PRODUCTIVITY AND ECONOMIC VIABILITY OF RICE UNDER DIFFERENT PLANTING PATTERN AND AGE OF SEEDLINGS THROUGH SYSTEM OF RICE INTENSIFICATION (SRI)

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ABSTRACT

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The system of rice intensification (SRI) aims to improve rice (Oryza sativa L.) yields through multiple management practices that have been presumed to interact synergistically. A new technology of rice farming believed to increase the yield, with simple manipulation of cultivation techniques was evaluated for the rice variety Ramdhan (OR) under different crop geometry (20, 25, 30 cm) in a square pattern and different age of seedlings (8, 15, 22 and 29) in farmers field. Field experiment was conducted in two factorial RCBD with three replications during rainy season of 2008, at Shivanagar VDC of Chitwan district.

Results showed that younger seedlings (15 days-old) yielded (6.59 t/ha) as compared to 29 days-old seedlings (4.42 t/ha) and reduction in grain yield due to 29 days seedlings was 32.96% and the reduction was significant. Similarly highest grain yield from 25 cm × 25 cm (6.04 t/ha) and lowest grain yield (5.37 t/ha) from 30 cm × 30 cm was 11.17% and the reduction was significant. Significantly higher gross return (Rs. 169.60 thousand/ha), net benefit (Rs. 125.00 thousand/ha) and B:C ratio (3.80) were obtained from 15 days old seedlings. Similar result was obtained in crop geometry of 25 cm × 25 cm.

The 15 days seedlings significantly produced more number of tillers at all crop growth stages and productive tillers per square meter (264.90) at harvest compared to 8, 16 and 25 days old seedlings. Optimum spacing of 25 x 25 cm was found to have significant influence on growth and yield parameters. Both age of seedlings and crop geometry significantly influence the number of grains per panicle.

Maximum number of grain per panicle was recorded with 15-day seedlings and 25 cm × 25 cm crop geometry. However, lowest sterility % was obtained in 15 days of seedlings. Age of seedlings and different crop geometry did not influence panicle length, panicle weight, and 1000 grain weight significantly. Dry matter production per plant differed significantly with age of seedling and crop geometry at 60, 75 and 90 DAT, but age of seedlings and crop geometry were non-significant at 30 DAT and 45 DAT respectively.

There was highly significant positive correlation (r = 0.878**) between total dry matter production at 90 DAT and yield (t/ha). Number of leaves per plant and LAI increased up to 75 DAT and thereafter decreased. There was significant positive correlation (r = 0.678*) between LAI and total dry matter production at 90 DAT. Plant height was found non-significant in all crop growth stages and attained maximum at 8 days of seedlings (99.45 cm) and at 25 cm × 25 cm (96.78.).

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ACRONYMS

%	Percent
@	At the rate of
^0C	Degree Celsius
ANOVA	Analysis of Variance
B: C	Benefit cost ratio
BRRI	Bangladesh Rice Research Institute
CBS	Central Bureau of Statistics
LSD	Least Significance Difference
cm	Centimeter
CV	Coefficient of variance
DAP	Diammonium phosphate
DAS	Days after sowing
DAT	Days after transplanting
DMRT	Duncan's Multiple Range Test
FAO	Food and Agricultural Organization
FYM	Farm Yard Manure
g	Gram
GDP	Gross domestic products
HI	Harvest index
IAAS	Institute of Agriculture and Animal Science
IRRI	International Rice Research Institute
Kg	Kilogram
Kg/ha	Kilogram per hectare
LAI	Leaf area index
m	Meter
m^2	Square meter
N	Nitrogen
NARC	Nepal Agriculture Research Council
GON	Government of Nepal
NH_4^+-N	Ammonical nitrogen

NMRP	National Maize Research Program
NO_3^--N	Nitrate nitrogen
NPK	Nitrogen, Phosphorus and Potash
NRRP	National Rice Research Program
NS	Non-significant
N_2	Nitrogen
OC	Organic carbon
O_2	Oxygen
PI	Panicle initiation
r	Correlation
R^2	Coefficient of determination
SEm (±)	Standard error of mean
t/ha	Ton per hectare
TGW	Thousand grain weight
VDC	Village Development Committee
Zn	Zinc

1 INTRODUCTION

Rice is the staple food in Nepal and a mainstay for the rural population and their food security. Rice is the most important commodity in Nepalese agriculture and it is grown in about 1.55 millions ha producing 4.21 millions tons of rough rice (NARC, 2007). In Nepal, agriculture holds major share of economy (38% of GDP) and it contributes 19.75 % to agricultural GDP (MOAC, 2005). The contribution of rice is nearly 50% to the calorie requirement of Nepalese people supplying per capita dietary energy, protein and fat is 38.5, 29.4 and 7.2% respectively (FAO STAT, 2004). The average productivity of rice in Nepal under conventional farming is very low i.e. 2.85 t/ha in 2004 and at a declining rate of 2.55 t/ha in 2007 as compared to the developed countries (MOAC, 2007). Rice straw is the main source of animal feed during dry season as it meets about 32-37% of total digestible nutrients (NRRP, 1997). The crop is grown in all agro-ecological zones from terai plains (60 masl) to the high hills up to 3000 masl (NARC, 2007) including valleys and foot hills (300-1000 masl) (Dhital *et al.,* 1995). In Nepal, about 71.57% of total rice area is located in terai where as hill and mountain occupy only about 24.81% and 3.62%, respectively (MOAC, 2003). Of this, about 7% is under rice crop and 9% is grown as broadcast sown rice in unbunded field locally known as Ghaiya. 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).

Majority of population in Nepal live below poverty line (30.08%) and have food security problems. There is vast regional variation in agriculture production and food balance in Nepal. The terai is food surplus while hill and mountain regions are in severely food deficit situation. Out of 75 districts, 57 are of food deficit. Overall the mountain and hill, deficit is nearly 416,000(17%) mt. Slow agricultural development, land shortage and population growth has pushed more and more families into vulnerable situation (Thapa, 2008). Poverty in Nepal is wide spread and About 37.7% of the total population in Nepal earns less than US $ 1 per day and 82.5 percent of the total population earns less than US $ 2 per day (UNDP, 2003).

The production and productivity has not geared up as much as required with traditional system of cultivation despite a lot efforts are being made. Nepal rice production has failed to keep pace with population growth and the country has now become a net food importer with an annual deficit of more than 150,000 tons. Lots of efforts and new concept is 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 not the 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).

Therefore, a System of Rice Intensification (SRI), based on some new insights into how rice can be grown best, translated into certain principles and practices, and was developed 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 (Uphooff, 2002). System Rice Intensification (SRI) as defined by Uphoff *et al*., (2002) is 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 system of rice intensification (SRI) has already helped many hundred of farmers of Madagascar to at least double their yields. With good management of plants, soil, and water, yields can be increased even more possibly to 6, 8, and even 10 t/ha. Rice plants grown with SRI methods have a different structure, with several times more tillers and much bigger roots that can be absorb more nutrients from the soil. They also have many times more grains. It has been possible to get more productivity. 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).

