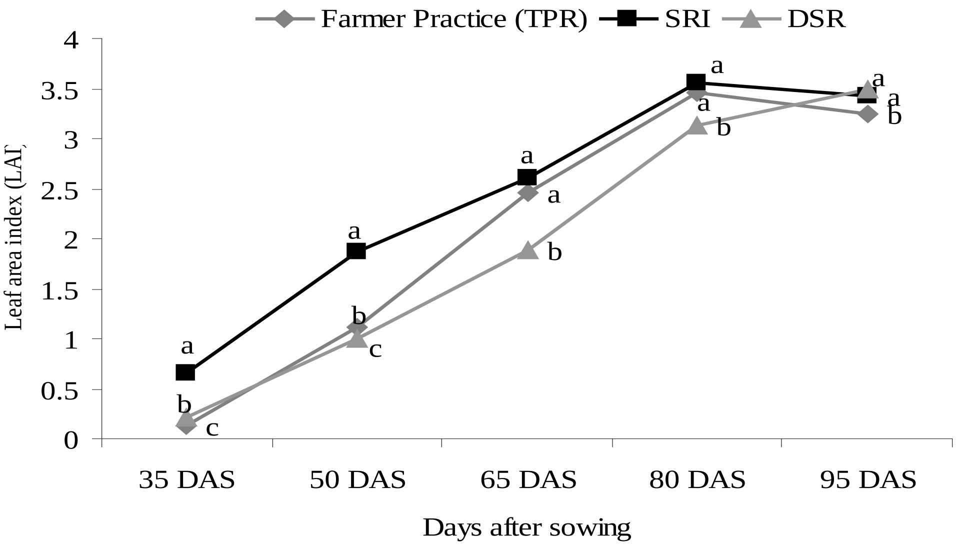

Figure 12. Leaf area index (LAI) as influenced by method of crop establishment of rice at Phulbari, Chitwan 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

The average leaf area index increased (Table 7) from 35 DAS to 80 DAS (3.39) and declined towards maturity mainly due to leaf senescence. Leaf area index ranged 0.135 to 4.01 from 40 DAS to 80 DAS.

At 35 DAS, leaf area index was significantly higher in SRI method (0.668), followed by DSR (0.221) and significantly lower leaf area index was observed in TPR (0.135). Significantly higher value (1.875) at 50 DAS was observed in SRI followed by TPR (1.114) and statistically lower value was observed in DSR (0.995). At 65 DAS, SRI method produced maximum LAI (2.599) and statistically similar value was observed in TPR (2.455), whereas the DSR (1.891) produced statistically lower LAI than SRI and TPR. At 80 DAS, maximum LAI value was observed in SRI (3.556) statistically similar value was observed in TPR (3.463) whereas the DSR (3.163), produced statistically lower LAI than SRI and TPR. Zheng *et al.* (2004) reported that SRI practices have shown higher

LAI than conventional rice production systems. Thakur *et al.* (2010) reported in spite of SRI having fewer hills per unit area, the leaf area index (LAI) with SRI practice was greater than recommended method due to larger leaves. These together with altered plant architecture, contributed to more light interception by SRI plants. At anthesis, the number of leaves and the leaf area per hill in the SRI treatment were significantly higher than in recommended management practice. SRI hills had more than twice the number of leaves and three times the total leaf area of each hill.

Table 7. Leaf area Index of rice as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Leaf Area Index				
	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS
Method of crop establishment					
Farmer Practice (TPR)	0.135^{c}	1.114^{b}	2.455^{a}	3.463^{a}	3.254^{b}
SRI	0.668^{a}	1.875^{a}	2.599^{a}	3.556^{a}	3.424^{a}
DSR	0.221^{b}	0.9947^{c}	1.891^{b}	3.136^{b}	3.500^{a}
LSD (P = 0.05)	0.032	0.089	0.184	0.255	0.138
SEM ±	0.009	0.026	0.053	0.074	0.040
Varieties					
Sabitri (V1)	0.287^{b}	1.181^{c}	1.912^{c}	3.330	3.283^{b}
Loktantra (V2)	0.296^{b}	1.311^{b}	2.104^{b}	3.268	3.870^{a}
Radha 4 (V3)	0.440^{a}	1.488^{a}	2.928^{a}	3.557	3.026^{c}
LSD (P = 0.05)	0.027	0.085	0.176	NS	0.196
SEM ±	0.009	0.029	0.059	0.092	0.066
CV %	11.05	7.41	8.81	9.43	6.69
Grand Mean	0.34	1.33	2.32	3.39	3.39

DAS, days after sowings; NS, non-significant. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

Relatively higher LAI was observed in Radha-4 from 35 DAS to 65 DAS. In case of Radha-4 and Sabitri, LAI increased up to 80 DAS but in Loktantra LAI increased up to 95 DAS. The significant effect of variety on LAI was observed at 35,50,65 and 95 DAS.

From 35 DAS to 65 DAS, significantly higher LAI was observed in Radha-4 followed by Loktantra and Sabitri was statistically lower. At 80 DAS, LAI was not statistically significant among the varieties. At 95 DAS maximum LAI was observed in Loktantra (3.87) followed by Sabitri (3.283) and the lowest was observed in Radha-4 (3.026). Higher LAI of variety Loktantra at 95 DAT was due to larger leaf size and statistically similar number of leaf per tiller among the varieties. Leaf expansion in variety Loktantra was rapid, which indicated that it had better growth rate during the vegetative stage compared to the other varieties. Higher LAI generally means higher light interception due to the leaf area's ratio to the ground area occupied by the crop and slower leaf senescence. Slower leaf senescence generally lead to higher photosynthesis due to the remaining larger green leaf area to intercept light for photosynthesis and to produce more assimilates. Shin and Kwon (1985) reported that the green leaf area 30 days after heading is positively correlated with grain weight. Gardner *et al.* (1985) reported that an LAI of 3-5 is necessary for maximum dry matter production of most cultivated crops.

4.2.3.1 Interaction effect of method of crop establishment and varieties on LAI

The interaction effect of method of crop establishment and varieties was observed at all dates of observation (Appendix 22 and 23). From 35 DAS to 65 DAS combination of SRI method and variety Radha-4 produced statistically the highest LAI, whereas the combination of TPR with Sabitri produced the lowest at 35 DAS, similarly combination of DSR and Sabitri produced the lowest LAI at 50 and 56 DAS. At 80 DAS, Loktantra under SRI (3.92) produced significantly higher LAI followed by Sabitri under SRI and DSR, Radha-4 under DSR, at the same time the lowest LAI was produced by Loktantra under DSR (2.45). This is due mainly to the slower crop growth rate of DSR crops up to 65 DAS. LAI at 95 DAS, when all the varieties under any method of crop establishment had crossed the phonological stage of heading play major role in yield formation also shows interaction effect. Significantly higher LAI was produced by the combination of variety Loktantra under TPR method (4.01) and was followed by Loktantra under SRI (3.77) and DSR (3.84), Sabitri under SRI (3.65), (Figure 13).

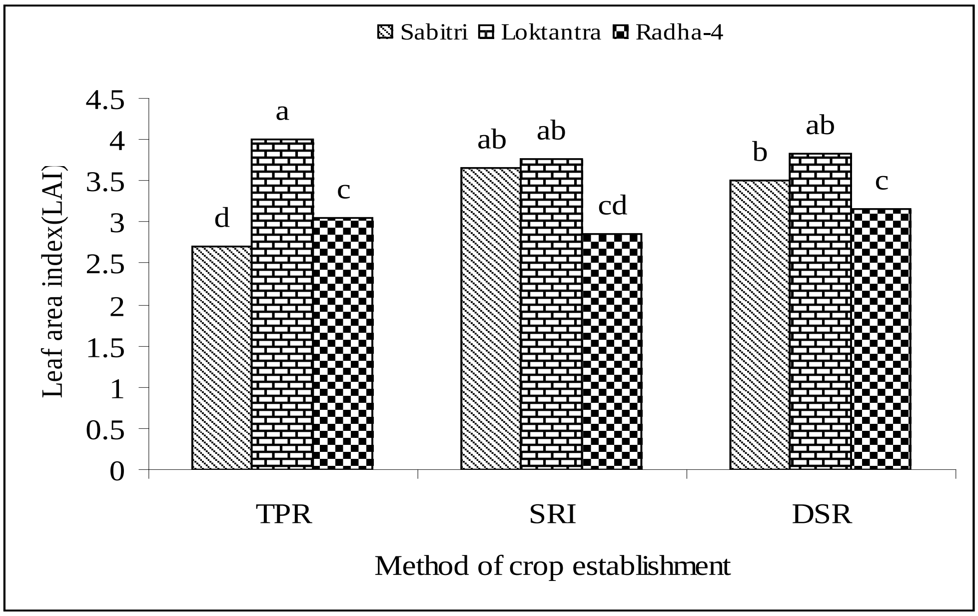

Figure 13. Interaction effect of method of crop establishment and variety on LAI at 95 days after sowing of rice at IAAS, Rampur, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

4.2.4 Dry mater production

High production of total dry matter per unit area is the first prerequisite for high yield. The amount of dry matter production depends on effectiveness of photosynthesis of crop and furthermore, on plants whose vital activities are functioning effectively. The total yield of dry matter is the total amount of dry matter produced, less the photosynthates used for respiration. Finally, the manner in which the net dry matter produced is distributed among different parts of the plant, which determine magnitude of the economic yield (Arnon, 1972).

Initially investment of new incremental biomass partitioning is on the leaves, roots and stem at the earlier stage of growth (50 DAS), later in stem, which increases up to (80 DAS and ultimately in the storage organ, i.e. panicle at the milking stage (95 DAS) (Table 8, 9, 10). At the initial stage 35 DAS of crop, the partitioning of root, stem and leaf, to the total dry matter was (30% by root, 36% by stem and 34% by leaf) but later stage the partitioning of the total dry matter in stem was comparatively higher (44.33% at 50 DAS, 44.85% at 65 DAS, 53.18% at 80 DAS, and 62.16% at 95 DAS). While at the booting to heading stage (95 DAS), the partitioning of the total dry matter in stem increased sharply (62.16%) which also include panicle development inside of the sheath, due to utilization of assimilates in the formation of panicle and partitioning of total dry matter towards stem covering panicle was higher than the leaf (20.56%). The partitioning of the total dry matter in leaves production higher (34.24%) at 35 DAS and their after declined due to higher proportionate increase in stem dry matter and at latter stage due to drying and shedding of old leaves. The data shows as 28.76% at 50 DAS, 25.86% at 65 DAS, 23.72% at 80 DAS, and 20.56% at 95 DAS, respectively at 70 and 85 DAS). The contribution of root in total dry matter was higher (29.82%) in the early growth stage (35 DAS) and their after declined gradually (26.08%, 29.28%, 23.73%, and 17.56%, respectively at 50, 65, 80 and 95 DAS). The reduction in dry matter of roots at later stage was due to degeneration of older roots Wu *et al.* (1998) observed similar trend in the partitioning of dry matter.

Table 8. Total dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Dry matter (g/0.25m^{2}) at 35 DAS				Dry matter (g/0.25m^{2}) at 50 DAS			
	Root	Stem	Leaf	Total	Root	Stem	Leaf	Total
Method of crop establishment								
Farmer Practice (TPR)	1.51^{c}	1.43	1.402^{b}	4.34^{c}	6.90^{c}	10.63^{c}	10.79^{b}	28.31^{c}
SRI	6.29^{a}	8.62^{a}	8.05^{a}	22.97^{a}	21.00^{a}	38.86^{a}	22.23^{a}	82.09^{a}
DSR	2.39^{b}	2.26^{b}	2.253^{b}	6.91^{b}	13.59^{b}	18.87^{b}	11.34^{b}	43.79^{b}
LSD (P = 0.05)	0.67	0.61	0.8634	1.94	2.33	5.82	1.677	7.79
SEM ±	0.19	0.18	0.2495	0.56	0.67	1.68	0.4845	2.25
Varieties								
Sabitri	3.70	4.00^{b}	3.607^{b}	11.30^{ab}	11.21^{b}	18.92^{b}	12.40^{c}	42.53^{c}
Loktantra	2.97	3.64^{b}	3.808^{b}	10.42^{b}	14.96^{a}	22.29^{b}	14.86^{b}	52.11^{b}
Radha 4	3.52	4.67^{a}	4.297^{a}	12.49^{a}	15.31^{a}	27.14^{a}	17.10^{a}	59.56^{a}
LSD (P = 0.05)	NS	0.51	0.4095	1.19	2.63	3.67	1.200	6.32
SEM ±	0.25	0.17	0.1378	0.40	0.88	1.24	0.4040	2.13
CV %	25.70	14.37	12.23	12.13	22.16	18.80	9.47	14.34
Grand Mean	3.40	4.10	3.904	11.40	13.83	22.79	14.785	51.40

DAS, days after sowings; NS, non significant. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

On an average, total dry matter production tendency of rice plants was found increasing from active vegetative stage (11.40 g/0.25 m^{-2} at 35 DAS) to (222.97 g/0.25 m^{-2} at 95 DAS), while root and leaves increased from active vegetative stage (3.40 and 3.90 g/0.25 m^{-2}, at 35 DAS, respectively) up to 80 DAS (47.62, 48.946 g/0.25m^{-2}, respectively) and there after dry matter of root and leaf declined from 80 DAS to 95 DAS (38.53 g/0.25m^{2} and 45.84 g/0.25m^{2}, respectively) but the stem dry matter increased from early stage 35 DAS(4.10g/0.25m^{2} to 95 DAS (138.60g/0.25m^{2}).

At 35 DAS, root, stem, leaf and total dry matter per unit area was significantly influenced by method of crop establishment (Table 8). Root dry matter was the highest due to SRI method (6.29 g/0.25m^{-2}) followed by DSR (2.39 g/0.25m^{-2}) which were statistically significant and TPR (45.92 g/0.25 m^{-2}) produced the least. Similar trend was observed in leaf, stem dry matter and total dry matter. SRI produced maximum of 22.97 g/0.25m^{2}, followed by DSR 6.91 and TPR produced 4.34 g/0.25m^{2}. At 50 DAS, also method of crop establishment significantly influenced in root, stem, leaf and total dry matter production. Significantly high root dry matter was produced by SRI method (21.0 g/0.25m^{2}) followed by DSR (13.19 g/0.25m^{-2}) and the lowest dry matter was produced under TPR method (6.9 g/0.25m^{-2}). Similarly the highest stem dry matter was also produced under SRI method and followed by DSR and the lowest under TPR method (Table 11). In case of leaf the highest dry matter was produced under SRI (22.23 g/0.25m^{-2}) and was significantly higher than DSR (11.34 g/0.25m^{-2}) and TPR (10.79 g/0.25m^{-2}) were statistically at par to each other. Total dry matter production also followed the same trend, i.e. SRI (82.90 g/0.25m^{-2}) with maximum dry matter followed by DSR(43.79 g/0.25m^{-2}) and the lowest by TPR (28.31 g/0.25m^{-2}).

Table 9. Total dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Dry matter(gm/0.25m^{2})at 65 DAS				Dry matter(gm/0.25m^{2})at 80 DAS			
	Root	Stem	Leaf	Total	Root	Stem	Leaf	Total
Method of crop establishment								
Farmer Practice (TPR)	30.59^{b}	40.88^{b}	28.37^{b}	99.85^{b}	39.48^{c}	84.68^{c}	44.04^{b}	168.2^{c}
SRI	44.59^{a}	83.94^{a}	41.72^{a}	170.3^{a}	56.30^{a}	141.6^{a}	57.20^{a}	255.1^{a}
DSR	34.29^{b}	42.81^{b}	26.56^{b}	103.7^{b}	47.10^{b}	102.9^{b}	45.59^{b}	195.6^{b}
LSD (P = 0.05)	4.10	6.41	3.032	11.24	5.42	12.75	3.224	17.63
SEM ±	1.17	1.85	0.8761	3.25	1.57	3.69	0.9318	5.10
Varieties								
Sabitri V1)	29.88^{b}	49.70^{b}	26.43^{c}	106.0^{c}	37.59^{b}	102.9^{b}	48.37^{b}	188.8^{b}
Loktantra (V2)	42.09^{a}	52.74^{b}	33.01^{b}	127.8^{b}	55.14^{a}	102.9^{b}	50.27^{a}	208.3^{a}
Radha 4 (V3)	37.51^{a}	65.18^{a}	37.22^{a}	139.9^{a}	50.14^{a}	123.4^{a}	48.19^{b}	221.7^{a}
LSD (P = 0.05)	5.42	5.59	2.858	8.44	5.19	10.29	1.836	14.40
SEM ±	1.82	1.88	0.9621	2.84	1.75	3.46	0.6179	4.85
CV %	17.31	11.67	10.37	7.90	12.72	10.93	4.37	8.14
Grand Mean	36.49	55.88	32.220	124.59	47.62	109.72	48.946	206.28

DAS, days after sowings; NS, non significant. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

Stem, leaf and total dry matter production were significantly influenced by method of crop establishment at 65 DAS (Table 9). Significantly higher stem dry matter was produced by SRI method (83.94 g/0.25m^{-2}) than DSR (42.81 g/0.25m^{-2}) and TPR (40.88 g/0.25m^{-2}), which were not significantly different to each other. Similar trend was followed in root, leaf and total dry matter production. Total dry matter production under SRI, DSR, and TPR were 170.3 g/0.25m^{-2}, 103.7 g/0.25m^{-2} and 99.85 g/0.25m^{-2}, respectively. At 80 DAS, method of crop establishment significantly influenced on root, stem, leaf and total dry matter production (Table 9). Higher dry matter in case of root was produced in SRI method (56.30 g/0.25m^{2}) this was followed by DSR (47.10 g/0.25m^{2}) and lower dry matter was produced by TPR (39.48g/0.25m^{2}). Similarly, stem and total dry matter followed the same sequence.