In Bangladesh 7.1 t/ha, in China 13.5 t/ha, in India 7.6 t/ha in Cuba 12.7 t/ha, in Madagascar 13.9, and in Nepal 6.2 t/ha and Sri Lanka the average highest SRI yield was obtained (Uphoff and Fernandes, 2002., Barrett *et al*., 2004; Husain *et al*., 2004; Latif *et al*., 2005). In Nepal, three years experiments on SRI revealed that SRI provides 28 to 49 % yield gain over farmers practice therefore, it can be recommended to the farmers with a complete package of practices (Tripathi *et al*., 2004).

In Nepal, SRI research is reported to be started in 1999 in Kathmandu valley (Adhikari, 2000) but in terai it was first started in 2001/02. Its 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 trial performance of SRI could vary from location to location.

In Nepal, testing carried out by ICIMOD farmer has considered SRI as an agronomic option to grow rice especially under irrigation management. Rice yields, grown under SRI system increased by 20 to 25%, in case of rainfed plots the yield increase was only 10%. Farmer perceived that SRI requires only 25% of seeds, 50% less labor for transplanting; and 50 to 60% less labor for irrigation and less use of pesticide than traditional method. At the same time there is about 40 to 50% increase in grain and 20 to 25% increase in biomass production. This was considered as advantageous for a smallholder farmer (ICIMOD, 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 (Satyanarayan *et al*., 2004). Similarly Uprety (2005) had also reported that seed requirement is 92,679.6 mt. (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 on only 10% of land and increase yield by only 1mt/ha (SRI potential is 2 to 3 times more than the present productivity), we can produce 1, 54,466 mt. more rice.

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 seen 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).

Therefore, such technologies are to be developed which are possible to use even by the poor farmers. Viewing these facts, an experiment was carried out by transplanting different age of seedlings with different crop geometry at farmers' field of Shivanagar, Chitwan during April to November 2008 with following objectives:

1. To determine the appropriate age of seedlings for system of rice intensification
2. To determine the optimum crop geometry for system of rice intensification
3. To know the interaction effect of age of seedling and crop geometry within system of rice intensification
4. To determine the economics of different treatments

2 LITERATURE REVIEW

In this section, an endeavor has been made to put a brief review of res findings available on performance in yield and yield attributing characters by different age of seedlings with respect to different crop geometry.

2.1 General backgrounds

World population is expected to increase from 6.0 billion in 1999 to 8.5 billion by 2025 (Singh and Singh, 2000) and global demand is expected to rise by 38% over the current production within 30 years (Surridge, 2004). Such an increase in population growth will intensify pressure on natural resources to achieve higher food production. Increased food production could be achieved by expanding land area under crops and by increasing yields per unit area through intensive farming. The FAO study, World agriculture: towards 2010 estimates that about two-third of the needed increase in crop production in developing countries like Nepal, will have to come from yield increase on land already under cultivation (FAO, 1995).

Overall, the total global rice is declining gradually even with the extensive use of the modern varieties such as high yielding and hybrid varieties. Moreover, the problems associated with the green revolution technological packages, compounded by the problems of soils, water, pest and diseases have further complicated the efforts to maintain farmer's existing yields.

There are various factors behind the low production of rice such as older-generation seed (most farmers have used their own seed for decades), low doses of chemical fertilizer, little use of improved cultivation practices and less care of plant protection.

The System of Rice Intensification (SRI) demonstrated that by changing the management of rice plant, soil, water and nutrient management, the yields in rice can be increased by about 25 or more while reducing water requirements by an equivalent percent. This gives farmers incentive to experiment with SRI method, which also reduces the cost of production and increases their net income per hactere by even more than yield. This benefit to the farmer is more than the contribution of increased yields (Satyanarayana, *et al.*, 2006). The aim is to create an optimal growing environment for the rice plant so that its genetic potential is better expressed.

2.2 The System of Rice Intensification

The System of Rice Intensification first originated in Madagascar around Antsirabe in the 1980s. This methodology for growing rice was developed by a French Jesuit priest, Henri de Laulanie, and it has enabled its practitioners to increase their grain yield from the national average of 2 t/ha to now 8 t/ha or more just by changing the rice management practices (Association Tefy Saina, 1992).

Rice has been cultivated under flooded conditions for centuries for various reasons. Reasons among others are the control of weeds and the belief that rice performs better under standing water (Reddy and Reddy, 1999). However, rice is only a flood-tolerant plant, not one that benefits from constantly saturated soil (Vartapetian, 1993). One of the key advantages of flooding a paddy field is to increase low soil pH up to a level of 6.7 to 7.2. Such a condition favors the release of the P element from aluminium or ferrous coated P. The cut off of soil oxygen supply, however, leads to a rapid decrease of the redox potential and thus a gradual appearance of soluble Mn, Fe and methane (Ponnamperuma, 1984). The SRI method follows transplanting of single plant in one clump at distances of 25×25 or 30×30 cm. The uniqueness of this method is that the transplanting is being done between 7^{th} and 9^{th} day of sprouting of seeds. The current practices of transplanting is after 4 to 8 weeks and often 5 to 10 plants in one clump that cause trauma as roots take 12 to 14 days for establishing after transplanting. In conventional way of thick planting (50 to 60 clumps in a square meter), roots of the plant cannot grow widely and deeply resulting in low nutrient uptake from different zones. Yield from SRI practices (3042 kg/ac) and yield form conventional practices (1874 kg/ac) and yield difference is 62.3% (Vishnudas, 2006).

The practices that bring about this different rice plant phenotype in physiological and morphological terms are simple, but they change radically a number of things that rice farmers have done for several thousand years. These practices made sense because they appeared to reduce risk, but in fact, we now believe, they suppress productive potential. According to proponents, SRI encompasses a set of five principles in contrast to conventional system, each of them fairly simple, but working synergistically with the others in order to achieve higher grain yield (Uphoff, 2000).

2.2.1 Early transplanting with a single seedling per clump

The key to success with SRI is early transplanting, i.e., before seedlings are 15 days old (before the fourth phyllochron), and as early as 8 or 10 days (Uphoff, 2000). The growing conditions under SRI facilitate an optimum environment for tillering expression by early transplating. Early transplantation in conjunction with the other practices allows a greater realization of the tillering potential of rice plants (Association Tefy Saina, 1992).

Before proceeding any further, the concept of phyllochrons, which applies to all members of the grass family, including cereals like rice, wheat and barley, must first be understood. Phyllochron, which has been used to characterize the growth dynamics of cereals, is defined as the interval of leaf emergence (Nemoto *et al*., 1995). A phyllochron is a period of time, 5 days at best but usually longer, during which one or more phytomers (units of a tiller, a leaf and a root) emerge from the base of the plant. 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 and Uphoff, 2000) (Table 1).