But in case of leaf dry matter SRI method produced the maximum, DSR (45.59 g/0.25m^{2}) and TPR (44.04 g/0.25m^{2}) which were statistically at par. At 95 DAS, method of crop establishment had significant effect on root, stem, leaf and total dry matter production. Root dry matter was significantly higher due to SRI method (49.93 g/0.25m^{2}) followed by DSR (37.14 g/0.25m^{2}) and the lowest in TPR (31.52 g/0.25m^{2}). Similar trend was observed in leaf, stem dry matter and total dry matter. Total dry matter produced was the highest in method SRI (259.4 g/0.25m^{2}) followed by DSR (240.9 g/0.25m^{2}) and the lowest in method TPR (168.7 g/0.25m^{2}).

Variety used in the experiment significantly influenced at 35 DAS in stem, leaf and total dry matter production (Table 8). There was no significant effect on root dry matter production at 35 DAS. Radha-4 produced significantly higher stem dry matter (4.67 g m^{-2}), and Sabitri (4.00 g/0.25m^{2}) and Loktantra (3.64 g/0.25m^{2}) were statistically at par. Leaf dry matter followed the same pattern as stem. Total dry matter produce was the highest in Radha-4 (12.49 g/0.25m^{2}) also Sabitri (11.30 g/0.25m^{2}) were statistically at par. Similarly Sabitri and Loktantra (10.42 g/0.25m^{2}) were also at par. At 50 DAS, root, stem, leaf and total dry matter production were significantly influenced by varieties. Higher root dry matter was produced by Radha-4 (15.31 g /0.25m^{-2}) statistically similar dry weight was produced by Loktantra (14.96 g /0.25m^{-2}) and lower root dry matter was observed in Sabitri (11.21 g /0.25m^{-2}). But, higher stem dry matter was produced by Radha-4 (27.14 g /0.25m^{-2}) followed by Loktantra (52.47 g /0.25m^{-2}) and Sabitri (49.70 g /0.25m^{-2}), which are statistically at par. Leaf dry matter was statistically higher in case of Radha-4 (17.10 g /0.25m^{-2}) followed by DSR (14.86 g /0.25m^{-2}) and significantly lower in Sabitri 12.40 g /0.25m^{-2}). Total dry matter followed the same trend as leaf dry matter. At 65 DAS root, stem, leaf and total dry matter production were significantly influenced by varieties. Root dry matter produced by Radha-4 and loktantra are statistically similar but Sabitri produced lower. Stem dry weight produced by variety Radha-4 was statistically higher and Loktantra and Sabitri produced similar quantity. Leaf dry matter produced was statistically higher in Radha-4 followed by Loktantra and the lowest in Sabitri. Similar trend was shown by total dry matter as Radha-4 (139.9 g /0.25m^{-2}) Loktantra 127.8 g /0.25m^{-2} and Sabitri 106.0 g /0.25m^{-2}. At 80 DAS, dry matter production was significantly influenced by method of establishment of rice. Significantly higher leaf dry matter was produced by Loktantra (50.27 g /0.25m^{-2}) and followed by Radha-4 (48.19 g /0.25m^{-2}) and Sabitri (48.37 g /0.25m^{-2}), which were statistically similar. Radha-4 produced higher stem dry matter and followed by Loktantra and Sabitri were at par. Root dry matter produced at 80 DAS was higher and statistically similar by Radha-4 and Loktantra and lower was produced by Sabitri. Similarly Loktantra (221.7g/0.25m^{-2}) and Radha-4 (208.0g /0.25m^{-2}) produce similar total dry matter, Sabitri (188.8 g /0.25m^{-2}) produced statistically lower dry matter. Finally, at 95 DAS (Table 10) root dry matter produced was higher in Loktantra followed by Sabitri and Radha-4 which are statistically similar. Stem dry matter produce followed the sequence of Radha-4, Loktantra, and Sabitri from higher to lower values. Leaf dry matter produced at 95 DAS was maximum in Loktantra (52.64 g /0.25m^{-2}), followed by Sabitri 46.19 g /0.25m^{-2}) and the least by Radha-4 (38.71 g /0.25m^{-2}). Total dry matter produced was higher by Radha-4 (229.8 g /0.25m^{-2}) and Loktantra (237.0 g /0.25m^{-2}) were statistically similar and lower was produced by Sabitri (202.1 g /0.25m^{-2}). Root dry matter increases from vegetative stage to 80 DAS in all varieties but it decreased after 80 DAS. In case of stem dry matter it increased in all observations. Leaf dry matter increased up to 80 DAS in Radha-4 and Sabitri varieties, where as it increased in all observations for loktantra variety. Evaluation of Mahajan and Sarao. (2009) on the performance of SRI against conventional transplanting method revealed that significant phenotypic changes occurred in plant structure and function.

Table 10. Total dry matter production as influenced by date of sowing and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Dry matter(gm/0.25m^2)at 95 DAS			
	Root	Stem	Leaf	Total
Method of crop establishment				
Farmer Practice (TPR)	31.52^c	97.32^b	39.84^b	168.7^c
SRI	46.93^a	161.4^a	51.10^a	259.4^a
DSR	37.14^b	157.1^a	46.60^a	240.9^b
LSD (P = 0.05)	4.86	9.62	4.659	10.33
SEM ±	1.41	2.78	1.346	2.99
Varieties				
Sabitri V1)	34.65^b	121.3^c	46.19^b	202.1^b
Loktantra (V2)	47.92^a	136.4^b	52.64^a	237.0^a
Radha 4 (V3)	33.02^b	158.1^a	38.71^c	229.8^a
LSD (P = 0.05)	3.44	7.72	2.743	9.46
SEM ±	1.16	2.60	0.9233	3.18
CV %	10.40	6.50	6.98	4.95
Grand Mean	38.53	138.60	45.845	222.97

DAS, days after sowings; NS, non-significant. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

4.2.4.1 Interaction effect of method of crop establishment and varieties on dry weight

The dry matter of root at 80 DAS and 95 DAS was significantly influenced by interaction between method of crop establishment and varieties (Appendix 26, 27). In both the dates combination of SRI method and Loktantra (70.06 g/0.25m^2 and 50.10 g/m^2, respectively) produced the highest dry matter per unit area. At 80 DAS, it was followed by Radha-4 under SRI and the lowest was produced by Sabitri variety in all the methods. At 95 DAS the interaction effect in root dry matter production showed the lowest dry weight in treatment combination of Sabitri variety under TPR (Figure 14).

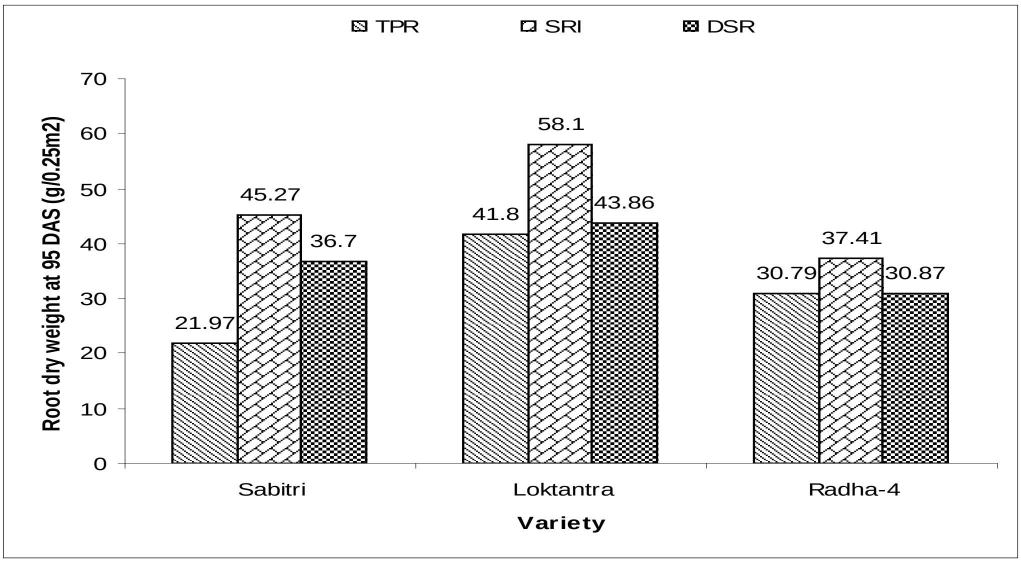

Figure 14. Interaction effect of method of crop establishment and varieties on dry weight of root (g/0.25 m^2) at 80 days after sowing of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

There was significant interaction between method of crop establishment and on dry weight of stem in all the dates (35DAS, 50DAS, 65 DAS, 80 DAS and 95 DAS) (Appendix 25, 26). The stem dry weight produced was the highest in treatment combination of Radha-4 under SRI method on all dates of observation from 35 DAS (0.83g/0.25m^2) to 95 DAS (188.2 g/0.25m^2). At 95 DAS the second ranking was the combination of Radha-4 under DSR (177.2g/0.25m^2) and was statistically similar to the first one and the least was produced under TPR of Sabitri (Figure 17).

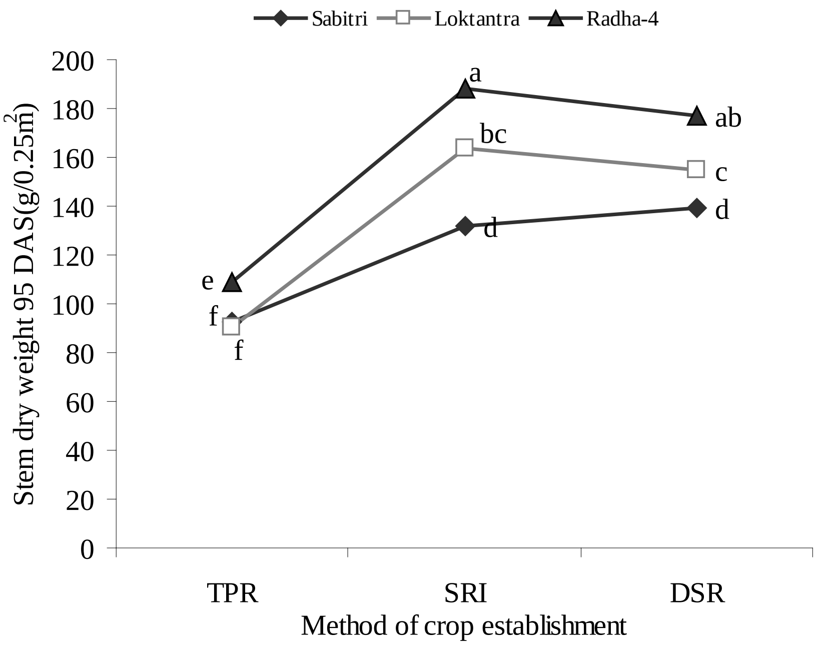

Figure 15. Interaction effect of method of crop establishment and varieties on dry weight of stem (g/0.25 m^2) at 95 days after sowing of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance.

Leaf dry weight production shows interaction effect on 50 DAS, 65 DAS, 80 DAS, 95DAS (Appendix 23, 24). Treatment combination of Radha-4 under SRI method produced higher dry weight per 0.25 m^2 area on 50 DAS (27.52 g) and 65 DAS (50.71 g). At 80 DAS, Loktantra under SRI (68.19 g/0.25m2) produced higher dry weight, and Loktantra under DSR and TPR, Sabitri under TPR produced the lowest and were statistically at par. At 95 DAS also Loktantra under SRI produced the higher leaf dry weight (60.94 g/0.25m^2) and the lowest by Radha-4 and Sabitri under TPR (34.96 and 37.13 g/0.25 m^2 respectively and was statistically similar (Figure 16).

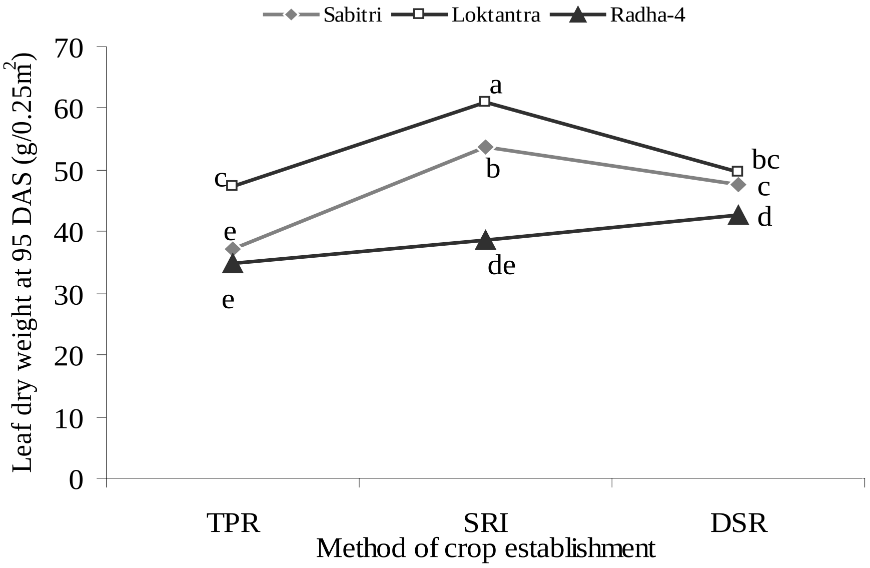

Figure 16. Interaction effect of method of crop establishment and varieties on dry weight of leaf (g/0.25 m^2) at 95 days after sowing of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

There was significant interaction between method of crop establishment and varieties on total dry matter at 35, 50, 65 and 80 DAS (Appendix 27, 28). At 35 DAS, Radha-4 (25.04 g/0.25m^2) and Sabitri (23.50 g/0.25m^2) under SRI produced higher and statistically similar dry weight. Similarly Radha-4 under SRI produced higher dry weight at 50 DAS, 65 DAS, and 80 DAS. Sabitri under TPR produced the lowest dry weight per unit area in all dates of observations (Figure 17).

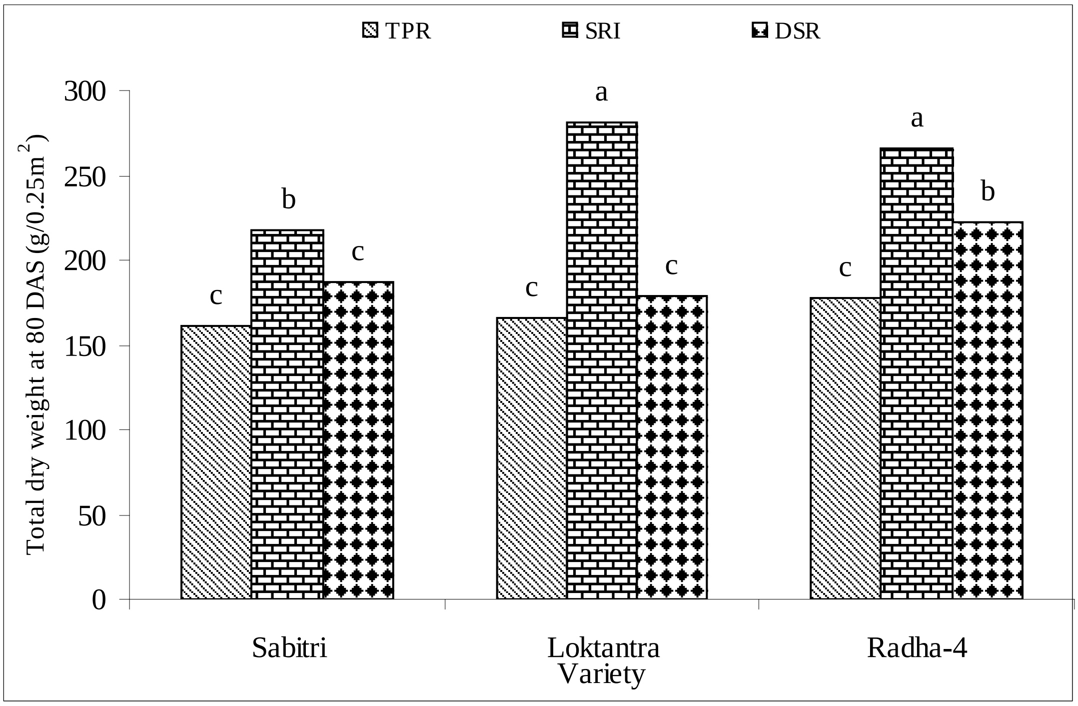

Figure 17. Interaction effect of method of crop establishment and varieties on total dry weight (g/0.25 m^2) at 80 days after sowing of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different to each other by DMRT at 5% level of significance.

4.2.5 Crop growth rate

The dry matter accumulation of the crop per unit land area in unit of time is referred to crop growth rate (CGR), expressed as g m^{-2} d^{-1}. CGR indicates the rate at which the crop is growing. It is evident from the (Table 11) that crop growth rate is significantly influenced by method of crop establishment and varieties. During the period of 0-35 DAS, the the highest CGR (1.90 g m $^{-2}$ d^{-1}) was observed in SRI method and followed by DSR (0.52 g m $^{-2}$ d^{-1}) and lower crop growth rate was observed in TPR, i.e. (0.32g m^{-2}d^{-1}) (Figure 18).

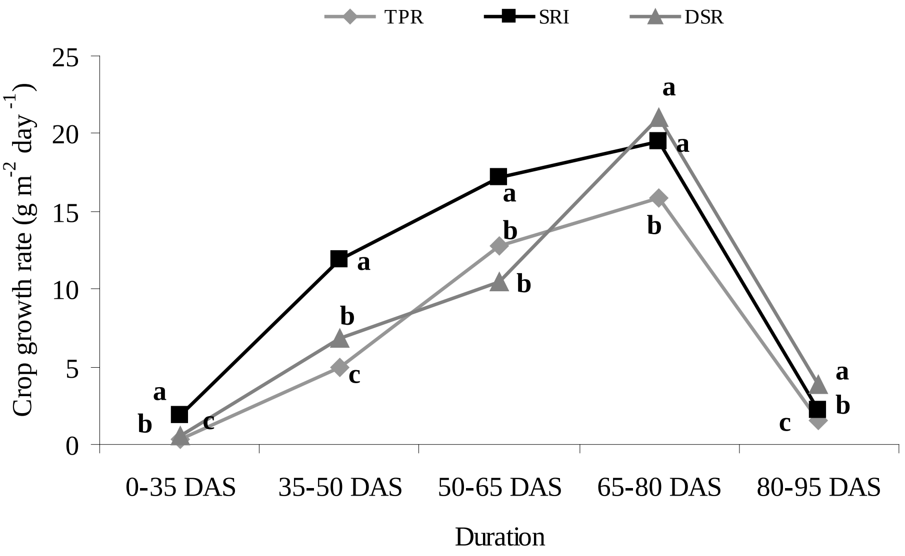

Figure 18. Crop Growth Rate (CGR) as influenced by method of crop establishment of rice at Phulbari, Chitwan 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance.

During 35-50 DAS, 50-65 DAS and 65-80 DAS (19.50 g m $^{-2}$ d^{-1}) the highest CGR was observed in SRI method and was followed by DSR up to 50-65 DAS (10.45 g m $^{-2}$ d^{-1}) and during 65-80 DAS, CGR of DSR (21.09 g m $^{-2}$ d^{-1}) was also statistically similar to that of SRI. During the same period TPR had the lowest CGR, at 65-80 DAS it was (15.86 g m $^{-2}$ d^{-1}). During 80-95 DAS the highest CGR was of DSR (3.85 g m $^{-2}$ d^{-1}) followed by SRI (2.17 g m $^{-2}$ d^{-1}) and the lowest was of TPR (1.56g m $^{-2}$ d^{-1}). In case of varieties Radha-4 had the highest CGR during 0-35DAS (1.03g m $^{-2}$ d^{-1}), 35-50 DAS (9.41 g m $^{-2}$ d^{-1}), and 50-65 DAS (15.51 g m $^{-2}$ d^{-1}) followed by Loktantra and Sabitri. During 65-80 DAS variety did not show significant difference in CGR. During 80-95 DAS Loktantra (3.03 g m $^{-2}$ d^{-1}) followed by Sabitri (2.08 g m $^{-2}$ d^{-1}) and Radha-4 (2.45 g m $^{-2}$ d^{-1}) which were statistically at par. During the growth period maximum CGR recorded by Loktantra under SRI had the highest CGR (21.09 g m $^{-2}$ d^{-1}).

Table 11. Crop growth rate of rice as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Crop growth rate				
	0-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	80-95 DAS
Method of crop establishment					
Farmer Practice (TPR)	0.32^{c}	4.96^{c}	12.76^{b}	15.86^{b}	1.56^{c}
SRI	1.90^{a}	11.84^{a}	17.22^{a}	19.50^{a}	2.17^{b}
DSR	0.52^{b}	6.85^{b}	10.45^{b}	21.09^{a}	3.85^{a}
LSD (P = 0.05)	0.16	1.79	3.62	2.29	0.54
SEM ±	0.05	0.52	1.05	0.66	0.16
Varieties					
Sabitri (V1)	0.87^{b}	6.32^{c}	11.95^{b}	20.02	2.089^{b}
Loktantra (V2)	0.85^{b}	7.92^{b}	12.96^{b}	17.98	3.035^{a}
Radha 4 (V3)	1.03^{a}	9.41^{a}	15.51^{a}	18.45	2.459^{b}
LSD (P = 0.05)	0.09	1.23	1.58	NS	0.47
SEM ±	0.03	0.41	0.53	0.88	0.16
CV %	11.44	18.22	13.66	16.16	21.53
Grand Mean	0.92	7.88	13.47	18.82	2.53

DAS, days after sowings; NS, non-significant. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

4.2.5.1 Interaction effect of method of crop establishment and varieties on crop growth rate (CGR)

There was significant interaction between method of crop establishment and varieties on crop growth rate during 0-35, 35-50, 50-65 and 60- 80 DAS (Appendix 29 and 30). Variety Radha-4 under SRI had significantly higher crop growth rate during 0- 35 DAS (2.15 g m $^{-2}$ d^{-1}) , 35-50 DAS (15.08 g m $^{-2}$ d^{-1}), 50-65 DAS (21.90 g m $^{-2}$ d^{-1}) but during 65-80 DAS Sabitri (25.11 g m $^{-2}$ d^{-1}) and Radha-4 (25.18 g m $^{-2}$ d^{-1}) under SRI had got maximum CGR. Generally, varieties under SRI method followed the maximum rate and the lowest was under TPR method. Due to the significant difference in phonological stages and maturity period the growth rate shows interaction effect between method of crop establishment and varieties. Varietal character played vital role in crop growth rate.

4.2.6 Relative growth rate (RGR)

The relative growth rate at which a plant incorporates new material into its sink is measured by relative growth rate (RGR) of dry matter accumulation and is expressed in g $g^{-1}d^{-1}$. Relative growth rate was worked out by following the formula of Radford (1967). Table 12 revealed that method of crop establishment and varieties showed significant effect on relative growth rate (RGR) at different stages. (Figure 19)

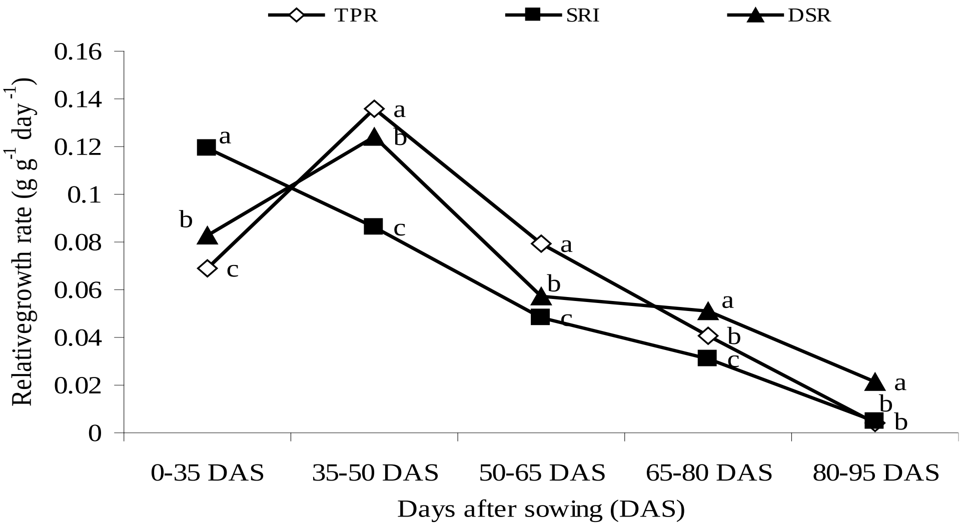

Figure 19. Relative growth rate (RGR) as influenced by method of crop establishment of rice at Phulbari, Chitwan 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

Table 12 depicts that relatively higher RGR was observed on SRI (0.083 g g^{-1} d^{-1}) method during the period of 0 -35 DAS, followed DSR (0.083 g g^{-1} $d^{-1)}$ and the lowest was in TPR (0.069 g g^{-1} d^{-1}). Similarly, during the same period, Radha-4 had the highest RGR value (0.094 g g^{-1} $d^{-1)}$ followed by Loktantra and the lowest in Sabitri (0.088 g g^{-1} d^{-1}). During 35-50 DAS, higher RGR was observed in TPR (0.136 g g^{-1} d^{-1}) followed by DSR

(0.124 g g^{-1} d^{-1}) and the least in SRI (0.086 g g^{-1} d^{-1}). In the same period, variety had no significant effect on RGR. Similar trend was followed during 50-65 DAS. In the same period, variety had no significant effect on RGR. During 65-80 DAS, higher RGR was observed in DSR and was followed by TPR and the lowest was of SRI.

Table 12. Relative growth rate of rice as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	RGR g g^{-1} day^{-1}				
	0-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	80-95 DAS
Method of crop establishment					
Farmer Practice (TPR)	0.069^{c}	0.136^{a}	0.079^{a}	0.041^{b}	0.0042^{b}
SRI	0.119^{a}	0.086^{c}	0.048^{c}	0.031^{c}	0.0045^{b}
DSR	0.083^{b}	0.124^{b}	0.057^{b}	0.051^{a}	0.0214^{a}
LSD (P = 0.05)	0.009989	0.0009989	0.0009989	0.0009989	0.0009989
SEM ±	0.002887	0.0002887	0.0002887	0.0002887	0.0002887
Varieties					
Sabitri V1)	0.088^{c}	0.111	0.063	0.048^{a}	0.0065^{c}
Loktantra (V2)	0.090^{b}	0.119	0.059	0.038^{b}	0.0148^{a}
Radha 4 (V3)	0.094^{a}	0.116	0.061	0.038^{b}	0.0089^{b}
LSD (P = 0.05)	0.0008577	NS	NS	0.0008577	0.0008577
SEM ±	0.0002887	0.0036	0.0024	0.0002887	0.0002887
CV %	3.53	10.87	13.64	11.77	43.52
Grand Mean	0.090	0.115	0.061	0.041	0.010

DAS, days after sowings; NS, non-significant. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

In the same period, higher RGR was observed in Sabitri variety followed by Loktantra and Radha-4, which were at par. During 80-95 DAS, higher RGR was found in DSR (0.0214 g g^{-1} d^{-1}) and followed by SRI (0.0045 g g^{-1} d^{-1}) and TPR (0.0042 g g^{-1} d^{-1}), which were statistically similar. During the same period variety Loktantra (0.0148 g g^{-1} d^{-1})

showed higher RGR followed by Radha-4 (0.0089 g g^{-1} d^{-1}) and the lowest was of TPR (0.0065 g g^{-1} d^{-1-}).

4.2.6.1 Interaction effect of method of crop establishment and varieties on relative growth rate (RGR)

There was significant interaction between method of crop establishment and varieties on relative growth rate during 60- 80, and 80-95 DAS (Appendix 30). During 65-80 DAS maximum RGR was observed in variety Sabitri under DSR method (0.0671 g g^{-1} d^{-1}) followed by Radha-4 under DSR (0.0539 g g^{-1} d^{-1}) and then Sabitri under TPR (0.0446 g g^{-1} d^{-1}) and the least was of Radha-4 under SRI this was mainly due to short duration variety and it already passed the vegetative stage. During 80-95 DAS, maximum RGR was found in variety Loktantra under DSR (0.032 g g^{-1} d^{-1}) followed by Radha-4 under DSR (0.017 g g^{-1} d^{-1}) and then by Sabitri under DSR (0.0153 g g^{-1} d^{-1}) and the least was of Sabitri under TPR (0.0009 g g^{-1} d^{-1}). The general trend shows higher RGR of DSR and lower of TPR during 80-95 DAS. This was mainly due to low root dry matter under TPR method and higher root dry weight per unit area to supply higher amount nutrients to store more dry matter.

4.3 Yield attributing attributes as influenced by different method of crop establishment and varieties in rice

4.3.1 Effective tiller per meter square

The average tiller per meter square was 233.41 ranged from 208.4 to 259.0 (Table 13). Method of crop establishment significantly influenced the effective tillers per meter square. Number of effective tillers per square meter in SRI method was significantly higher (256.9) followed by DSR (234.4) per square meter and statistically lower number of tiller was produced under TPR method. Significantly higher effective tiller per meter square in SRI might be due to individual plants with more favorable growing conditions have shorter phyllochrons, which resulted in more, and more productive-, tillers and larger root systems (Katayama, 1951).

There were significant differences in effective tillers per square meter among varieties. Radha-4 had the the highest number of tillers per square meter (259.0) which was significantly more than Sabitri (232.8) and significantly lower effective tiller was of Loktantra (208.41). The difference in tiller production among cultivars may be attributed to varietal characters (Chandrashekhar *et al.*, 2001). There was highly significant positive correlation (r = 0.712**) between effective tillers per square meter and yield t ha^{-1} (Appendix 37).

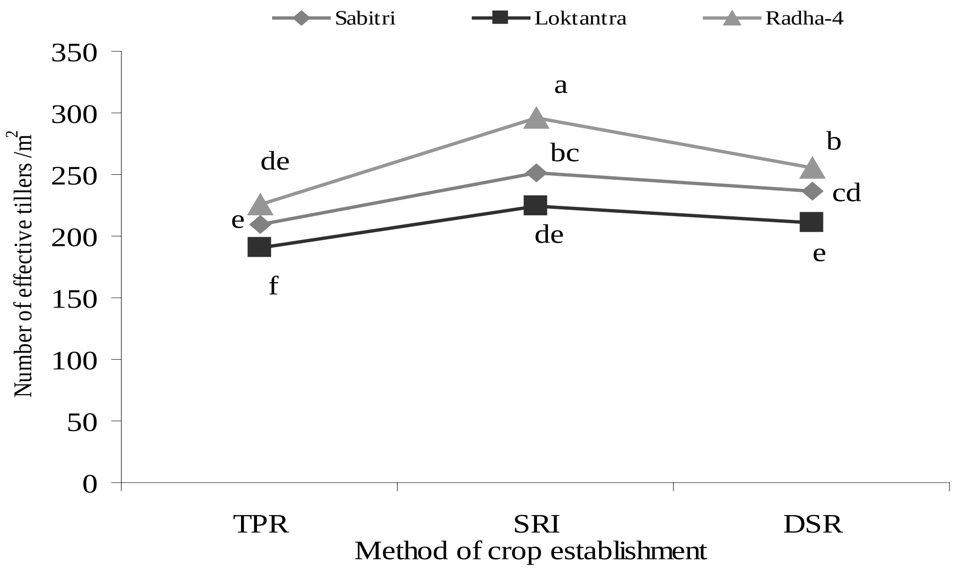

Figure 20. Interaction effect of method of crop establishment and varieties on effective tillers per square meter of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

Interaction effect of method of crop establishment and varieties also had significant influence on effective tillers (Figure 20). The interaction of Radha-4 with all the method of crop establishment produced more effective tillers whereas the interaction of Loktantra with different method showed lower number of effective tiller. The interaction of SRI method and Radha-4 variety produced more tillers (295.4) and followed by Radha-4 under DSR method (255.8) and then Sabitri under SRI (251.4), significantly the lowest number of tillers was observed in the combination of Loktantra under TPR (191.10) (Appendix 33).

4.3.2 Panicle length

The average panicle length was 25.84 cm. Panicle length was significantly influenced by method of crop establishment as well as varieties (Table 13). The DSR method had longer panicle length (27.05 cm) than that of SRI method (26.89 cm), but are statistically similar. Significantly shorter panicle length was observed in TPR method (23.57cm) (Figure 23). Similar result was observed by Thakur *et al.* (2010) in similar comparative research between SRI (21.61 cm) and conventional TPR recommended practice (18.66 cm).

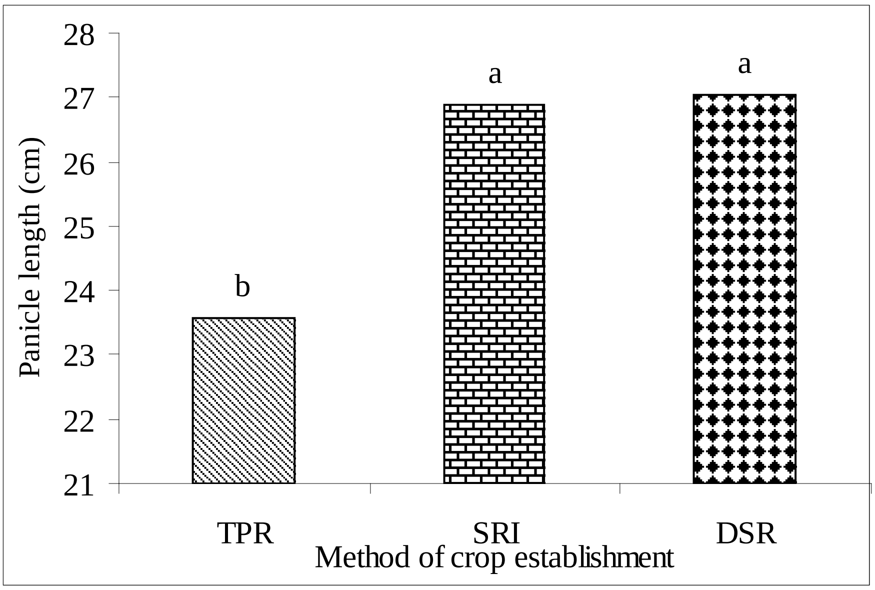

Figure 21. Panicle length (cm) as influenced by method of crop establishment of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

Panicle length of varieties differed significantly among each other (Figure 21). Loktantra had longer panicle (26.92 cm), which was statistically similar with Sabitri (26.69 cm). But Radha-4 had significantly shorter panicle length i.e. 23.90 cm.

Interaction effect of method of crop establishment and varieties had no significant influence on panicle length (Appendix 32). In general, Loktantra with different method of crop establishment produced longer panicle length whereas Radha-4 under different method produced shorter panicle length. Comparatively longer panicle length in the experiment was observed with the interaction of Loktantra under SRI (28.39 cm) followed by the interaction of Sabitri and DSR (28.06 cm) and relatively shorter panicle length was produced in the combination of Radha-4 under TPR (21.52 cm). There was highly significant positive correlation (r= 0.455^{**}) between panicle length and grain yield. (Appendix 37)

4.3.3 Panicle weight

The average panicle weight was 3.86 g. Panicle weight was significantly influenced by method of crop establishment as well as varieties (Table 13). The DSR method had higher panicle weight (4.474 g) than panicle weight of SRI method (4.176 g) but were statistically similar. Significantly lower panicle length was observed in TPR method (2.929 g). Panicle weight of varieties differed significantly among each other. Loktantra had higher panicle weight (4.624 g), followed by Sabitri (3.879 g). But Radha-4 had significantly lower panicle weight i.e. 3.076 g. There was no significant interaction between method of crop establishment and varieties on panicle weight (Appendix 32). There was significant positive correlation (r=o $.383^{*}$) panicle weight and grain yield. (Appendix 37).

4.3.4 Filled grains per panicle

The average number of grains per panicle was 156.55 (Table 13) and it ranged from 113.7 to 183.2 depending upon the treatment combinations. Number of filled grains per panicle was significantly influenced by method of crop establishment and the varieties. Under different methods filled grain per panicle was the highest in SRI method (181.9) followed by DSR (174.0) and was statistically similar. Lower number of filled grain was observed in TPR method and was (113.7). Sanjeewane *et al.* (2009) reported higher number of filled grains per panicle in SRI (132.5) than in DSR with other SRI management practices (107.8). The longer SRI panicles carried nearly 1.7 times more number of grain compared to panicles obtained from conventional recommended TPR plots (Thakur *et al.* 2010). Thus, lower number of filled grains per panicle in TPR method might be due to shorter panicle length and higher sterility percentage. In case of varieties Loktantra had significantly higher number of filled grains per panicle (183.2) followed by Sabitri (152.9) and Radha-4 (133.5) and was statistically similar.