Table 1. Increase in number of tillers that can be produced by rice plants in successive phyllochrons (De Laulanié 1993).

Phyllochrons	1	2	3	4	5	6	7	8	9	10	11	12
New tillers	1	0	0	1	1	2	3	5	8	12	20	31
Total tillers	1	1	1	2	3	5	8	13	21	33	53	84

Note: The number of new tillers in later phyllochrons does not follow the Fibonacci series exactly apparently because there is not enough physical space for as many new tillers to emerge as there is genetic potential.

Conventional methods are characterized by a transplanting of more than 3 or more seedlings per clump. As far as traditional farming practices in Nepal are concerned, planting more seedlings per clump is thought to provide farmers assurance that if one plant dies, others can still grow and therefore a lower percentage of hills will be missing. With SRI seedlings are transplanted singly, so that there is no competition among plant roots to inhibit growth. Seedlings are transplanted carefully and quickly after removal from their nursery, and with their roots carefully laid into the soil so that the tip is well-positioned to resume downward growth. The 1 to 2 week period of plant recovery after “normal” transplanting (Kirk and Solivas, 1997) deprives the plant of its most prolific intervals of tiller growth.

SRI, however, recommends the transplanting of one seedling per clump (Association Tefy Saina, 1992). Research done in 1998 showed that a single rice plant could express its tillering potential better than a larger number of plants in a clump (Joelibarison, 1998). Transplanting three seedlings together impeded rice growth in that the adjacent plants had to compete for nutrients, space and light. This competition repressed root growth and proliferation. When root systems are poorly developed, the plant devotes its energy for developing the seedlings in height to the detriment of the production of tillers (Joelibarison, 1998).

2.2.2 Wider spacing

Instead of planting seedlings densely, as is common because having more plants seems likely to produce more rice, with SRI seedlings are planted widely spaced, in a square pattern (to facilitate weeding as well as to give more space between plants), 25 by 25 cm or more widely, up to 50 by 50 cm. It seems counter-intuitive that fewer plants should give much more yield (seeding rates with SRI are 5-10 kg/ha compared to over 100 kg/ha with traditional methods). Yet innovative farmer practices for growing wheat in Mexico, documented by CIMMYT, showed that wide spacing can give much better yields (Sayre and Moreno, 1997). Plants with more room to grow; have a larger root system and better exposure to light and air.

Wider spacing improves the canopy's photosynthesis which leads to greater root growth and accompanying productive tillering percentage and the spikelet number per panicle, provided that other favorable conditions for growth such as soil aeration are provided (Zhu, 2002).

2.2.3 Mechanical weeding

Mechanical Weeding early and frequent should start about 10 days after planting and should be done at least twice, preferably three or four times, until the canopy closes and provide smothering effect on weed growth and makes further weeding difficult. In one Madagascar community, farmers who did no mechanical weeding got 6.0 t/ha., farmers who did one or two weeding got 7.5 t/ha., but the farmers who weeded three times averaged 9.2 t/ha., and the farmers who were willing and able to weed four times got 11.8 tons/ha (Uphoff, 2002).

2.2.4 Maintaining moist soil under non-saturated conditions during the vegetative phase

Irrigated rice plants are grown under standing water throughout the season because most farmers and agronomists believe that rice performs well under flooded conditions. Rice and water are all linked together from the field to the pots. Instead of keeping paddy fields continually flooded, with SRI soils are kept well-aerated during the vegetative growth phase. They are periodically irrigated to keep the soil usually moist, but it should not become saturated (hypoxic). Periodic drying, even to the point of cracking, is recommended, quite in contradiction to common recommended practice. During the reproductive phase, after panicle initiation, a thin layer of water (1 to 3 cm) is kept on the field. Water is applied only as needed to keep the soil moist but never letting it become saturated. Rice plants, when grown under saturated condition, develop more hairy, fine and branched secondary adventitious and surficial roots near the root-soil interface in order to absorb the dissolved oxygen in the oxidized layer close to the water-soil interface (Obermueller and Mikkelsen, 1974).

When rice is grown under intermittent dry and flooded conditions, the same condition as that of the SRI system, there are fewer surficial roots and more tap roots and primary roots. Such rooting pattern is apparently the result of the soil aeration brought about by the intermittent drainage. A study done by Kar *et al*. (1974) showed that 78% of the roots die back at the flowering stage when rice is grown under flooded conditions as compared to that under aerated conditions.

2.2.5 Compost application

Proponents of SRI recommend the use of organic fertilization (compost) instead of chemical fertilizer. The idea is to capitalize on the biological resources and organic matter in the compost and to maintain optimum biological activity of the soil. This organic fertilization is thought to improve the soil structure and the continual release of nutrients.

2.3 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 effects 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 for the young plant that are so favorable that its growth, when handled carefully, is accelerated. There are three dramatic observable and measurable effects:

(1) There is much greater root growth, which supports (2) and (3). 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).

(2) 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. Why rice plants have so many more 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).

(3) 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 t/ha to 8 t/ha.

2.4 Beneficial effects of SRI on farmers, consumers and the environment

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, there should be beneficial effects on soil and water quality and health.

2.4.1 Water saving and increasing yield possibilities associated with SRI

One of the features that make SRI attractive is its water saving potential. SRI methods can reduce water requirements for irrigated rice by 25 to 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).

Yuan (2002) reported that the research held on China National Hybrid Rice Research and Development Center, it was found 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; Lazaro, 2004; Namara *et al*., 1995).

2.4.2 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 t/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 t/ha). Harvesting sooner reduces crops' exposure to storm or other damage; it also reduces total amount of irrigation water needed (Satyanarayana *et al*., 2006).

2.4.3 Less economic risk

SRI fields are able to withstand the adverse effects of drought , rain and wind that cause other rice fields to lodgeFarmers 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: "SRI is an economically attractive methodology for rice cultivation with a lower economic risk compared to other cultivation practices.

2.4.4 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 effects 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.

2.5 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, e.g., 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 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).

2.6 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 t/ha average for SRI vs. nearly 4 t/ha with farmer methods and nearly 6 t/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 8.07t/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 t/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 t ha^{-1}), biological yield (11.65 t ha^{-1}) 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 produce significantly higher grain yields (8821 kg/ha), 30x30 cm^2 produce (7627 kg/ha) and 40x40 cm^2 produce (5747 kg/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 ton per hectare) 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 CH_4 emissions but result in significant increases in NO_x emissions. The effect of nitrous oxide is nearly 35 times greater than CH_4. 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 the following headings.

3.1 Description of the experimental site

3.1.1 Location

The field experiment was conducted at the farmers' field at Meldanda, Sharadanagar VDC which is near to the Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan. The experiment was conducted during the rainy season from May to October 2008. This site is situated at 9.8 km south-west from Bharatpur, headquarter of Chitwan distirct. This location is situated at 27° 37' north latitude and 84° 25' east longitude with elevation of 256 masl (Thapa and Dangol, 1988). In the experiment block wheat crop was grown in the winter season before that an experiment of main season rice was conducted in this block. This location falls in inner terai region of central development region of Nepal.

3.1.2 Physico-chemical characterization of experimental soil

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

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

Table 2. Physical-chemical characteristics of the soil at the experimental site

S.N.	Properties	Average content	Rating
1	**Physical properties**		
	Sand	63%	
	Silt	29%	
	Clay	8%	
2	**Chemical properties**		
	Soil pH	6.3	Acidic
	Soil organic matter (%)	2.1	Low
	Total nitrogen (%)	0.11	Medium
	Available phosphorus(kg/ha)	26	Low
	Available potassium kg/ha	107	Low
3	**Texture/Rating**	Sandy Loam	

From the soil analysis, sand (63%) was dominant in the physical properties of soil compared to silt (29%) and clay (8%). On the other hand, chemical properties like organic matter (2.1%), available potassium (107 kg/ha) and available phosphorus (26 kg/ha) were observed in lower amount and total nitrogen (0.11%) in medium amount in the upper (0 to 15 cm) soil layer. Soil pH (6.3) was found to be acidic in the experimental field within a range considered suitable for nitrogen use efficiency in rice (Mikkelsen and De Datta, 1979). According to Khatri Chettri (1991), available phosphorus, available potassium and organic matter of the experimental field were indicative of lower soil fertility, while total nitrogen indicated medium soil fertility status (Jaishy, 2000) (Appendix 4).

3.1.3 Climatic condition during experimentation

The experimentation site lies in the subtropical humid climate belt of Nepal. The area has sub-humid type of weather condition with cool winters, hot summers and distinct rainy season with annual rainfall of about 1919.5 mm (NMRP, 2000). It is characterized by three distinct seasons: rainy season (June to October), and 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. June and July receive the highest amount of 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 Fig. 1. Weekly average data on temperature, RH and rainfall are given in Appendix 1.

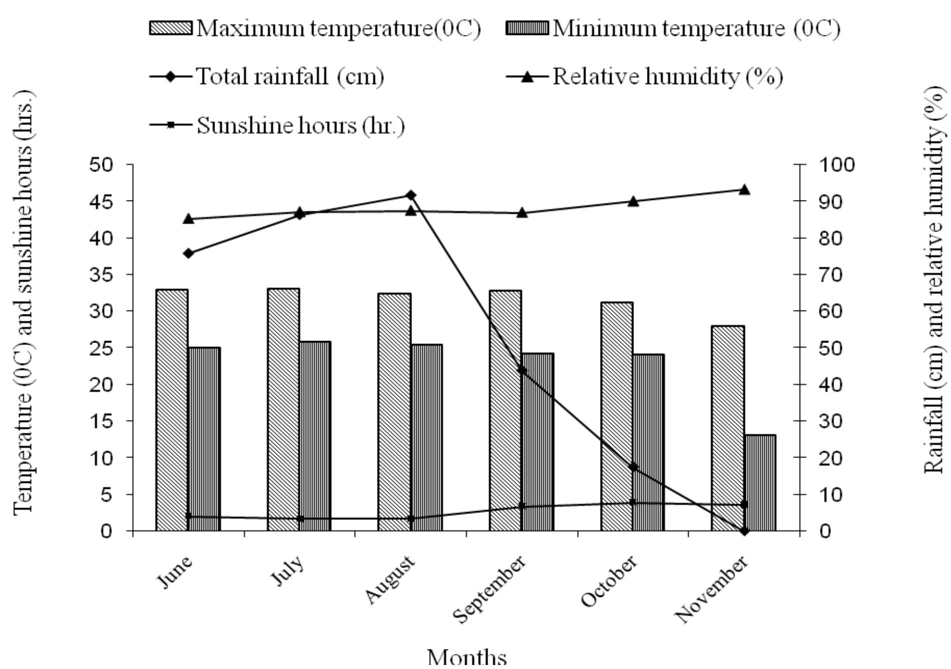

Fig 1. Weather condition during the course of experimentation at farmer's field, Rampur, Nepal, 2008 (Source: NMRP, 2008)

During the crop cycle, average maximum (33.23, 33.16, 32.53, 33.10, 31.35, 28.09 and 24^{0}C). Minimum (25.08, 25.75, 25.55, 24.31, 24.93, 13.77 and 11.98^{0}C) temperatures were recorded from June to December, respectively. The average relative humidity during the period of experimentation (June to December) was 83.53, 87.42, 87.74, 86.83, 89.42, 94.77 and 97.55, respectively. During the period of tillering stage (July to August), the average temperature was 29.25^{0}C, which was suitable for the rice growth. Ustimesko-Bakumovsky (1983) has reported that the rice crop had normal vegetative growth 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 (Oct. to Nov.) 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., June to December, was 1573.92 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 for rice

The experimental field was laid out in two factorial randomized complete block design (RCBD) with three replications and 12 treatments with different combinations. The factor A treatments consisted of age of seedling at seven days interval starting from 8 days (8, 15, 22, 29 days of seedling). The factor B consisted of three different crop geometry (20×20) cm^2, (25×25) cm^2, and (30×30) cm^2 was having 5 cm intervals. Plot having (20×20) cm^2, (25×25) cm^2, and (30 × 30) cm^2 have the total no of rows 15, 12, 10 respectively and no of plants 30, 24, and 20 per row respectively. The gross size of each plot was 18m^2 (6m X 3m) and net size of each plot for harvesting was 8.4 m^2 (6m×1.4m) for (20×20) cm^2 and 9m^2(6m×1.5m) for 25 and 30 cm crop geometry. Total field area was

914.5m^2 (15.5m X 59m). There was a bund of 0.5 m width between two experimental plots and each replication was separated by bund of 1 m width.