Interaction effect of method of crop establishment and varieties had no significant influence on filled grains per panicle (Appendix 32). In general, Loktantra under different method of crop establishment produced more number of filled grains, whereas Radha-4 with different method recorded lower number of filled grains. Comparatively higher number of filled grain per panicle was observed in the interaction of Loktantra under SRI method. There was significant positive correlation (r = 0.369*) between filled grains per panicle and yield (t ha^{-1}) (Appendix 37).

4.3.5 Thousand grain weight (test weight)

The average thousand grain weight was 24.68 gm (Table 13). The thousand grain weight was not influenced by method of crop establishment but was influenced by variety. Although thousand grain weight was not significantly influenced by method of crop establishment , comparatively higher thousand grain weight was observed in SRI method (25.22 g), followed by DSR (25.13 gm), and TPR (23.69g). The thousand grain weight was significantly influenced by the varieties. The Radha-4 had significantly higher test weight (26.84 g) than Loktantra (23.92 g) and significantly lower test weight of Sabitri (23.29 g). Higher thousand grain weight of Loktantra was probably due to the facts that it seeds were long and bulkier. There was no significant interaction between method of crop establishment and varieties on thousand grain weight. Mahajan and Sarao (2009) in the similar treatments found no significant difference in test weight among TPR, SRI and DSR. Soga and Nozaki (1957) and Yoshida (1981) too reported that 1000-grain weight remained stable as far as there was no water stress during grain filling, and Ashraf *et al.* (1999) and Trillana *et al.* (2001) reported grain weight to be the least affected by the environment. There was no significant interaction between method of crop establishment and varieties on thousand grain weight (Appendix 33). There was significant positive correlation (r = 0.38*) between thousand grain weight and yield (mt ha^{-1}) (Appendix 37).

4.3.6 Sterility percentage

The average sterility percentage in the present experiment was 9.667 % and it ranged from 6.707 to 14.42 % depending upon the treatment combination (Table 13). Statistical analysis of the data indicated that the sterility percentage was not affected by method of crop establishment, but was significantly influenced by varieties (Figure 22). Significantly more sterility was observed in Radha-4 (14.42 %) followed by Loktantra (7.88%) and Sabitri (6.7%) which were statistically at par. Among the methods SRI had the lowest sterility percentage (8.335%) although it was not significant to DSR and TPR (Figure 24). Similar non insignificant difference in sterility percentage due to method of crop establishment was reported by Mahajan and Sarao (2009) in his research at Punjab. Higher sterility in Radha-4 was due to rice ear head bug sucking and bird damage, due to its earlier milking stage than other varieties. Interaction effect of date of sowing and varieties had no significant influence on sterility percentage (Appendix 33).

Table 13. Yield attributes as influenced by method of crop establishment and varieties of rice at Phulbari, Chitwan, Nepal, 2010

	Yield Attributes					
Treatments	No. of effective tillers	Panicle length (cm)	Panicle weight (g)	No. of filled grains	Sterility %	Test weight (g)
Method of crop establishment						
Farmer Practice	208.9^{c}	23.57^{b}	2.929^{b}	113.7^{b}	11.239	23.691
SRI	256.9^{a}	26.89^{a}	4.176^{a}	181.9^{a}	9.427	25.225
DSR	234.4^{b}	27.05^{a}	4.474^{a}	174.0^{a}	8.335	25.135
LSD (P = 0.05)	13.33	0.2605	0.4717	15.61	NS	NS
SEM ±	3.852	0.07528	0.1363	4.511	0.7567	0.4864
Varieties						
Sabitri (V1)	232.8^{b}	26.69^{a}	3.879^{b}	152.9^{b}	6.707^{b}	23.29^{b}
Loktantra (V2)	208.4^{c}	26.92^{a}	4.624^{a}	183.2^{a}	7.880^{b}	23.92^{b}
Radha 4 (V3)	259.0^{a}	23.90^{b}	3.076^{c}	133.5^{b}	14.42^{a}	26.84^{a}
LSD (P = 0.05)	9.396	0.4314	0.5160	21.08	2.066	1.661
SEM ±	3.162	0.1452	0.1737	7.094	0.6952	0.5592
CV %	4.69	1.95	15.59	15.70	24.91	7.85
Grand Mean	233.411	25.840	3.860	156.551	9.667	24.684

gm, gram; DAS, days after sowing. Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

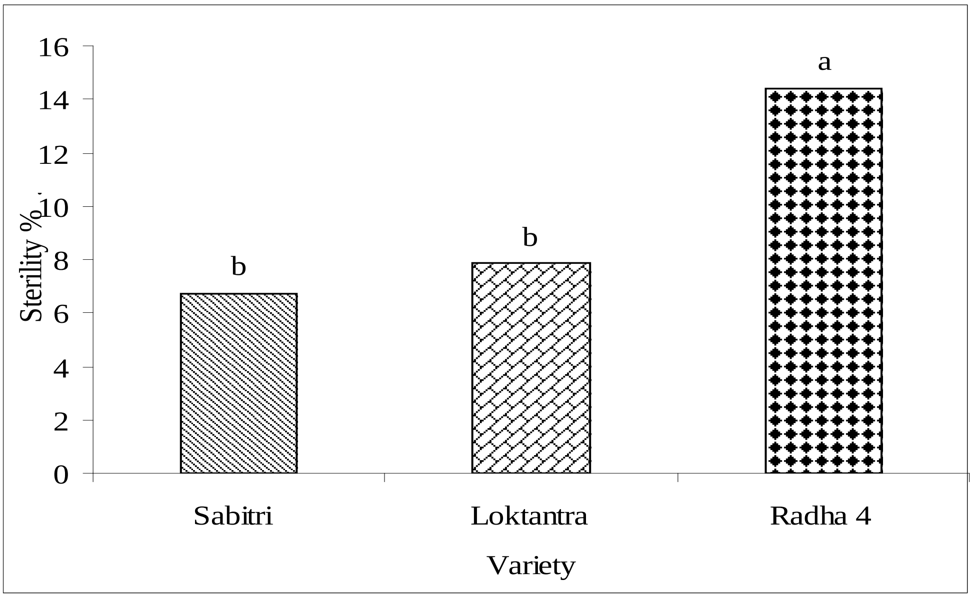

Figure 22. Influence of variety on sterility % in different methods of Rice cultivation at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

4.4 Yield as influenced by date of sowing and varieties in DSR

4.4.1 Grain yield

The grain yield was influenced by varieties as well as crop establishment but not by their interaction. The data regarding the grain yield (mt/ha) are presented in Table 14 .The grain yield ranged from 3.68 mt/ha to 7.38 mt/ha among the combination of different method of crop establishment and varieties, and the average yield in the experiment was 5.935 mt/ha. SRI method of crop establishment had produced significantly higher grain yield (6.95 mt/ha) followed by DSR yield (6.2 mt/ha^{-1}) and the lowest yield was under TPR method i.e. 4.18 mt/ha. The higher grain yield in SRI method was because of higher number of effective tillers per unit area as well as higher number of filled grains per panicle as compared with TPR method. The higher yield in SRI as compared with DSR was due to more numbers of effective tillers per unit area. Sanjeewane *et al.* (2009)

reported transplanted rice (8 days old seedlings) with alternate wetting and drying irrigation (AWD) had higher yield (6.8 mt/ha) than direct seeded rice with AWD (4.7 mt/ha). The higher yield in case of SRI method was due to more number of productive tillers, and increased 1000-grain weight.

The rice plant utilizes two sources of nutrients in order to satisfy its demand when forming and filling grain. One source is the nutrients already contained in the rice shoot. These nutrients are remobilized to the grain sink at the post-anthesis stage. This remobilization leads to less shoot nutrient content at the maturity stage compared to that pre-anthesis. The second source is the indigenous nutrient supply. The utilization of this source, however, is closely linked to the capacity of the roots to take up nutrients. That capacity itself is a function of root growth and proliferation.

The yield attributes i.e. panicle length, number of panicles per hill, total number of grains per panicle were significantly higher than other treatments during wet season in 14 days old seedlings + 25 × 25 cm spacing + water saving irrigation + SRI weeding. During dry season, more panicle length, number of panicles per hill and filled grains per panicle were recorded in the treatment combination of 14 days old seedlings + 25 × 25 cm spacing + water saving irrigation + SRI weeding. The grain yield and water productivity were significantly increased at SRI weeding with 14 days dapog seedlings planted at 25 × 25 cm spacing to achieve 7009, 5655 kg/ha and 0.610 and 0.494 kg per m^3 of water respectively in wet and dry season (Vijayakumar *et al*., 2006).

Radha-4 produced significantly higher grain yield (6.26 mt/ha) as compared to Sabitri (5.677 mt/ha) and Loktantra (5.39 mt/ha) which were statistically at par. The higher grain yield of Radha-4 was because of higher LAI, slower leaf senescence, which contributed to better light interception and higher assimilates production, higher dry matter production especially at the later growth stage of crop (Table 7, 8, 9) and higher harvest index (Table 13). The greater remobilization of stem reserve towards the grain resulted in higher gain yield in Radha-4. Some amount of carbohydrates formed before flowering are stored in culms and leaf sheaths and later re-translocated to the grain (Reddy and Reddi, 2005). Hayashi *et al. (*2007) reported that in DSR there was a longer period of growth in the paddy field; an absence of transplantation shock, and a higher plant population density, some early- to intermediate-maturing genotypes gave higher yields in DS compared with TPR. Similarly during 2007, varietal performance was studied in SRI system. SRI transplanting (10 days old seedling) resulted 11.8 and 27.9% increase in yield over conventional transplanting method and SRI direct seeding method, respectively (Mahajan and Sarao. (2009). In SRI plants, delayed senescence could derive from having increased root growth, higher leaf area and chlorophyll content, and perhaps by gene expression of enzymes contributing to photosynthesis during the latter part of the growth cycle (Ookawa *et al*., 2004; Suzuki *et al*., 2001).

The yield attributing characters (Table 13) effective tillers per square meter, panicle length, grains per panicle were higher in the SRI method followed by DSR, which was responsible for the increased grain yield. Lower yield in the TPR was attributed due to the lower numbers of effective tillers per square meter, less panicle length, low numbers of grain per panicle and lower test weight (Table 13). The pattern of grain yield production was similar to effective tillers per square meter indicating highly significant correlation (r = 0. 712**between these two parameters (Appendix 37, Figure 23). The contribution from effective tillers per meter square to grain yield was 81% while from other parameter was 19%.

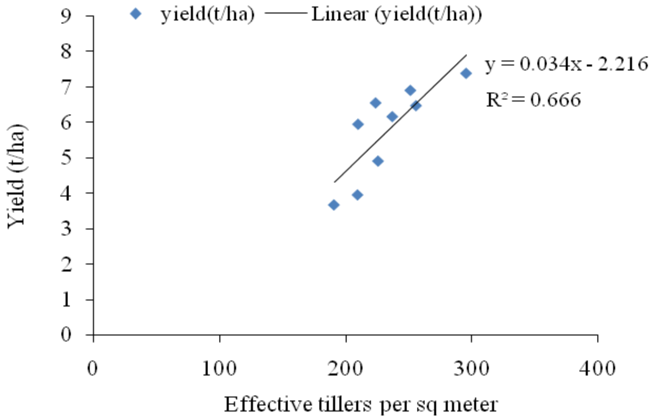

Figure 23. Relationship between effective tillers per square meter and grain yield of rice at Phulbari, Chitwan, 2010

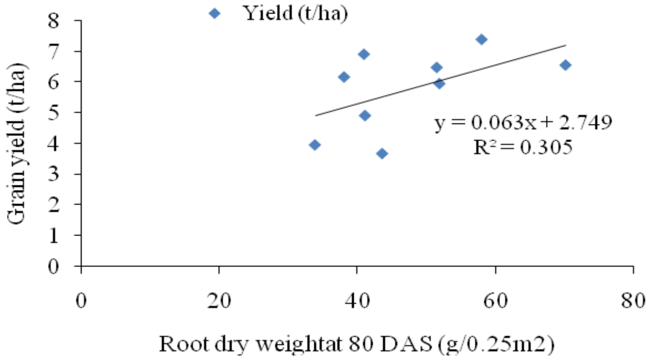

Figure 24. Relationship between root dry weight at 80 DAS and grain yield of rice at Phulbari, Chitwan, 2010

Root dry matter after reproductive stage played vital role in yield formation, this was shown by the correlation studies, there was positive correlation (r = 0.553) between root dry weight at 80 DAS and yield formation (Appendix 37 and Figure 24). In TPR most of the root degenerate due to anaerobic soil condition during vegetative stage and the nutrient supply being poor at grain filling stage compared to SRI method.

Interaction between method of crop establishment and varieties on grain yield was not significant (Appendix 34). However, Radha-4 under SRI method of crop establishment produced comparatively higher grain yield i.e. 7.38 mt/ha and followed by Sabitri and Loktantra under SRI and relatively lower grain yield of Loktantra under TPR (3.68 mt/ha) among all treatments combinations (Figure 25). The regression analysis (Table 14) depicts that grain yield depends on various yield attributing traits.

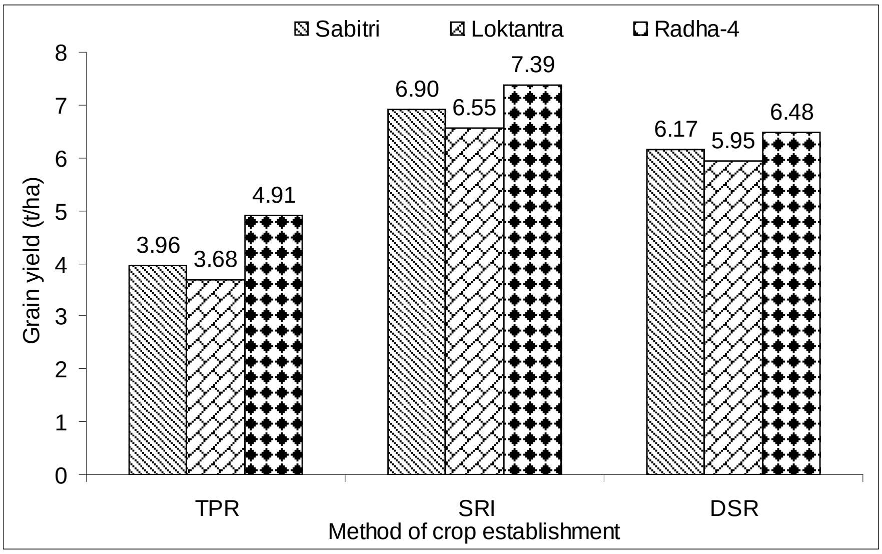

Figure 25. Interaction effect of method of crop establishment and varieties on grain yield (mt/ha) of rice, at Phulbari, Chitwan, 2010

Table 14. Grain yield, straw yield and harvest index as influenced by method of crop establishment and varieties of rice at Phulbari, Chitwan, Nepal, 2010

Treatments	Yield		
	Grain yield (mt/ha)	Straw yield (mt/ha)	Harvest Index (HI)
Method of crop establishment			
Farmer Practice	4.18^{c}	6.50^{c}	0.39^{c}
SRI	6.95^{a}	9.10^{a}	0.41^{b}
DSR	6.20^{b}	8.30^{b}	0.43^{a}
LSD (P = 0.05)	0.33	0.91	0.01
SEM ±	0.10	0.26	0.003
Varieties			
Sabitri (V1)	5.67^{b}	7.79^{b}	0.42
Loktantra (V2)	5.39^{b}	7.85^{b}	0.41
Radha 4 (V3)	6.26^{a}	9.13^{a}	0.41
LSD (P = 0.05)	0.44	0.71	NS
SEM ±	0.15	0.24	0.01
CV %	8.96	10.08	4.15
Grand Mean	5.78	8.26	0.41

Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

Table 15. Linear regression equations for grain yield (t/ha) against effective tillers per m^{-2}, panicle length (cm), filled grains per panicle, panicle weight (g), root dry weight (g) at 80 DAS, total dry matter (g) at 95 DAS , thousand grain weight, straw yield, harvest index

Linear regression	Equations (Y = a + bx)	r value
Yield (t/ha) against effective tillers per square meter	y = 0.034x - 2.216	0.712^{**}
Yield (t/ha) against panicle length (cm)	y = 0.284x - 1.561	0.455^{**}
Yield (t/ha) against filled grains per panicle	y = 0.014x + 3.566	0.369^{*}
Yield (t/ha) against panicle weight (g)	y = 0.553x + 3.639	0.383^{*}
Yield (t/ha) against root dry weight (g) at 80 DAS	y = 0.063x + 2.749	0.494^{**}
Yield (t/ha) against total dry matter (g) at 95 DAS	y = 0.025x + 0.112	0.814^{**}
Yield (t/ha) against thousand grain weight (g)	y = 0.410x - 4.350	0.380^{*}
Yield (t/ha) against straw yield (t/ha)	y = 0.705x - 0.051	0.893^{**}
Yield (t/ha) against harvest index	y = 32.16x - 7.439	0.404^{*}

r, correlation coefficient; Y, dependent variable; x, independent variable

4.4.1.1 Correlation studies

In order to assess the relationship between crop yield with growth components, simple correlation coefficients were worked out for rice (Table 15). It is evident from the table that there was significant positive correlation between crop yield and growth characteristics, like root dry weight (g) at 80 DAS, total dry matter at 95 DAS, filled grains per panicle and panicle weight. The grain yield increased to 2.74, 0.112, 3.56 and 3.63 units for every one unit increase in root dry weight (g) at 80 DAS, total dry matter at 95 DAS, filled grains per panicle and panicle weight, respectively. Hasanuzzaman *et al.* (2010) and Balasubramanian and Krihnarajan (2001) also found that there exists a significant relationship between dry matter accumulation and yield. The result is in corroboration with Ibeawuchi *et al.* (2008) who observed the positive relationship between dry matter accumulation and yield in maize.