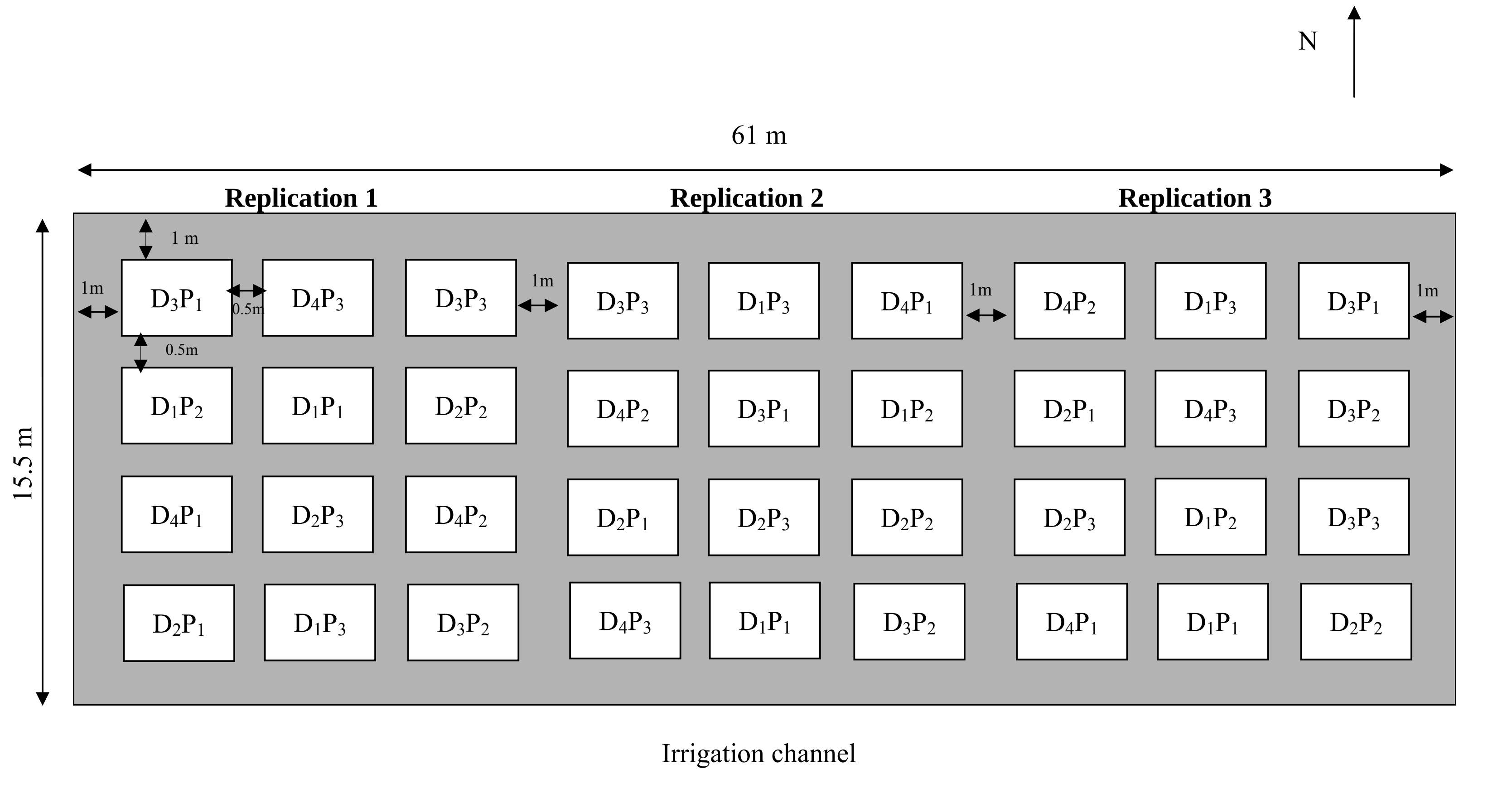

Figure 2. Field layout of the experimental site for rice under SRI at Shivanagar VDC, Chitwan, 2008

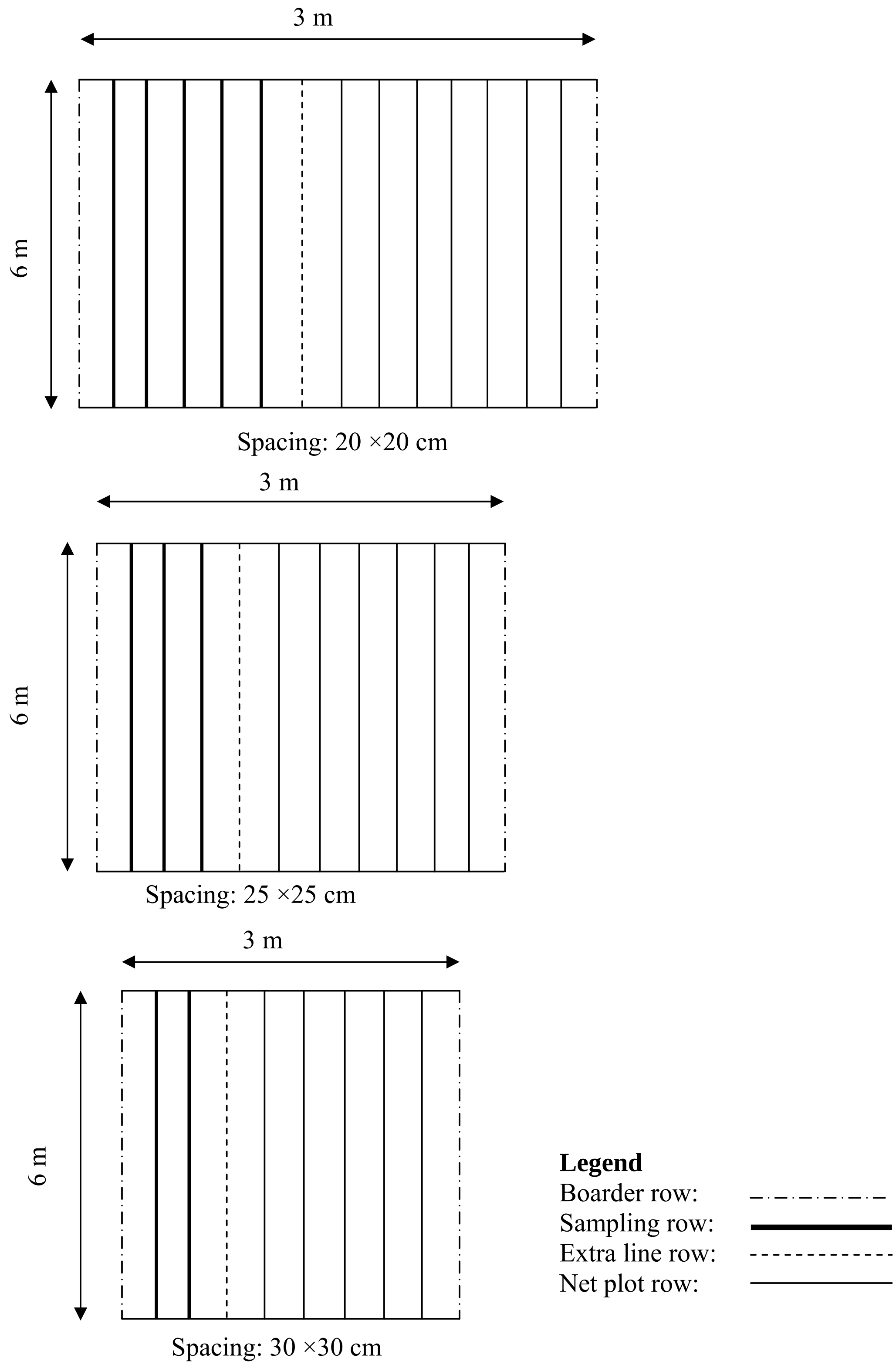

Figure 3. Individual layout of the experimental site for rice under SRI at Shivanagar VDC, Chitwan, 2008

3.2.2 Treatments details and symbols

Factor A (different age of seedlings)

D_1 = 8 days seedlings

D_2 = 15 days seedlings

D_3 = 22 days seedlings

D_4 = 29 days seedlings

Factor B (spacing)

P_1 = (20×20) cm^2 spacing

P_2 = (25×25) cm^2 spacing

P_3 = (30×30) cm^2 spacing

Table 3. Details of the treatments in rice under SRI experimentation during May to November 2008 at Shivanagar VDC, Chitwan, Nepal

Symbol			Treatment combinations	S.N.
	P_1	D_1P_1	8 days seedlings, 20×20 cm spacing	T_1
D_1	P_2	D_1P_2	8 days seedlings, 25×25 cm spacing	T_2
	P_3	D_1P_3	8 days seedlings, 30×30 cm spacing	T_3
	P_1	D_2P_1	15 days seedlings, 20×20 cm spacing	T_4
D_2	P_2	D_2P_2	15 days seedlings,25×25 cm spacing	T_5
	P_3	D_2P_3	15 days seedlings, 30×30 cm spacing	T_6
	P_1	D_3P_1	22 days seedlings, 20×20 cm spacing	T_7
D_3	P_2	D_3P_2	22 days seedlings, 25×25 cm spacing	T_8
	P_3	D_3P_3	22 days seedlings, 30×30 cm spacing	T_9
	P_1	D_4P_1	29 days seedlings, 20×20 cm spacing	P_{10}
D_4	P_2	D_4P_2	29 days seedlings, 25×25 cm spacing	T_{11}
	P_3	D_4P_3	29 days seedlings, 30×30 cm spacing	T_{12}

3.3 Description of tested rice variety

Ramdhan (OR- 367) is a high yielding rice variety having yield potential of average yield of 4.845 (4-7.3 t/ha) released in 2006 for general cultivation. Though it was released for inner terai region (Siwalik region) of Makwanpur, Chitwan and Nawalparasi Districts (200-350 m) and similar agro-eco regions it can be successfully grown in the foot hills like Ghorlikharka (600-730 m) of Dhankuta district. This variety is popularly known by its original name OR-367 in the farmers' community of the region. Original designation/symbolic name used in testing were OR-367-SP-11. Cross parents of this variety were Mansuli and IR30 and country of origin was India. This rice can be grown successfully in irrigated and rain fed lowland of terai and inner terai of Siwalik region.

The characteristics of this crop (OR-367) is a semi dwarf (80-110 cm) high tillering (10-17 tillers/hill), that matures in 130-137 days after seeding. At maximum tillering stage it has spreading nature of tillers. Panicles are long (20-31cms) and whitish, size of grains (milled rice) is medium long (6.78 mm) and slender (3.44 mm) and is brighter whitish in color. It has good kernel elongation (72.04%) and volume expansion (62.16%) while cooking. It is resistant to the important disease like seedling and leaf blast. It can also tolerate high disease pressure in blast prone areas. Being semi dwarf is tolerant to lodging and responsive to high inputs management.

3.4 Cultivation practices

Date wise detail of various cultivation practices recorded for the rice from sowing to harvesting is presented in Appendix 2

3.4.1 Raising of seedlings and transplanting/gap filling

Four raised nursery seed beds at the rate of 8 kg/ha seed rates of 2 m length and 1.5 m breadth for different age of seedlings were prepared for raising seedlings. For 29 days of seedling nursery bed were raised at 31 May, 2008 (2065-02-18) and similarly other nursery beds were raised at 7 days of interval at different times for different age of seedlings respectively. Seed soaking was done for 14 hours and kept for 34 hours in jute bag for rapid germination of seed for different age of seedlings. Each nursery beds were fertilized as recommended @ 100:45:40 kg N/ha through urea (46% N), DAP (18% N and 46% P_2O_5) and MOP (60% K_2O). Frequent irrigation through hand watering jar was given to recover the seedling from the drought.

The different age of seedlings (8, 15, 22 and 29 days of seedlings) were transplanted in experimental plots with single seedlings per hill on a square pattern having 20 cm×20 cm**,** 25 cm × 25 cm and 30 cm × 30 cm respectively row to row and plant to plant distance. Seedlings were transplanted on 28, June, 2008 (14^{th} Ashad B.S.). Gap filling were done after a week of rice transplanting to maintain the desired plant population in the experimental plots.

3.4.2 Land preparation and fertilizer application

The experimental field was ploughed two times by using disc plough and weeds were removed. Field was puddled and final ploughing followed by planking was done. The organic manures and inorganic fertilizers were applied in the field. The source of organic manures was farm yard manure and was applied @ 6 t/ha as basal application at final land preparation. Nitrogen, Phosphorus and Potash was applied as recommended @ 100:45:40 kg N/ha through urea (46% N), DAP (18% N and 46% P_2O_5) and MOP (60% K_2O). Half dose of Nitrogen, full dose of Phosphorus and Potash was applied before final land preparation as basal dose treatments. Remaining half dose of N was applied in two split doses at active tillering stage and panicle initiation for all treatments. Zinc Sulphate (commercial product) was applied @ 20 kg/ha at basal treatments at final land preparation for zinc deficiency.

3.4.3 Weed management

Three hand weeding operations were done to reduce the competition between weeds and crop for nutrients. First weeding was done earlier at 15 days after transplanting (DAT). Second weeding was done at 30 days after transplanting (DAT) which is the initiation of active tillering stage and third weeding was done at 45 DAT before panicle initiation stage. This is necessary due to poor growth of single seedlings at earlier stage, fields are not kept continuously flooded, seedlings are transplanted in wider spacing and field was upland type.

3.4.4 Plant protection measures

Single spraying of insecticide Cypermethrin 10% EC (Fighter) @ 2 ml/litre of water was applied before panicles emergence and at milking stage of crop to control insects.

3.4.5 Water management

Water was applied only as needed to keep the soil moist, but never letting it become saturated. Several times during the growing period, the field was left unwatered for 2-6 days so that the soil dries out to the point where there is surface cracking. Once the tillering process was complete, standing water of one inch /2.5 cm height was maintained.

3.4.6 Harvesting and threshing

The crop from the net plot area was harvested manually with the help of sickles. Harvested plants were left in-situ in the field for 3 days for sun drying. Threshing was done three times. It was done manually and grains were cleaned by winnowing and weighted at their exact moisture.

3.5 Observation recorded in rice

3.5.1 Biometrical observations

3.5.1.1 Plant height (cm)

Randomly selected entire two rows and tagged 10 hills was used for the measurement of plant height at an interval of 15 days from 30th day after transplanting up to physiological maturity stage and averaged from net plot area. It was measured from base to tip of the upper leaves of the main stem.