4.4.2 Straw yield

Straw yield (t ha^{-1}) was significantly influenced by the method of crop establishment and varieties (Table 14). The straw yield was the highest (9.1 t ha^{-1}) in SRI method which was significantly superior to the straw yield from DSR (8.3 t ha^{-1}) and the lowest in TPR (6.5 mt/ha). Similarly, significantly the highest straw yield was observed in Radha-4 (9.1 mt/ha) and straw yield of Sabitri (7.8 mt/ha) and Loktantra (7.85 mt/ha) were statistically at par.

4.4.2.1 Interaction effect of method of crop establishment and varieties on straw yield

The significant interaction between method of crop establishment and varieties on straw yield was observed (Appendix 34). In general, SRI method produced higher straw in all the varieties, followed by DSR and TPR (Figure 26). The interaction of Radha-4 under SRI method produced the highest straw yield (11.14 mt/ha) and it was significantly higher than all other interaction of method of crop establishment and varieties. This was followed by Sabitri and Loktantra under SRI and Radha-4 under DSR, and then Sabitri and Loktantra under DSR. Whereas, Sabitri under TPR produced the lowest straw yield (5.58 mt/ha).

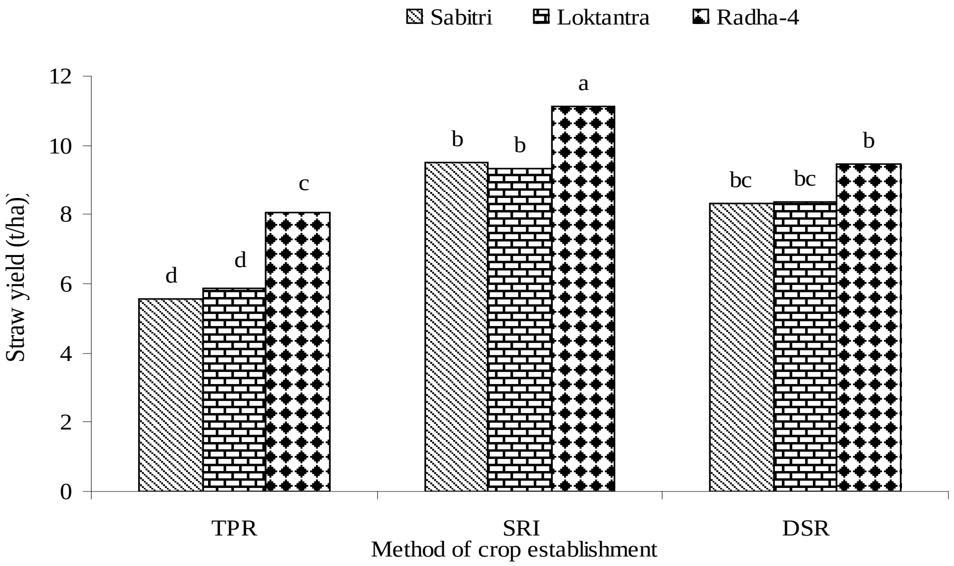

Figure 26. Interaction effect of method of crop establishment and varieties on straw yield (t ha^{-1}) of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance.

4.4.3 Harvest index (HI)

Harvest index indicates the efficiency of assimilate partition to the parts of economic yield of the rice plants (i.e. panicle). Higher harvest index indicates better assimilate transport to the panicle. The significant difference was observed on Harvest index (HI) due to different method of crop establishment, but no significant difference in harvest index observed due to varieties used in the experiment (Table 14). The average harvest index in the experiment was 0.41. Significantly higher harvest index was obtained in DSR (0.43) followed by SRI (0.41), and the lowest was of TPR (0.39). There was a significant interaction between establishment method and water management for HI (Sanjeewane *et al.* 2009), and the highest HI (0.64) was found in SRI, i.e. TPR with alternate wetting and drying every 2 week.

From the Table 14 HI of Sabitri was the highest (0.42) and Loktantra and Radha-4 had equal HI, i.e. 0.41. Better assimilate partitioning from the source (leaf and non-laminar organ i.e. leaf sheath, stem, flag leaf) to the panicle (sink) occurred in DSR method than in SRI and TPR. Higher harvest index (HI) in SRI and DSR was related to their higher grain yields, while lower harvest index (HI) in the TPR was likewise related to lower grain yields. There were no significant interactions in HI between the method of crop establishment and the variety used (Appendix 34).

4.5 Water requirement and water productivity of rice

4.5.1 Quantity of irrigation water for rice

Table 16 shows that the total quantity of irrigation water used and frequency of irrigation were higher in TPR followed by DSR and the least irrigation water was required in SRI method. To complete a crop from sowing to harvest TPR method was irrigated with (4,383 m^3/ha) water which was significantly higher than applied in DSR (3,525 m^3/ha) and the least water was needed in SRI method (3,113 m^3/ha). Here SRI reduced the irrigation water by 29% and DSR reduced by 20% compared to continuous flooded TPR. This is supported by Yuan (2002) in his research in China National Hybrid Rice Research and Development Center; he found that the water applications could be reduced by as much as 65% on SRI plots compared with conventional irrigated ones. Similarly, water saving with SRI was calculated as 40% in Indonesia, 67% in Philippines and 25% in Sri Lanka while conducting different trials comparing with that of conventional system (Sato, 2006; Lazaro, 2004; Namara *et al.*, 1995). Here higher irrigation water was required in DSR than in transplanted SRI, which is contradictory to previous findings, this is mainly due to two times more irrigation was applied in DSR, one prior to transplantation of SRI and the next at maturity stage. The early maturity of SRI plots saves this irrigation.

Table 16. Irrigation water, effective rainfall, total water required for crop and water productivity of rice as influenced by method of crop establishment and varieties of Rice at Phulbari, Chitwan, Nepal, 2010

Treatments	Irrigation water (m^3/ha)	Effective rainfall (m^3/ha)	Total water (m^3/ha)	Water productivity (kg /m^3)
Method of crop establishment				
Farmer Practice (TPR)	4,383^a	11,873.33	16,260^a	0.259^c
SRI	3,113^c	10,513.33	13,630^b	0.514^a
DSR	3,525^b	10,073.33	13,600^b	0.456^b
LSD (P = 0.05)	188.4	NS	188.4	0.032
SEM ±	54.45	0.0	54.45	0.00913
Varieties				
Sabitri (V1)	4036^a	10956.67	14990^a	0.3871^b
Loktantra (V2)	3953^a	10903.33	14860^b	0.3726^b
Radha 4 (V3)	3032^b	10600.00	13630^c	0.4692^a
LSD (P = 0.05)	125.9	NS	125.0	0.027
SEM ±	42.38	0.0	42.06	0.00913
CV %	3.97	0.0	1.01	9.28
Grand Mean	3673.61	10820.00	14493.61	0.41

Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

First irrigation lies prior to the onset of monsoon and the last one in late monsoon, thus these can't be avoided without significant sacrifice in yield. Irrigation required in DSR can be reduced by selecting the sowing date just after first shower of monsoon. Similarly, the irrigation water was significantly influenced by varieties. Sabitri required maximum irrigation (4036m^3/ha) followed by Loktantra (3953m^3/ha) which were statistically at par and statistically lower irrigation water was required in Radha-4 (3032 m^3/ha). This difference in irrigation water among the varieties is mainly due to their maturity period. In general, long duration varieties required higher quantity of irrigation water. There was significant interaction between method of crop establishment and variety on quantity of irrigation water required. The interaction of SRI and Radha-4 required the least and the interaction of Sabitri and TPR required the highest (Appendix 35, Figure 27).

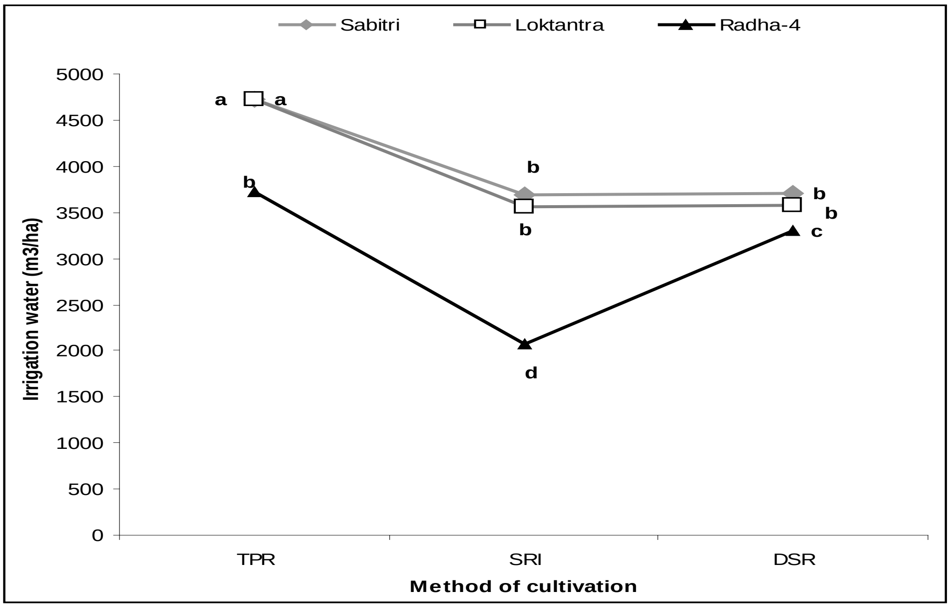

Figure 27. Interaction effect of method of crop establishment and varieties on quantity of irrigation water (m^3 ha^{-1}) for rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

4.5.2 Effective rainfall in rice crop season

Effective rainfall was the highest for TPR (11,873.33m^3/ha) followed by DSR (10,513.33m^3/ha), and the lowest in SRI (10,073.33 m^3/ha). Rice thrives under conditions of abundant water supply, hence the practice of land submergence. Depth of flooding is governed by the variety grown and its height, the height of field bunds and availability of water. The water requirements of rice include evapotranspiration and percolation. Measuring effective rainfall is thus more complicated (Kung, 1971). The effective rainfalls for different method thus differ due to alternate wetting and drying of fields in DSR and SRI. Similarly, maturity period of the crop, i.e. SRI mature earlier than other method thus rainfall received latter are ineffective. The effective rainfall was different for different varieties, maximum effective rainfall for Sabitri and then Loktantra and the lowest for Radha-4, although they are statistically similar (Table 16).

4.5.3 Total quantity of water in rice for a crop season

Table 16 revealed that, total water required for rice was significantly higher in TPR (16,260 m^3/ha), followed by SRI (13,630 m^3/ha) and DSR required less (13,600 m^3/ha). But the quantity of water was not significantly different in SRI and DSR, this was mainly due to more number of irrigation required in DSR. SRI and DSR with water management as in SRI required 17% less water than conventional TPR. The water requirement in SRI can be further reduced by shallow irrigation during reproductive stage to maturity stage, i.e. lowering water depth from 5cm to 2 cm. The total quantity of water required was also significantly influenced by variety, Sabitri required maximum water (14,900m^3/ha) followed by Loktantra (14,860 m^3/ha) and the lowest by Radha-4 (13,630 m^3/ha). This difference was due to difference in maturity period of the varieties. Generally, longer duration variety required higher quantity of water and shorter duration variety the less. There was significant interaction between variety and method of crop establishment on total quantity of water required the crop period. The combination of Sabitri and Loktantra under TPR required the maximum quantity of water (16,730 m^3/ha). The lowest was required by Radha-4 under SRI (12,480 m^3/ha) and DSR (13,100 m^3/ha). Similarly, Loktantra and Sabitri under SRI required more water than same variety under DSR (Figure 28, Appendix 35). Mann *et al.* (2004) also reported that higher water requirement of TPR than DSR.

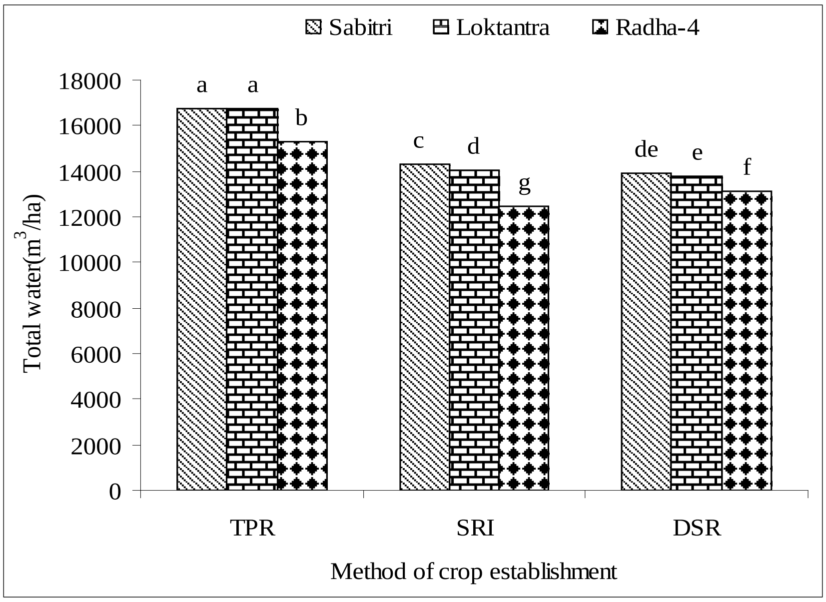

Figure 28. Interaction effect of method of crop establishment and varieties on Total quantity of water (t ha^{-1}) of rice at Phulbari, Chitwan, 2010. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at 5% level of significance

4.5.4 Water productivity of rice

In this experiment the preliminary concept of Indian empirical method of effective rainfall computation was used. Theoretically, this method has medium accuracy so it needs verification but it has high practicability. Water productivity computed under this effective rainfall is also with medium accuracy but with high practicability. The experiment shows the highest water productivity in SRI methods (0.514 kg/m^3), followed by DSR (0.456

kg/m^3) and the lowest in TPR (0.259 kg/m^3). Similarly, water productivity was also influenced by varieties of rice Radha-4 (0.4692 kg/m^3) which significantly had higher water productivity followed by Sabitri (0.3871 kg/m^3) and Loktantra (0.3726 kg/m^3) which were statistically at par (Table 16). The water productivity of varieties was influenced by its maturity and yield. The maturity period again is affect the effective rainfall and irrigation water requirement. There was no significant interaction between variety and method of crop establishment in water productivity. Treatment combination of Radha-4 under SRI method (0.593 kg/m^3) had the highest water productivity and the least was of Loktantra under TPR (0.22kg/m^3). This finding is supported by Vijayakumar *et al*. (2006) in his research he found higher water productivity in transplanting under SRI method than conventional TPR with continuous flooding. Water productivity can be increased from two times to even six times (Ceesay *et al.*, 2007). There was no significant interaction between method of crop establishment and varieties (Appendix 35).

4.6 Economic analysis

4.6.1 Cost of cultivation

In this experiment three different methods of crop establishment were tested for three different varieties. The cost of cultivation was calculated for the different method of crop establishment. The cost of cultivation was calculated for one hectare area from the cost involved in experimental plots. Research involves extra costs that are not necessary in the farmers field are not included in the cost. The cost for watching birds at maturity stage of crop was not included here because it is not needed in farmer’s field. Cost of cultivation was almost similar for all treatment (Table 17). In general SRI method involves higher cost than DSR and TPR. Major variables that differs the cost of cultivation in this experiment were seed, seed bed preparation, irrigation, and weed management. The higher cost in SRI was mainly due to seed bed solarization, the extra cost in DSR was for thinning and weed management. The average cost of cultivation calculated in this experiment was Rs 65.1 thousand per hectare for SRI, Rs 61.42 thousand for TPR method and for DSR was Rs 61.1 per hectare.

Table 17. Economic parameters of rice cultivation as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatments	Economic Parameters			
	Total cost Rs, '000	Gross return Rs, '000	Net return Rs, '000	B:C ratio
Method of crop establishment				
Farmers practice (TPR)	61.42	107.2^{c}	45.81^{c}	1.746^{c}
SRI	65.10	175.8^{a}	110.7^{a}	2.70^{a}
DSR	61.10	154.8^{b}	93.73^{b}	2.53^{b}
LSD (P = 0.05)		8.90	8.90	0.141
SEM ±		2.57	4.40	0.041
Varieties				
Sabitri (V1)		138.9^{b}	76.3^{b}	2.21^{b}
Loktantra (V2)		144.2^{ab}	81.64^{ab}	2.30^{ab}
Radha 4 (V3)		154.8^{a}	92.27^{a}	2.47^{a}
LSD (P = 0.05)		10.77	10.77	0.17
SEM ±		3.63	3.63	0.06
CV %		8.60	15.05	8.69
Grand Mean		145.95	83.41	2.33

Treatments means followed by common letter (s) within column are not significantly different among each other by DMRT at 5% level of significance.

4.6.2 Gross return

The gross return per hectare was significantly influenced by the method of crop establishment and varieties (Table 17). In general, the higher gross return (Rs. 175.8 thousand) per hectare was obtained from SRI method followed by DSR (Rs. 154.8 thousand), whereas significantly lower gross return (Rs.107.2 thousand) was received from TPR method. The significantly higher gross return from SRI method was due to higher grain and straw yield per ha.

Varieties also significantly influenced on the gross return. Among the varieties, significantly higher gross return (Rs. 154.8 thousand) was obtained from Radha-4 followed by Loktantra (Rs. 142.2 thousand) and significantly lower gross return was received from Sabitri (Rs. 138.9 thousand). The significantly higher gross return from Radha-4 was due to its higher grain yield and straw yield. Although Loktantra had significantly lower yield than Radha-4, gross return was statistically at par because of its higher market price. At that time the market price was Rs 20/kg of Sabitri and Radha-4 and for Loktantra it was Rs 22 per kg. The market price of rice straw was Rs 3.25 per kg.