3.5.1.2 Number of leaves per plant and tillers per plant

Number of leaves was counted from the sample of two hills at 15 days interval from 30th days after transplanting from destructive sampling experimental plot area during growth analysis and mean was calculated. Tiller per plant was counted from the randomly selected sample of 5 hills of each plot from two rows at 15 day intervals from 15th days after transplanting from net plot area and mean was calculated. Main stem was also included to calculate the total tillers per plant.

3.5.1.3 Leaf Area Index (LAI)

Leaf area (cm^2) of the functional leaves obtained at 15- day interval from 30th day from two hills of five plants which were selected randomly for growth analysis i.e. drawn for dry matter accumulation study. The leaf area was measured by Automated Leaf Area Meter. The leaf area so obtained was then used to calculate the leaf area index.

Leaf area index (LAI) = Leaf area/ground area

3.5.1.4 Growth analysis

Plant samples were taken from the two hills of sampling rows at an interval of 15 days from 30th day after transplanting ending with just flowering for each treatment from destructive sampling plot area. At the time of sampling plant was taken from an area of (20 cm×20 cm × 2) 0.08 m^2**, (**25 cm × 25 cm ×2) 0.625 m^2 and (30 cm × 30 cm × 2) 0.9 m^2. Plant from each hill was taken by digging to the depth of 25 cm from a distance of 10 cm from all sides. Thereafter total dry weight of plant samples of leaves, stems and panicles was worked out. Dry matter deposition was determined by drying plant organs at a temperature of 70^{0}C in hot oven till constant weight (48 hours).

3.5.2 Yield attributing characters of rice

3.5.2.1 Number of effective tillers per square meter

Observation regarding the effective tillers per square meter was recorded within each net plot from five randomly selected hills just before harvesting the crop and the average values was used to obtain the effective tillers per square meter.

3.5.2.2 Length and weight of panicle

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

3.5.2.3 Number and weight of grains per panicle

It was counted and weighted in electronic balance by taking the panicles from 20 panicles of net plot just before harvesting. At the same time, number of filled and unfilled grains was counted to determine the number filled grains per panicle.

3.5.2.4 Thousand-grain weight (test grain weight)

Thousand grains were counted from the randomly-selected grain yield of net plot and weighed with the help of electronic balance.

3.5.2.5 Sterility percentage

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

Sterility percent= (Number of unfilled grains×100)/ Total number of grains.

3.5.2.6 Biomass yield and grain yield

Biomass (straw) yield and grain yield were taken at harvesting from net plot consisting of each plot which was 8.4 m^2 (6m×1.4m) for (20×20) cm^2, 9m^2(6m×1.5m) for (25×25) cm^2 and 9m^2(6m×1.5m) for (30×30) cm^2 from the net plot area. The crop was dried, threshed, sun dried, cleaned and again was dried to maintain 12% moisture and final weight was 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. Dicky Johns Multi-grain moisture meter or 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).

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

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.

3.5.2.7 Harvest index

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

HI% = (grain yield × 100)/ (grain yield + straw yield)

3.5.3 Economic analysis

3.5.3.1 Cost of cultivation

Cost of cultivation was calculated on the basis of local charges for different agro inputs viz. labor, fertilizer, compost, and other necessary materials.

3.5.3.2 Gross return

Economic yield (grain + straw) of rice was converted into gross return (Rs / ha) on the basis of local market price.

3.5.3.3 Net returns

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

3.5.3.4 B: C ratio

It was calculated by following formula

B: C ratio = Gross return / Cost of cultivation

3.6 Statistical analysis

All the recorded data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) for mean separations from the reference of Gomez and Gomez (1984). A simple correlation and regression analysis was run between selected parameters. Regarding the software programs, Microsoft word 2007 was used for word processing, MS excels for tables, graphs, and simple statistical analysis and, MSTAT-C Microsoft computer programs was used for running statistical analysis. And SPSS was used for the regression analysis. ANOVA was done to test the significance difference for each parameter. Calculation was done at 5% significance level.

4 RESULTS AND DISCUSSION

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

4.1 Biometrical observations

4.1.1 Plant height

Plant height was not significantly influenced by the age of seedlings and crop geometry in all different observed data from 30 DAT to 105 DAT. The plant height varied from 33.13 cm (30 DAT) to 99.45 cm (105 DAT) and increased up to 105 DAT starting from tillering (30 DAT). The average plant height obtained in the experiment was 96.851 (Table 4). The increment in plant height was prominent (53.62%) between 30 DAT and 50 DAT which represents the rapid vegetative growth stage of plant and coinciding with the stage of maximum tillering.

The data analyzed from the different age of seedlings showed no significant in plant height from 30 DAT to 105 DAT. However, at the initial stage the plant height with 29 days of seedlings was found to be the highest in 30, 45, 60 DAT. This might be due to the transplantation of old seedlings which had gain height at nursery stage. But in later stage at 75, 90 and 105 DAT plant height was found maximum in young seedlings (Table 4). Transplanting of seedlings from younger stage provides sufficient nutrients for vegetative growth and also for reproductive phase which ultimately leads to increased plant height. Similar finding was reported by Krishna (2000).

Similarly, different crop geometry had no significant effect on plant height from 30 DAT to 105 DAT. This might be due to the lesser competition for nutrients and light as SRI principle is to transplant in wider spacing. There was non significant positive correlation (r = 0.276) between plant height at 105 DAT and yield (Appendix 5).

Table 4. Effect of age of seedlings and crop geometry on plant height (cm) of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Plant height (cm)**					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**
Age of seedlings						
8 days seedlings	35.55	53.10	64.97	81.78	94.16	99.45
15 days seedlings	35.84	54.24	66.50	80.42	93.75	98.33
22 days seedlings	33.13	53.84	65.63	77.58	90.18	94.05
29 days seedlings	37.90	57.60	68.53	81.33	92.72	95.57
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Sem ±	1.200	1.267	1.910	1.565	1.935	1.685
Spacing (cm^2)						
20 cm × 20 cm	36.21	54.41	66.43	79.63	90.91	94.74
25 cm × 25 cm	35.63	54.23	65.90	80.08	92.42	96.78
30 cm × 30 cm	34.97	55.44	66.90	81.12	94.78	99.04
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Sem ±	1.039	1.097	1.654	1.355	1.676	1.459
CV %	10.11	6.95	8.63	5.85	6.26	5.22
Grand mean	35.60	54.69	66.41	80.28	92.70	96.85

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5 % level of significance.

4.1.2 Number of tillers per plant

This advantage of SRI method in enhancing tiller numbers has been reported by Gaini *et al*. (2002). Substantial differences were observed in the number of tillers per plant for the age of seedlings and crop geometry from the analyzed data. Both age of seedlings and crop geometry significantly influenced the number of tillers per plant (Table 5) but their interaction did not influence the number of tillers per plant (Appendix 6). The observed result showed that average number of tillers per plant increase up to 60 DAT (30.39%). The increment in the average number of tillers per plant was remarkably high 106.60% in the period between 30 DAT (12.86) to 45 DAT (26.57).