Regarding the interaction effect of method of crop establishment and variety on gross return, no significant difference was observed (Appendix 36). However the treatment combination of SRI and Radha-4 produced the highest gross return (Rs.183.93 thousands) and was followed by Loktantra and Sabitri under SRI and Radha-4 under DSR. The lowest gross return was obtained from treatment combination of Sabitri under TPR method (Rs. 97.33 thousands).

4.6.3 Net return

The net return per hectare was significantly influenced by the method of crop establishment and varieties (Table 17). Significantly higher net return (Rs. 110.7 thousand) per hectare was obtained from SRI method followed by DSR method (Rs. 93.73 thousand) and the lowest in TPR method. Significantly higher net return from SRI was due to higher grain yield and straw yield.

Within the varieties, significantly higher net return per hectare was observed in the Radha-4 (Rs. 92.27 thousands), followed by Loktantra (Rs. 81.64 thousands) were statistically similar and Sabitri (Rs. 76.32 thousands) which was significantly lower than Radha-4 but at par with variety Loktantra. The significantly higher net return from Radha-

4 was due to its higher grain and straw yield and that from Loktantra is due to higher per unit price of grain. Interaction effect of method of crop establishment and varieties did not influence the net return (Appendix 36). However, interaction of SRI method with different varieties produced comparatively higher net return. The highest net return (Rs.118.83 thousands) obtained from interaction of SRI method and Radha-4, whereas the lowest net return was obtained from the interaction TPR method and Sabitri.

4.6.4 Benefit-cost ratio

Benefit-cost ratio is the ratio of gross returns to cost of cultivation which can also be expressed as return per rupee invested. Any value greater than 2.0 is considered safe as the farmers gets Rs. 2.00 for every rupee invested (Reddy and Reddi, 2002). Similar as the gross return per hectare and net return per hectare, B: C ratio was significantly influenced by the method of crop establishment and varieties (Table 17). The significantly higher B: C ratio was calculated in SRI method (2.7), followed by DSR method (2.52) and statistically lower B:C ratio was for TPR (1.75). Similarly, in case of varieties higher B: C ratio was observed in the Radha-4 (2.47) followed by Loktantra (2.30), which were statistically at par and Sabitri (2.21) this was also statistically similar with variety Loktantra. Higher B: C ratio in Radha-4 was due to higher yield and which ultimately caused the higher gross return. Interaction effect of method of crop establishment and varieties did not influence on B: C ratio (Appendix 36). However relatively higher B: C ratio was obtained from the interaction of SRI method with different varieties whereas lower B: C from the TPR with Sabitri and Loktantra varieties. The interaction of SRI and Radha-4 revealed comparatively higher B: C ratio (2.82) and at the same time combination of TPR and Sabitri resulted lower B: C ratio (1.58) (Appendix 36).

5 SUMMARY AND CONCLUSIONS

5.1 Summary

A field experimentation to determine the growth and yield of rice varieties under different methods of crop establishment was carried out at Phulbari, Chitwan during rainy season of 2010. Three rice varieties namely Sabitri, Loktantra and Radha-4 were tested under three different method of crop establishment; i) SRI; ii) direct seeded rice with management practices similar to SRI (DSR); and iii) general system of transplanted rice cultivation (TPR) in split plot design; method of crop establishment as main plot and variety in sub plot with four replication. The soil of experimental site was sandy loam in texture with pH 5.4. The soil was low in organic matter content (1.9%), poor in available nitrogen (0.09%), high in available phosphorus and potassium. The experimental site received total rainfall of 2235.8 mm during the cropping season of rice with the maximum temperature and relative humidity ranged from 27.8 to 35.54^{0}C and 77.47 to 93%, respectively. The results of the experiment are summarized below.

All the growth stages were significantly early in SRI method and on an average it took 91% of time period required by TPR. DSR method took 95% of the time period of TPR. In case of variety, Sabitri required longer period for all the phenological stages to express. At panicle initiation stage, the interaction of Sabitri TPR method took significantly more days whereas significantly earlier panicle initiation was observed in the combination of SRI and Radha-4. Significantly late maturity was recorded in the interaction of TPR and Sabitri.

Plant height was significantly influenced by method of crop establishment at all the observation dates. The increment in plant height was prominent (42.33 %) between 35 DAS and 50 DAS, which represented the rapid vegetative growth stage of plant coinciding with the stage of maximum tillering. At harvest, maximum plant height was observed in SRI method (115.1 cm) followed by DSR method (110.1 cm) and the shortest was observed in TPR (104.7 cm). There was significant interaction between method of crop establishment and varieties at 80 DAS and 95 DAS on plant height. At 80 DAS interaction effect of SRI method and Radha-4 variety recorded the maximum height (126.9 cm) and at 95 DAS maximum plant height was recorded in combination of Loktantra under SRI (137.3 cm). The lowest plant height was observed in combination of TPR and Sabitri (105.20 cm).

Tillers were increased up to 65 DAS, there after decreased till harvesting due to tiller mortality. The highest number of tiller increased during 35-50 DAS (111.67%). Significantly higher number of tillers per square meter was observed in SRI method in all the observations except 80 DAS. Maximum number of tillers per square meter was observed in TPR (390), SRI (409) and DSR (350). Maximum effective tillers per meter square were observed in SRI 23% more than TPR (208.9) and DSR produced 12.5% more effective tillers than TPR. This may be due to the better tillering and faster growth with suitable temperature and soil moisture regime present in the soil. Varieties had significant influence on tillers per square meter at all the observation dates. Significantly the highest tiller numbers per square meter at harvest was recorded in Radha-4 (259) and the lowest numbers in Loktantra (208.4). The difference in tiller production among cultivars may be attributed to varietal characters. There was highly significant positive correlation (r = 0.712**) between the number of tillers per square meter at harvest and yield (mt/ha). There was significant interaction between rice varieties and method of crop establishment on tillers per square meter at harvest. Radh-4 produced the significantly the highest number of tillers under SRI method (295.4) and significantly lower number of tillers (191.1) at harvest was observed in the interaction of Loktantra under TPR.

The average Leaf area index ranged from 0.34 to 3.39 in 35 DAS to 95 DAS. Similarly, Loktantra had higher LAI (3.87) as compared to Radha-4 (3.026) and Sabitri (3.28) at 95 DAS.

At the initial stage 35 DAS of crop the partitioning of root, stem and leaf, to the total dry matter was (30% by root, 36% by stem and 34% by leaf) but later stage the partitioning of the total dry matter in stem was comparatively higher (44.33% at 50 DAS, 44.85% at 65 DAS, 53.18% at 80 DAS, and 62.16% at 95 DAS). This is due to utilization of assimilates in the formation of panicle and partitioning of total dry matter towards stem covering panicle was higher than the leaf (20.56%). Among the different methods SRI produced the highest root and stem dry matter per 0.25 square meter and was 50%,and 53% more than that of general TPR at 80 and 95 DAS, respectively. From 80-95 DAS, 20% root degenerated in TPR method whereas 17% in SRI and depending upon the variety it is reproductive to maturity stage. There was highly significant positive correlation ($r=0.494^{**}$) and significant positive correlation ($r=0.404^{*}$) between root dry weight per 0.25 sq meter at 80 DAS and 95 DAS respectively. At 95 DAS the total dry matter production per 0.25 sq meter was maximum in SRI method (259.4g) and was 53% more than TPR. Similarly, DSR produced 41% more total dry matter than TPR at 95 DAS.

On an average, total dry matter production tendency of rice plants was found increasing from active vegetative stage (11.4 g/ 0.25 m^2 at 35 DAS) to heading stage (222.97 g/ 0.25 m^2 at 95 DAS) while stem and leaves increased from active vegetative stage (4.1 and 3.9 g/ 0.25 m^2, respectively) up to panicle initiation stage (109.70, 48.94 g/0.25 m^2 respectively at 80 DAS) and there after dry matter of leaf declined at heading stage (45.84 g/ 0.25m^2 at 95 DAS). Root, stem and total dry matter was significantly influenced by varieties in all the dates of observation. Significantly higher total dry matter was produced by Radha-4 and Loktantra than Sabitri in all the dates of observation. There was significant interaction between method of crop establishment and varieties on total dry matter at 35, 50, 65 and 80 DAS. At 35 DAS Radha-4 (25.04g/0.25m^2) and Sabitri (23.50g/0.25m2) under SRI produced higher but statistically similar dry weight. Similarly Radha-4 under SRI produced higher dry weight at 50 DAS, 65 DAS, and 80 DAS. While Sabitri under TPR produced the lowest dry weight per unit area in all dates of observation.

In all the dates of observation, SRI had the the highest value of CGR followed by DSR and the the lowest in TPR. But during 65-80 DAS, DSR had the highest CGR (21.09 g m $^{-2}$ d^{-1}). In the research, SRI attained maximum CGR of value (19.5 g m $^{-2}$ d^{-1}); similarly, DSR (21.09 g m $^{-2}$ d^{-1}) and TPR (15.86 g m $^{-2}$ d^{-1}). The highest value of CGR among the observation was recorded in Loktantra under SRI (21.9 g m $^{-2}$ d^{-1}) during 50-65 DAS. In case of varieties Radha-4 had the highest CGR during 0-35DAS (1.03g m $^{-2}$ d^{-1}), 35-50 DAS (9.41 g m $^{-2}$ d^{-1}), and 50-65DAS (15.51 g m $^{-2}$ d^{-1}) followed by Loktantra and Sabitri. During 65-80 DAS variety did not show any significant difference in CGR.

The interaction of Radha-4 with all method of crop establishment produced more effective tillers, whereas the interactions of Loktantra with different method of crop establishment resulted lower number of effective tiller. The interaction of SRI and Radha-4 produced more tillers i.e. 295.4 and significantly lower numbers of tillers observed in the combination of TPR and Loktantra (191.1). There was highly significant positive correlation (r = 0.712**) between effective tillers per square meter and yield t ha^{-1}.

The average panicle length was 25.84 cm. Panicle length was significantly influenced by method of crop establishment as well as varieties. The DSR method had longer panicle length (27.05 cm) than that of SRI method (26.89 cm), but are statistically similar. Significantly, shorter panicle length was observed in TPR method (23.57cm). Loktantra had longer panicle (26.92 cm), which was statistically similar with Sabitri (26.69 cm). But Radha-4 had significantly shorter panicle length, i.e., 23.90 cm. Interaction effect of method of crop establishment and varieties had no significant influence on panicle length. Panicle length had highly significant positive correlation(r= 0.455^{**}) with grain yield (mt/ha).

Under different methods, filled grain per panicle was the highest in SRI method (181.9) followed by DSR (174.0) which were statistically similar. Lower number of filled grain was observed in TPR method (113.7). In case of varieties, Loktantra had significantly higher number of filled grains per panicle (183.2) followed by Sabitri (152.9) and Radha-4 (133.5) and was statistically similar. Interaction effect of method of crop establishment and varieties had no significant influence on filled grains per panicle. There was significant positive correlation (r = 0.369*) between filled grains per panicle and yield (mt/ha).

The average thousand grain weight was 24.68 gm (Table 12). The thousand grain weight was not influenced by experimental factor i.e. method of crop establishment. The thousand grain weight was significantly influenced by the varieties. The Radha-4 had significantly higher test weight (26.84 gm) than Loktantra (23.92 gm) and significantly lower test weight was recorded on Sabitri (23.29 g). Higher thousand grain weight of Loktantra was probably due to the facts that its seeds were long and bulkier. There was significant positive correlation (r = 0.38*) between thousand grain weight and grain yield.

The average sterility percentage in the present experiment was 9.667% and it ranged from 6.707 to 14.42%. Sterility percentage was not affected by method of crop establishment, but was significantly influenced by varieties. Significantly higher sterility was observed in Radha-4 (14.42%), followed by Loktantra (7.88%) and Sabitri (6.7%) which were statistically at par. Among the methods SRI (8.335%) had the lowest sterility percentage although it was not significant to DSR and TPR.

The grain yield ranged from 3.68 mt/ha (Loktantra under TPR) to 7.38 mt/ha (Radha-4 under SRI) among the combination of different method of crop establishment and varieties, and the average yield in the experiment was 5.935 mt/ha. Both different method of crop establishment and varieties significantly influenced the gain yield but their interaction did not influence the grain yield. SRI method of crop establishment produced significantly higher grain yield (6.95 mt/ha) followed by DSR yield (6.2 mt/ha) and the lowest yield was under TPR method, i.e., 4.18 mt/ha. SRI produced 51% and DSR produce 48% higher grain yield than general TPR. Among the varieties, Radha-4 produced significantly higher grain yield (6.26 mt/ha) as compared to Sabitri (5.677 mt/ha) and Loktantra (5.39 mt/ha) which were statistically at par. Interaction between method of crop establishment and varieties on grain yield was not significant. The yield attributing characters effective tillers per square meter, panicle length, grains per panicle were higher in the SRI method followed by DSR, which was responsible for the increased grain yield. Straw yield was also the highest in treatment combination of SRI and Radha-4 (11.14 mt /ha). The straw yield was the highest (9.1 mt/ha) in SRI method which was significantly superior to the straw yield from DSR (8.3 mt/ha) and the lowest in TPR (6.5 mt/ha). SRI and DSR produced 40% and 27% more straw yield, respectively than TPR. The highest harvest index was observed in DSR (0.43) followed by SRI (0.41) and the lowest in TPR (0.39).

SRI method reduced the irrigation water by 29% and DSR reduced 20% compared to continuous flooded TPR. Here higher irrigation water was required in DSR than in transplanted SRI which was mainly due to two times more irrigation applied in DSR, and was due to continuous flooding and puddling water required in TPR. Total water requirement for complete crop season was the highest in TPR (16260 m^3/ha), followed by SRI (13630 m^3/ha) and the lowest for DSR (13600 m^3/ha). SRI and DSR required 17% less water than TPR. In case of varieties the quantity of water required differs due to their maturity period. The experiment shows the highest water productivity in SRI methods (0.514 kg/m^3), followed by DSR (0.456 kg/m^3) and the lowest in TPR (0.259 kg/m^3).

Treatment combination of Radha-4 under SRI method (0.593 kg/m^3) had the highest water productivity, and was due to short maturity period, higher yield and water saving method of irrigation.

The average cost of cultivation calculated in this experiment was Rs 65.1 thousand per hectare for SRI, Rs 61.42 thousand for TPR method and for DSR is Rs 61.1 per hectare. In general, the higher gross return (Rs. 175.8 thousand) per hectare was obtained from SRI method followed by DSR (Rs. 154.8 thousand), whereas significantly lower gross return (Rs.107.2 thousand) was observed from TPR method. The significantly higher gross return from SRI method was due to higher grain and straw yield per ha. Among the varieties significantly higher gross return obtained from Radha-4 (Rs. 154.8 thousand) followed by Loktantra (Rs.142.2 thousand) and significantly lower gross return was received from Sabitri (Rs.138.9thousand). Loktantra had significantly lower yield than Radha-4, and gross return was statistically at par because of its higher market price. At that time, the market price was Rs 20/kg of Sabitri and Radha-4 and for Loktantra it was Rs 22 per kg. The market price of rice straw was Rs 3.25 per kg.

Significantly higher net return (Rs. 110.7 thousand) per hectare was obtained from SRI method followed by DSR method (Rs. 93.73 thousand) and the lowest in TPR method. Within the varieties significantly higher net return per hectare was observed in the Radha-4 (Rs. 92.27 thousands) followed by Loktantra (Rs. 81.64 thousands) which were statistically similar and Sabitri (Rs. 76.32 thousands) which was significantly lower than Radha-4 but statistically at par with variety Loktantra. The highest net return (Rs. 118.83 thousands) obtained from interaction of SRI method and Radha-4.

The significantly higher B:C ratio was observed in SRI method (2.7) followed by DSR method (2.52) and statistically lower B:C ratio was obtained in TPR (1.75). Similarly, in case of varieties higher B:C ratio was observed in the Radha-4 (2.47) followed by Loktantra (2.30) which are statistically at par and Sabitri (2.21) was also statistically similar with variety Loktantra. Interaction effect of method of crop establishment and varieties did not influence on B: C ratio. However, relatively higher B: C ratio was obtained from the interaction of SRI method with different varieties.

5.2 Conclusions

Among the different method of crop establishment, SRI method yielded the highest grain and straw (51% and 40% higher than TPR, respectively). It was superior in all the vegetative and yield-contributing characteristics, and the cost of cultivation was not significantly higher, but the B:C ratio was significantly (2.7) compared to DSR and TPR methods. SRI also saved 29% of irrigation water; it matured about 10 days earlier, providing time for early planting of winter crops. There was no significant interaction between varieties and method of crop establishment on yield, which shows that all the varieties response positively with SRI method. In this experiment Radha-4 under SRI yielded maximum. Variety Radha-4 seemed superior in yield water productivity, matured early and have higher B:Cratio. Where labour is shortage at planting time and puddling water is not available on time, direct seeding can be done and latter follow the SRI management practices which produce significantly higher grain and straw yield, superior vegetative characters, higher water productivity than TPR with B:C ratio about 2.5. Thus, SRI method can be a good option for farmers to earn more from less.

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APPENDICES

Appendix 1. Monthly weather data of the experimental field from May 2010 to November 2010 at Phulbari, Chitwan, Nepal

Month	Week	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)	Total Rainfall (mm)	Relative Humidity (%)
May	4	35.47	25.67	4.00	90.83
June	1	35.50	27.50	44.80	78.00
June	2	36.50	27.49	19.40	77.10
June	3	35.57	28.11	8.60	76.60
June	4	34.50	25.69	299.00	82.40
July	1	34.50	27.29	84.00	80.14
July	2	32.18	25.93	335.00	88.00
July	3	32.93	26.61	53.00	85.86
July	4	34.25	26.20	251.80	93.25
August	1	34.61	27.50	11.50	96.00
August	2	34.46	26.93	37.50	96.00
August	3	33.57	26.68	176.00	96.00
August	4	31.98	25.95	416.20	96.00
September	1	33.21	26.07	120.00	87.57
September	2	33.54	25.96	151.50	86.29
September	3	32.64	25.75	168.70	88.57
September	4	31.89	25.42	83.00	88.89
October	1	33.36	23.48	4.50	95.20
October	2	31.21	23.43	15.10	95.10
October	3	30.93	23.61	11.50	95.15
October	4	30.60	21.18	17.50	95.15
November	1	29.25	17.68	0.00	95.70
November	2	28.14	17.89	0.00	95.90
November	3	26.01	17.57	0.00	95.65

Appendix 2. Details of various cultural practices in the experimental plot of DSR from May to November 2010 at Phulbari, Chitwan

S.N.	Cultural operations	Date
1	Primary land preparation, layout of plot, and bund construction	15-June-10
2	FYM application, removal of stubbles and weeds	16-June-10
3	Seed collection, seed soaking, and seed treatment	16-June-10
5	Nursery bed preparation and seed sowing	18-June-10
5.1	Final land preparation, seed sowing and basal dose of fertilizer application in DSR plots	18-June-10
5.2	Irrigation in nursery bed and DSR plots	19-June-10
5.3	Final land preparation and application of basal dose of fertilizer for SRI	28-June-10
5.4	Transplanting in SRI plots	29-June-10
	Thinning and weed removal in DSR plots	29-June-10
6	Final land preparation for TPR	14-July-10
6.1	Transplanting in TPR plots	16-July-10
7	Weed management	
7.1	First weeding with rotatory weeder in SRI and DSR plots	13-July-10
7.2	Second weeding with rotatory weeder in SRI and DSR plots	30-July-10
7.3	First manual weeding in TPR plots	6-July-10
7.4	Second manual weeding in TPR plots	28-July-10
8	Irrigation	
8.1	Irrigation for DSR and SRI plots	8-July-10
8.2	Irrigation for TPR	4-Aug-10
8.3	Irrigation for TPR	13-Aug-10
8.4	Irrigation for whole field	5-Sep-10
	Irrigate field except Radha-4 under SRI	27-Sep-10
	Irrigate field except Radha-4 under DSR	3-Oct-10
	Irrigate field except Radha-4 under TPR	11-Oct-10
	Irrigate field for Loktantra and Sabitri under TPR	18-Oct-10
9	Top dressing of nitrogenous fertilizer	
9.1	1st top dressing of urea for SRI and DSR	22-Jul-10
9.2	1st top dressing of urea for TPR	10-Aug-10
9.5	2nd top dressing for SRI and DSR	18-Aug-10
9.6	2nd top dressing for TPR	10-Sep-10
10.2	Insecticide application for SRI and DSR plots	15-Sep-10
11	Harvesting	
11.1	1st harvesting	04-Oct-10
11.2	2nd harvesting	13-Oct-10
11.3	3rd harvesting	21-Oct-10
11.4	4th harvesting	01-Nov-10
11.5	5th harvesting	09-Nov-10
12	Threshing	
12.1	1st threshing and cleaning	08-Oct-10
12.2	2nd threshing and cleaning	15-Oct-10
12.3	3rd threshing and cleaning	25-Oct-10
12.4	4th threshing and cleaning	04-Nov-10
12.5	5th threshing and cleaning	13-Oct-10
13	Drying and weighing	16-Oct-10

Appendix 4. General cost of rice production through general recommended method for transplanted rice (TPR) in NRs ha^{-1} from June 2010 to November 2010

Particulars	Unit	Quantity	Rate (Rs.)	Total (Rs.)
Nursery raising (500 m2)				
Land preparation (3 ploughing)	minute	10	15	150
Seed bed preparation	Labor	1	300	300
Application of fertilizer and sowing seeds	Labor	1	300	300
Seed	kg	45	40	1800
(Fertilizer @ 100:30:30 NPK Kg/ha)				
Urea	kg	9.1	30	273
DAP	kg	4.35	38	165.3
MOP	kg	2.5	27	67.5
FYM	kg	500	1.5	750
Cost of uprooting seeds	Labor	4	200	800
Irrigation		1	100	100
Transplanting field (1 ha)				0
Primary land preparation	hour	3	900	2700
Puddling and levelling	hour	2.5	900	2250
Bunding	labor	5	300	1500
Farm Yard Manure	ton	10	1000	10000
Urea	kg	179.12	30	5373.6
Diammonium phosphate	kg	97.83	38	3717.54
Murate of potash	kg	75	27	2025
Micro nutrients	kg	20	85	1700
Insecticides	kg	0.75	1000	750
Fungicides tricyclazole	kg	1	750	750
Transplanting	labor	20	200	4000
hand weeding 2 times	labor	35	200	7000
Irrigation electricity	unit	150	3	450
Irrigation	labor	5	250	1250
Manure and fertilizer application	labor	3	250	750
Pesticide application	labor	2	250	500
Harvesting	labor	20	250	5000
Threshing	hour	5	900	4500
Threshing	labor	5	250	1250
Cleaning, drying and storage	labor	5	250	1250
Total				61421.94

Appendix 5. General cost of rice production through system of rice intensification (SRI) in NRs ha^{-1} from June 2010 to November 2010

Particulars	Unit	Quantity	Rate (Rs.)	Total (Rs.)
Nursery raising (100 m2)				
Land preparation through disc harrow	Min.	5	15	75
Nursery bed preparation	Labour	1	300	300
Solarization with 300 gauge plastic sheet	Sq. m	100	40	
Seed	kg	10	40	400
(Fertilizer @ 100:30:30 NPK Kg/ha)				
Urea	kg	1.82	30	54.6
DAP	kg	0.87	38	33.06
MOP	kg	0.5	27	13.5
FYM	kg	100	1.5	150
Cost of uprooting seeds	labor	3	200	600
Irrigation		1	100	100
Transplanting field (1 ha)				
Primary land preparation	hour	3	900	2700
Puddling and leveling	hour	2.5	900	2250
Bunding	labor	5	300	1500
Farm Yard Manure	ton	10	1000	10000
Urea	kg	179.12	30	5373.6
Diammonium phosphate	kg	97.83	38	3717.54
Murate of potash	kg	75	27	2025
Micro nutrients	kg	20	85	1700
Insecticides	kg	0.75	1000	750
Fungicides tricyclazole	kg	1	750	750
Transplanting	labor	30	200	6000
Weeding with rotatory weeder (2 times)	labor	16	300	4800
Rotatory weeder	number	1	4000	4000
Irrigation electricity	unit	100	3	300
Irrigation	labor	6	250	1500
Pipe			1400	1400
Repair and maintenance			600	600
Manure and fertilizer application	labor	3	250	750
Pesticide application	labor	2	250	500
Harvesting	labor	20	250	5000
Threshing	hour	5	900	4500
Threshing	labor	8	250	2000
Cleaning, drying and storage	labor	5	250	1250
Total				65092.3

Appendix 6. General cost of rice production through direct seeding with other SRI management practices (DSR) method in NRs ha^{-1} from June 2010 to November 2010

Particulars	Unit	Quantity	Rate (Rs.)	Total (Rs.)
Primary land preparation	hour	3	900	2700
Land preparation leveling, planking	hour	2.5	900	2250
Bunding	labour	5	300	1500
Seed	kg	20	40	800
Seed dibbling	labor	20	200	4000
Thinning	labor	15	200	3000
Farm Yard Manure	ton	10	1000	10000
Urea	kg	179.12	30	5373.6
Diammonium phosphate	kg	97.83	38	3717.54
Murate of potash	kg	75	27	2025
Micro nutrients	kg	20	85	1700
Insecticides	kg	0.75	1000	750
Fungicides tricyclazole	kg	1	750	750
Weeding with rotatory weeder (2 times)	labor	16	300	4800
Irrigation electricity	unit	80	3	240
Labor	labor	6	250	1500
Pipe			1400	1400
Repair and maintenance			600	600
Manure and fertilizer application	labor	3	250	750
Pesticide application	labor	2	250	500
Harvesting	labor	20	250	5000
Threshing	hour	5	900	4500
Threshing	labor	8	250	2000
Cleaning, drying and storage	labor	5	250	1250
Total				61106.14

Appendix 7. Price of different product and by-products of rice at farmer's field, Phulbari-9, Chitwan, Nepal, 2010

S. N.	Products and by-products	Price rate(Rs./kg)
1	Rice grain	
	Sabitri	20
	Loktantra	22
	Radha-4	20
3	Rice straw	3.25

Appendix 8. Rating chart of soil values to determine the fertility status of experimental soil

Nutrient	Low	Medium	High
Available nitrogen, N (%)	<0.10	0.1-0.2	>0.2
Available phosphorus, P_2O_5(kg/ha)	<30	30-55	>55
Available potash, K_2O(kg/ha)	<110	110-280	>280
Organic matter (%)	<2.5	2.5-5.0	>5.0
Soil pH	<60 (Acidic)	6.0-7.5(Neutral)	>7.5 (Alkali)

Source: (Khatri Chhetri, 1991; Jaishy, 2000)

Appendix 9. Mean squares from ANOVA associated to plant height (cm) and number of tillers per square meter as influenced by method of crop establishment and variety of rice at farmer's field,Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Plant height						Number of tillers per square meter				
		35 DAS	50 DAS	65 DAS	80 DAS	95 DAS	At harvest	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS
Replication	3	12.59	76.39	70.342	93.84	168.14	42.45	655.67	21432.514	8712.47	1283.659	716.712
Factor A	2	1734.67**	601.41**	539.37**	612.05**	334.12**	325.92**	69651.45**	32444.118**	10383.62*	207.756	7230.664*
Error	6	13.76	15.90	26.92	31.06	39.11	20.22	2371.21	1930.132	1536.62	454.525	977.988
Factor B	2	108.80**	99.82**	304.18**	569.19**	903.67**	1502.09**	4713.25	24808.083**	10452.25*	14629.635**	3023.144*
AB	4	15.66	25.74	32.68	257.97**	81.30*	17.85	1994.32	4169.917	2617.37	1991.784	512.338
Error	18	9.68	14.54	17.14	28.17	27.50	31.42	1734.45	3360.093	2580.65	2093.758	571.348

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 10. Mean squares from ANOVA associated to number of leaf per tiller and leaf area index (LAI) as influenced by method of crop establishment and variety of rice at farmer's field,Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Number of leaves per tiller					Leaf area index (LAI)				
		35 DAS	50 DAS	65 DAS	80 DAS	95 DAS	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS
Replication	3	0.330	0.023	0.316	0.429	0.643	0.001	0.003	0.034	0.018	0.071
Factor A	2	0.090	1.153**	0.290	1.498*	0.882	0.982**	2.737**	1.679**	0.585*	0.190*
Error	6	0.202	0.091	0.196	0.176	0.427	0.001	0.008	0.034	0.065	0.019
Factor B	2	0.022	0.522*	0.044	3.311**	3.511**	0.089**	0.279**	3.495**	0.279	2.243**
AB	4	0.153	0.026	0.303	0.423	1.152*	0.009**	0.310**	0.180*	1.021**	0.510**
Error	18	0.240	0.093	0.143	0.387	0.258	0.001	0.010	0.042	0.102	0.052

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 11. Mean squares from ANOVA associated to root and stem dry matter as influenced by method of crop establishment and variety of rice at farmer's field, Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Root Dry Matter(gm/0.25m^2)					Stem Dry Matter(gm/0.25m^2)				
		35 DAS	50 DAS	65 DAS	80 DAS	95 DAS	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS
Replicatio	3	1.317	1.180	63.636	13.837	53.993	0.776	57.922	8.107	8.923	52.497
Factor A	2	77.51**	596.68*	631.370*	851.227**	729.445**	185.84*	2530.080*	7100.66*	10129.27**	15391.37
Error	6	0.450	5.426	16.460	29.459	23.701	0.37	33.968	41.21	163.032	92.79
Factor B	2	1.710	62.17**	456.335*	981.055**	801.662**	3.29**	204.903**	807.44**	1682.080**	4110.63*
AB	4	1.017	3.635	12.137	112.469*	99.570**	3.04**	58.376*	523.94**	618.053*	469.81**
Error	1	0.763	9.387	39.922	36.670	16.046	0.35	18.346	42.51	143.854	81.06

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 12. Mean squares from ANOVA associated to leaf and total dry matter as influenced by method of crop establishment and variety of rice at farmer's field,Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Leaf Dry Matter(gm/0.25m^2)					Total Dry Matter(gm/0.25m^2)				
		35 DAS	50 DAS	65 DAS	80 DAS	95 DAS	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS
Replicatio	3	1.207	11.501	6.188	1.148	6.822	9.376	139.323	101.486	11.686	78.318
Factor A	2	157.410*	499.949*	822.598*	621.080*	385.754*	1222.83*	9197.278*	18813.74*	23672.38*	27566.60*
Error	6	0.747	2.817	9.210	10.419	21.754	3.795	60.730	126.621	311.588	106.95
Factor B	2	1.511**	66.434**	354.661*	15.965	583.324*	12.927**	874.464**	3541.82**	3285.98**	4073.71**
AB	4	0.118	21.560**	44.625*	266.689*	84.540**	6.280*	170.359*	891.91**	1710.47**	243.87
Error	1	0.228	1.959	11.170	4.582	10.230	1.915	54.290	96.883	281.773	121.615

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 13. Mean squares from ANOVA associated to days to phonological stages as influenced by method of crop establishment and variety of rice at farmer’s field, Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Phenological stages						
		Panicle initiation	Booting	Heading	Flowering	Milking	Dough	Maturity
Replication	3	3.583	4.185	4.250	2.917	2.991	3.435	4.991
Factor A	2	188.028**	213.361**	201.86**	286.75**	266.58**	257.53**	291.03**
Error	6	4.472	4.991	1.639	2.750	0.991	1.269	2.435
Factor B	2	840.444**	895.194**	1112.028**	1026.58**	943.58**	995.44**	1273.36**
AB	4	7.403*	5.861*	2.278	2.333	6.42*	8.78**	5.57*
Error	18	1.898	1.750	2.787	2.194	1.546	1.741	1.648

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 14. Mean squares from ANOVA associated to yield attributes as influenced by method of crop establishment and variety of rice at farmer’s field, Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Yield attributes					
		ET	Panicle length	Panicle weight	Grains per panicle	Sterility percentage	TWG
Replication	3	258.755	1.117	0.013	143.953	1.054	9.320
Factor A	2	6934.95**	46.32**	8.060**	16715.830**	25.810	8.884
Error	6	178.07	0.068	0.223	244.215	6.872	2.839
Factor B	2	7684.50**	34.018**	7.185**	7518.305**	207.016**	43.027**
AB	4	407.44*	0.641	0.145	706.387	6.795	3.016
Error	18	120.00	0.253	0.362	603.827	5.800	3.752

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 15. Mean squares from ANOVA associated grain yield, straw yield, harvest index, gross return, net return, and B:C ratio as influenced by method of crop establishment and variety of rice at farmer's field,Phulbari-9, Chitwan, Nepal, 2010

Source	df	Grain yield	Straw yield	Harvest index (HI)	Gross return	Net return	B:C Ratio
Replication	3	0.212	0.671	0.000	148.902	148.902	0.039
Factor A	2	24.519**	36.600**	0.004*	14809.276**	13584.993**	3.119**
Error	6	0.108	0.834	0.000	79.337	79.337	0.020
Factor B	2	2.330**	6.802**	0.001	792.189*	792.189*	0.203*
AB	4	0.161	2.294*	0.001	198.048	198.048	0.053
Error	18	0.268	0.693	0.000	157.662	157.662	0.041

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 16. Mean squares from ANOVA associated to crop growth rate(CGR) and relative growth rate(RGR) as influenced by method of crop establishment and variety of rice at farmer's field,Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Crop growth rate (CGR)					Relative growth rate (RGR)				
		0-35	35-50	50-65	65-80	80-95	0-35	35-50	50-65	65-80	80-95
Replication	3	0.050	8.893	5.426	1.787	2.610	0.000	0.001	0.001	0.000	0.000
Factor A	2	8.951**	151.954**	142.294**	86.364**	525.413**	0.008**	0.008**	0.003*	0.001**	0.001**
Error	6	0.027	3.226	13.514	5.326	6.095	0.000	0.000	0.000	0.000	0.000
Factor B	2	0.109**	28.541**	40.341**	13.769	88.486**	0.000**	0.000	0.000	0.000**	0.000**
AB	4	0.054**	7.917*	25.249**	182.950**	23.834*	0.000	0.000	0.000	0.001**	0.000**
Error	18	0.011	2.064	3.389	9.252	5.611	0.000	0.000	0.000	0.000	0.000

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 17. Mean squares from ANOVA associated to crop Growing degree days of phonological stages as influenced by method of crop establishment and variety of rice at farmer’s field,Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Phonological stages						
		Panicle initiation	Booting	Heading	Flowering	Milking	Hard dough	Maturity
Replication	3	2938.225	1589.119	1483.354	26507.302	34051.853	28265.467	1155.952
Factor A	2	58000.048**	80736.705**	73703.845**	221456.140*	201219.706*	100989.526	68782.837**
Error	6	2106.144	1869.830	567.383	27374.887	28891.651	23907.720	633.554
Factor B	2	277819.838**	343977.536**	404910.655**	245056.596**	303691.794**	444067.741**	345003.775**
AB	4	1353.496	2213.699*	1146.772	21438.568	25928.692	16596.510	2030.581**
Error		1284.118	656.649	982.806	27754.483	28843.144	22296.979	414.536

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 18. Mean squares from ANOVA associated to quantity of water irrigated, effective rainfall, total quantity of water, and water productivity as influenced by method of crop establishment and variety of rice at farmer’s field,Phulbari-9, Chitwan, Nepal, 2010

Sources	df	Water quantity parameters			
		Irrigation (m^3/ha)	Effective rainfall (m^3/ha)	Total water (m^3/ha)	Water productivity(kg/m^3)
Replication	3	5043818.409**	0.000	115439.815	0.001
Factor A	2	35578.709	10566400.000	27977542.501**	0.214**
Error	6	3726457.942**	0.000	35578.704	0.001
Factor B	2	496666.726**	444133.333	6738254.967**	0.033**
AB	4	21226.855	34133.333	349466.514**	0.001
Error	18	5043818.409**	0.000	21226.852	0.001

**significant at the 0.01 level of significance; * significant at the 0.05 level of significance; df, degree of freedom; Factor A, method of crop establishment ; Factor B, variety; DAS, days after sowing

Appendix 19. Interaction effect on panicle initiation (PI), booting and milking stages of rice as influenced by Method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Panicle Initiation (PI) (DAS)			Booting Stage (DAS)			Milking stage (DAS)		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	81.75^{a}	73.00^{bc}	65.25^{d}	97.25^{a}	88.75^{c}	80.25^{e}	116.5^{a}	111.3^{b}	99.00^{e}
SRI	74.00^{bc}	67.00^{d}	55.25^{f}	89.00^{c}	82.00^{e}	70.00^{g}	107.5^{c}	102.8^{d}	88.25^{g}
DSR	76.00^{b}	70.75^{c}	61.25^{e}	91.00^{b}	85.75^{d}	75.50^{f}	109.8^{b}	106.5^{c}	95.25^{f}
$LSD_{(0.05)}$		3.142			1.965			2.553	
SEM±		1.057			0.6614			0.8594	

Appendix 20. Interaction effect on dough, and physiological maturity stages of rice as influenced by Method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties					
	Dough stage (DAS)			Physiological maturity (DAS)		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment						
Farmers practice	127.3^{a}	123.3^{b}	110.8^{e}	141.3^{a}	136.3^{b}	121.3^{f}
SRI	118.8^{c}	115.8^{d}	99.0^{g}	131.8^{d}	127.5^{e}	110.3^{h}
DSR	120.8^{c}	119.3^{c}	106.0^{f}	133.8^{c}	130.3^{d}	116.5^{g}
$LSD_{(0.05)}$		1.960			1.907	
SEM±		0.6597			0.6419	

Appendix 21. Interaction effect of method of crop establishment and varieties on plant height and number of leaf per tiller of rice at Phulbari, Chitwan, 2010

Treatment	Varieties								
	Plant height 80 DAS			Plant height 95 DAS			No.of leaf per tillers 95 das		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	90.38^{d}	105.40^{b}	96.10^{cd}	105.20^{e}	126.70^{bc}	123.00^{cd}	4.94^{bcd}	4.58^{cde}	4.87^{bcd}
SRI	99.50^{b}	108.30^{b}	126.90^{a}	123.10^{cd}	137.30^{a}	126.20^{bc}	5.31^{abc}	5.27^{abc}	3.86^{e}
DSR	99.85^{bc}	108.30^{b}	105.20^{b}	117.20^{d}	133.60^{ab}	119.30^{cd}	5.69^{ab}	5.84^{a}	4.29^{de}
$LSD_{(0.05)}$	7.89				7.79			0.76	
SEM±		2.65			2.62			0.25	

Appendix 22. Interaction effect on Leaf Area Index as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Leaf area index 35 DAS			Leaf area index 50 DAS			Leaf area index 65 DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	0.09^{f}	0.13^{ef}	0.1827^{d}	1.02^{e}	1.37^{c}	0.95^{ef}	2.12^{cd}	2.22^{c}	3.02^{b}
SRI	0.60^{b}	0.59^{b}	0.8219^{a}	1.70^{b}	1.63^{b}	2.29^{a}	2.04^{cd}	2.28^{c}	3.47^{a}
DSR	0.18^{de}	0.17^{de}	0.3177^{c}	0.83^{f}	0.93^{ef}	1.22^{d}	1.57^{e}	1.81^{de}	2.29^{c}
$LSD_{(0.05)}$	0.047			0.149			0.305		
SEM±	0.016			0.050			0.103		

Appendix 23. Interaction effect on Leaf Area Index and leaf dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Leaf area index 80 DAS			Leaf area index 95 DAS			Leaf Dry Matter (gm/0.25m^{2}) 50DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	3.13^{c}	3.43^{bc}	3.84^{ab}	2.70^{d}	4.01^{a}	3.06^{c}	8.95^{e}	12.37^{c}	11.04^{cde}
SRI	3.39^{abc}	3.92^{a}	3.35^{bc}	3.65^{ab}	3.77^{ab}	2.86^{cd}	18.67^{b}	20.51^{b}	27.52^{a}
DSR	3.47^{abc}	2.45^{d}	3.49^{abc}	3.50^{b}	3.84^{ab}	3.16^{c}	9.56^{de}	11.71^{cd}	12.74^{c}
LSD$_{(0.05)}$		0.475			0.339			2.079	
SEM±		0.160			0.114			0.700	

Appendix 24. Interaction effect on leaf dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Leaf Dry Matter (gm/0.25m^{2}) 65 DAS			Leaf Dry Matter (gm/0.25m^{2}) 80 DAS			Leaf Dry Matter (gm/0.25m^{2}) 95 DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	23.16^{e}	29.43^{d}	32.53^{cd}	41.21^{e}	41.35^{e}	49.58^{c}	37.13^{e}	47.42^{c}	34.96^{e}
SRI	34.94^{bc}	39.52^{b}	50.71^{a}	53.65^{b}	68.19^{a}	49.78^{c}	53.82^{b}	60.94^{a}	38.54^{de}
DSR	21.19^{e}	30.09^{cd}	28.41^{d}	50.25^{c}	41.29^{e}	45.23^{d}	47.62^{c}	49.55^{bc}	42.62^{d}
LSD$_{(0.05)}$		4.951			3.180			4.752	
SEM±		1.666			1.070			1.599	

Appendix 25. Interaction effect on stem dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Stem Dry Matter (gm/0.25m^2) 30 DAS			Stem Dry Matter (gm/0.25m^2) 50 DAS			Stem Dry Matter (gm/0.25m^2) 65 DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	0.09^{f}	0.13^{ef}	0.18^{d}	1.02^{e}	1.37^{c}	0.95^{ef}	2.12^{cd}	2.223^{c}	3.018^{b}
SRI	0.60^{b}	0.59^{b}	0.83^{a}	1.70^{b}	1.63^{b}	2.29^{a}	2.04^{cd}	2.281^{c}	3.473^{a}
DSR	0.18^{de}	0.17^{de}	0.32^{c}	0.83^{f}	0.93^{ef}	1.22^{d}	1.57^{e}	1.809^{de}	2.292^{c}
LSD$_{(0.05)}$	0.047			0.149			0.3045		
SEM±	0.016			0.050			0.1025		

Appendix 26. Interaction effect on stem dry matter and root dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Stem Dry Matter (gm/0.25m^2) 80 DAS			Stem Dry Matter (gm/0.25m^2) 95 DAS			Root Dry Matter (gm/0.25m^2) 80 DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	86.64^{d}	80.78^{d}	86.62^{d}	92.65^{f}	90.39^{f}	108.9^{e}	33.82^{d}	43.54^{cd}	41.07^{d}
SRI	123.6^{c}	142.7^{ab}	158.3^{a}	131.9^{d}	164.0^{bc}	188.2^{a}	40.91^{d}	70.06^{a}	57.92^{b}
DSR	98.29^{d}	85.19^{d}	125.2^{bc}	139.2^{d}	154.9^{c}	177.2^{ab}	38.03^{d}	51.82^{bc}	51.44^{bc}
LSD$_{(0.05)}$	17.82			13.37			8.996		
SEM±	5.997			4.502			3.028		

Appendix 27. Interaction effect on root dry matter and total dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Root Dry Matter (gm/0.25m2) 95 DAS			Total Dry Matter (gm/0.25m2) 35 DAS			Total Dry Matter (gm/0.25m2) 50 DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	21.97^{e}	41.80^{bc}	30.79^{d}	3.724^{d}	4.073^{d}	5.216^{cd}	22.75^{e}	31.73^{de}	30.46^{de}
SRI	45.27^{b}	58.10^{a}	37.41^{c}	23.50^{a}	20.36^{b}	25.04^{a}	69.55^{b}	78.09^{b}	98.64^{a}
DSR	36.70^{cd}	43.86^{b}	30.87^{d}	6.689^{c}	6.825^{c}	7.209^{c}	35.28^{d}	46.51^{c}	49.57^{c}
$LSD_{(0.05)}$	5.951			2.056			10.95		
SEM±	2.003			0.6919			3.684		

Appendix 28. Interaction effect on total dry matter production as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	Total Dry Matter (gm/0.25m^2) 65 DAS			Total Dry Matter (gm/0.25m^2) 80 DAS					
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	89.55^{ef}	103.8^{de}	106.2^{cd}	161.7^{c}	165.7^{c}	177.3^{c}			
SRI	148.0^{b}	160.0^{b}	202.8^{a}	218.2^{b}	281.0^{a}	266.0^{a}			
DSR	80.53^{f}	119.7^{c}	110.8^{cd}	186.6^{c}	178.3^{c}	221.9^{b}			
$LSD_{(0.05)}$	14.62			24.94					
SEM±	4.921			8.393					

Appendix 29. Interaction effect on crop growth rate (CGR) of rice as influenced by Method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	0-35 DAS			35-50 DAS			50-65 DAS		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	0.26^{f}	0.33^{ef}	0.38^{def}	4.37^{e}	5.47^{de}	5.03^{de}	12.51^{bcd}	12.00^{cd}	13.76^{bcd}
SRI	1.86^{b}	1.71^{b}	2.15^{a}	9.20^{bc}	11.25^{b}	15.08^{a}	15.37^{b}	14.39^{bc}	21.90^{a}
DSR	0.48^{cde}	0.52^{cd}	0.55^{c}	5.40^{de}	7.041^{cd}	8.11^{c}	7.97^{e}	12.49^{bcd}	10.87^{d}
$LSD_{(0.05)}$		0.156			2.134			2.738	
SEM±		0.052			0.718			0.922	

Appendix 30. Interaction effect on crop growth rate (CGR) and relative growth rate (RGR) of rice as influenced by Method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	65-80DAS CGR			65-80DAS RGR			80-95DAS RGR		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	16.60^{bc}	14.33^{bc}	16.65^{bc}	0.0446^{c}	0.0387^{f}	0.0410^{e}	0.0009^{g}	0.0080^{d}	0.0038^{f}
SRI	18.36^{b}	26.62^{a}	13.51^{bc}	0.0325^{g}	0.0426^{d}	0.0186^{h}	0.0034^{f}	0.0045^{ef}	0.0058^{e}
DSR	25.11^{a}	12.99^{c}	25.18^{a}	0.0671^{a}	0.0326^{g}	0.0539^{b}	0.0153^{c}	0.0320^{a}	0.017^{b}
$LSD_{(0.05)}$		4.519			0.0015			0.0015	
SEM±		1.521			0.0005			0.0005	

Appendix 31. Interaction effect on growing degree days (GDD) of phonological stages of rice as influenced by Method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Varieties								
	booting			maturity					
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	1940^{a}	1782^{c}	1613^{e}	2683^{a}	2610^{b}	2375^{e}			
SRI	1787^{c}	1647^{e}	1410^{g}	2550^{c}	2482^{d}	2184^{g}			
DSR	1825^{b}	1722^{d}	1520^{f}	2581^{b}	2528^{c}	2293^{f}			
LSD$_{(0.05)}$		38.07			30.25				
SEM±		12.81			10.18				

Appendix 32. Interaction effect of method of crop establishment and varieties on panicle length, panicle weight and filed grains per panicle, of rice at Phulbari, Chitwan, 2010

Treatment	Varieties								
	Panicle length (cm)			Panicle weight (g)			Filled grain per panicle		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	24.481	24.725	21.512	2.955	3.766	2.067	114.012	150.725	76.350
SRI	27.537	28.394	24.750	4.006	4.920	3.601	168.113	205.900	171.750
DSR	28.063	27.656	25.438	4.676	5.185	3.561	176.725	192.938	152.450
LSD$_{(0.05)}$		NS			NS			NS	
SEM±		0.2515			0.3009			12.2864	

Appendix 33. Interaction effect of method of crop establishment and varieties on number of effective tillers, thousand grain weight and sterility % of rice at Phulbari, Chitwan, 2010

Treatment	Varieties								
	No.of effective tillers per m2			Thousand grain weight (g)			Sterility %		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice	209.70^{e}	191.10^{f}	225.9^{de}	23.033	21.853	26.188	9.357	8.055	16.305
SRI	251.40^{bc}	224.00^{de}	295.4^{a}	23.309	24.837	27.529	6.737	7.892	13.651
DSR	237.10^{cd}	210.20^{e}	255.8^{b}	23.533	25.069	26.803	4.026	7.691	13.289
LSD$_{(0.05)}$		16.27			NS			NS	
SEM±		5.477			0.9685			1.2042	

Appendix 34. Interaction effect of method of crop establishment and varieties on grain yield, straw yield, and harvest index of rice at Phulbari, Chitwan, 2010

Treatment	Varieties								
	Grain yield (t/ha)			Straw yield (t/ha)			Harvest index (HI)		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice(TPR)	3.960	3.678	4.912	5.58^{d}	5.86^{d}	8.05^{c}	0.415	0.386	0.380
SRI	6.905	6.553	7.386	9.49^{b}	9.34^{bc}	11.14^{a}	0.422	0.413	0.400
DSR	6.165	5.950	6.475	8.31^{bc}	8.37^{bc}	8.18^{bc}	0.426	0.416	0.441
LSD$_{(0.05)}$		NS			1.37			NS	
SEM±		0.2588			0.46			0.0085	

Appendix 35. Interaction effect on irrigation water, total water and water productivity as influenced by method of crop establishment and varieties at Phulbari, Chitwan, Nepal, 2010

Treatment	Irrigation								
	Irrigation quantity (m^3/ha)			Total water (m^3/ha)			Water productivity (kg/m^3)		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice(TPR)	4717^{a}	4717^{a}	3717^{b}	16730^{a}	16730^{a}	15320^{b}	0.237	0.220	0.321
SRI	3692^{b}	3567^{b}	2079^{d}	14340^{c}	14060^{d}	12480^{g}	0.482	0.466	0.593
DSR	3700^{b}	3575^{b}	3300^{c}	13910^{de}	13790^{e}	13100^{f}	0.443	0.432	0.494
$LSD_{(0.05)}$		218.1			216.4			NS	
SEM±		73.41			72.85			0.0190	

Appendix 36. Interaction effect of method of crop establishment and varieties on gross return, net return and B:C ratio of rice at Phulbari, Chitwan, 2010

Treatment	Varieties								
	Gross return Rs.'000.			Net return Rs.'000.			B:C Ratio		
	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4	Sabitri	Loktantra	Radha-4
Method of crop establishment									
Farmers practice(TPR)	97.33	99.95	124.42	35.91	38.53	63.00	1.585	1.627	2.026
SRI	168.93	174.50	183.93	103.83	109.40	118.83	2.595	2.681	2.825
DSR	150.31	158.09	156.09	89.21	96.97	94.99	2.460	2.587	2.555
$LSD_{(0.05)}$		NS			NS			NS	
SEM±		6.2782			6.2782			0.0584	

Appendix 37. Correlations

	ET	LAI@80	LAI@95	rdm@80	rdm@95	lpt@80	lpt@95	tdm@80	tdm@95	pwt	plgth	GPP	S%	SY	TGW	HI	GY
ht@ ht	-0.3	-0.042	.704**	.567**	.718**	.583**	0.207	.345*	.510**	.622**	.570**	.612**	-0.3	0.199	-0.08	-0.03	0.188
ET		0.12	-.414*	0.206	-0.03	-0.22	-.345*	.555**	.515**	-0.03	-0.01	0.017	0.279	.695**	.447**	0.18	.712**
LAI@80			-0.032	0.171	0.138	-0.02	-0.2	.386*	0.068	-0.3	-0.17	-0.19	0.138	0.164	-0.01	-0.25	0.058
LAI@95				0.199	.606**	.534**	0.282	-0.05	0.239	.570**	.547**	.571**	-.506**	0.004	-0.31	-0.08	0.002
rdm@80					.582**	.448**	-0.03	.814**	.754**	.343*	0.288	.350*	0.114	.531**	0.315	-0	.494**
rdm@95						.607**	0.21	.504**	.646**	.578**	.584**	.619**	-.372*	.418*	-0.09	-0.01	.404*
lpt@80							0.226	0.269	.472**	.548**	.467**	.515**	-0.27	0.213	-0.07	0.252	0.32
lpt@95								-0.16	0.019	.383*	.393*	0.164	-.390*	-0.03	-0.1	0.086	0.015
tdm@80									.807**	0.209	0.32	0.272	0.104	.710**	.372*	0.158	.726**
tdm@95										.565**	.608**	.581**	-0.08	.713**	.390*	.343*	.814**
pwt											.817**	.787**	-.582**	0.211	-0.15	.390*	.383*
plgth												.799**	-.691**	0.268	-0.16	.470**	.455**
GPP													-.572**	0.294	-0.12	0.236	.369*
S%														0.069	.451**	-0.19	-0.02
SY															.444**	-0.04	.893**
TGW																-0.05	.380*
HI																	.404*

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed). ht@ht ,plant height at harvest ; ET, Effective tiller per square meter ; LAI@80 , leaf area index at 80 days after planting; LAI@95 , leaf area index at 95 days after planting ; rdm@80 , root dry matter at 80 days after planting ; rdm@95 , root dry matter at 95 days after planting ; lpt@80 ; leaf per tiller at 70 days after planting; lpt@95 , leaf per tiller at 70 days after planting ; tdm@80 , total dry matter at 80 days after planting ; tdm@95 , total dry matter at 95 days after planting ; pwt, panicle weight; plgh, panicle length; GPP , grain per panicle; S% , sterility percentage ; SY , straw yield ; TGW , thousand grain weight ; HI, Harvest Index ; GY , Grain yield.

BIOGRAPHICAL SKETCH

Mr. Krishna Dhital, was born on 12th February, 1985 in Patlekhet-3, Kavre as the eldest son of Mrs. Padma Devi and Mr. Laxmi Prasad Sharma Dhital. His school education was completed in 2001 from Sanjiwani English School, Dhulikhel, Kavre. He joined Kathmandu University and completed the intermediate level in science in the year 2003. Then he joined Institute of Agriculture and Animal Science, Rampur, Chitwan in 2004 and completed Bachelor degree of Agriculture with major in Agricultural Economics in 2008. Again he enrolled in the Post Graduate Program for Master of Science in Agriculture at the same university in 2009 with major in Agronomy. Now he is working as an Extension Officer in District Agriculture Development Office, Baitadi.

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