It was observed that the age of seedlings was significantly affected numbers of tillers per plant at 15, 30, 45 and 60 DAT (Appendix 6). Among the age of seedlings, the highest number of tillers per plant was obtained from that of 15 days of young seedlings at 15, 30, 45, and 60 DAT as compared to all other age of seedlings (Table 5). At 15, 45 and 60 DAT, ages of seedlings were found significantly different with each other. At 15 DAT higher numbers of tillers per plant obtained were 7.09 in 15 days of seedlings and lower 4.289 in 29 days of seedlings. Similarly higher tiller obtained was 33.76 and lower 19.71 in 45 DAT likewise in 60 DAT higher 38.11 and lower 23.29 in 15 and 29 days of seedling respectively. Similarly, in 30 DAT, higher number of tillers per plant was observed in 15 days of seedlings (15.98) but at par with 8 (12.89), 22 (12.69) and 29 (9.89) days of seedlings. Thus the number of tillers per plant varied significantly due to age of the seedlings at different growth stages of the crop growth.

Furthermore, it was observed that crop geometry significantly influenced number of tillers per plant at 15, 30, 45 and 60 DAT (Appendix 6). The observed result showed that average number of tillers per plant among the different crop geometry, was obtained from that of 25 cm × 25 cm in 15, 30, 45, and 60 DAT as compared to all crop geometry.

Table 5. Effect of age of seedlings and crop geometry on number of tillers per plant of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Numbers of tillers per plant**			
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**
Age of seedlings				
8 days seedlings	5.87[b]	12.89[b]	28.44[b]	32.27[b]
15 days seedlings	7.09[a]	15.98[a]	33.76[a]	38.11[a]
22 days seedlings	4.96[c]	12.69[b]	24.38[c]	27.89[c]
29 days seedlings	4.29[d]	9.89[b]	19.71[d]	23.29[d]
CD (P = 0.05)	0.3315**	3.067**	2.210**	2.931**
Sem ±	0.1130	1.046	0.7230	0.9993
Spacing (cm^2)				
20 cm × 20 cm	5.50[b]	12.43[ab]	26.43[b]	30.60[ab]
25 cm × 25 cm	5.93[a]	14.82[a]	28.73[a]	32.48[a]
30 cm × 30 cm	5.22[b]	11.33[b]	24.55[c]	28.08[b]
CD (P = 0.05)	0.2871**	2.656*	1.836**	2.538**
Sem ±	0.09789	0.9056	0.6261	0.8654
CV %	6.11	24.39	8.16	9.86
Grand mean	5.55	12.86	26.57	30.39

SRI, System of Rice Intensification; DAT, days after transplanting; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

In 15 DAT, 15 days of seedlings were found significantly different among the others and higher number of tillers per plant was 5.59 in 25 cm × 25 cm and lower was 5.22 in 30 cm × 30 cm which was at par with 20 cm×20 cm (5.50). In 30 DAT and 60 DAT, 25 cm×25 cm obtained higher number of tillers per plant (14.82 and 32.48) and were significant at 30 cm × 30 cm. At 45 DAT, crop geometry was significant with each other and higher in 25 cm × 25 cm (28.73) and lower in 30 cm × 30 cm (24.55). Thus number of tillers per plant reduced significantly with decrease in spacing. Similar findings were reported by Narayana Reddy (2002) that crop geometry 25 cm × 25 cm produced higher number of tillers per plant.

Thus higher numbers of tiller per plant (60 DAT) causes the higher number of leaves per unit area (60 DAT). The higher number of leaves produced high LAI (75 DAT) ultimately the more photosynthesis, more dry matter production (90 DAT) and thus ultimately more yield. This indicates that there was highly significant positive correlation between the maximum tillering stage (60 DAT) and yield (r = 0.948**) (Appendix 16).

4.1.3 Number of leaves per plant

Leaves are the plant organ primarily responsible for photosynthesis and synthesis of other nitrogenous compounds required for plant growth and development (Keulen and Seligman, 1987). The leaf number depends on growing points, the length of time during which leaves are produced, the rate of leaf production during the period and the length of life of leaves (Reddy and Reddi, 2002). In general, up to 14 leaves are formed in the rice plant. The first four leaves supply assimilates to the formation of roots and that of middle layer takes part in the formation of panicle. The rice productivity depends on the activity of these middle layer leaves. Moreover in the last stage, the remaining green leaves supply product of photosynthesis to generative organs (Ustimenko Bakumovsky, 1983).

The observed result showed that average number of leaves per plant increase up to 60 DAT (134.903 cm) and thereafter gradually declined due to senescence of older leaves up to 105 DAT (46.72) (Table 6). The increment in the average number of leaves per plant was remarkably high in the period between 30 DAT to 45 DAT (83.84%) than 45 DAT to 60 DAT (56.88%). The average number of leaves per plant was decreased from 60 DAT to 105 DAT (65.37%). Statistically it was observed that the factor age of seedlings was significantly different at 30, 45, 60 and 90 DAT. Among the age of seedlings, the highest number of leaves per plant was obtained from that of 15 days of young seedlings in 30, 45, 60, 75 and 105 DAT as compared to all other age of seedlings. 75 DAT and 105 DAT were found non significant in the case of age of seedlings. In 30 DAT and 45 DAT, ages of seedlings were found significantly different with each other. In 15 days of seedling higher number of leaves per plant was 67.22 and lower were 31.17 in 30 DAT and higher 107.9 and lower 66.78 in 45 DAT. The average number of leaves per plant in 30 DAT and 45 DAT were 46.78 and 86 respectively. Similarly, in 60 DAT, higher number of leaves per plant was observed in 15 days of seedlings but at par with 8 (136.8) and 22 (133.1) days of seedlings and lowest was observed in 29 days of seedlings (132.2).

Statistically it was observed that the factor crop geometry was significantly different at 30, 45, 60, 90 and 105 DAT from the analyzed data (Table 6). Among the different crop geometry, the highest number of leaves per plant was obtained from that of 25 cm × 25 cm in 30, 45, 60, 75, 90 and 105 DAT as compared to all other crop geometry. 75 DAT was found non significant in the case of different crop geometry.

At 30 DAT, crop geometry was found significantly different with each other. Higher number of leaves per plant was 50.04 in 25 cm × 25 cm and lowest was 43.13 in 30 cm × 30 cm in 30 DAT. In 45 DAT and 105 DAT, 20 cm × 20 cm and 25 cm × 25 cm were par at each other but were significant at 30 cm × 30 cm. At 60 DAT and 90 DAT, 20 cm × 20 cm, 30 cm × 30 cm were at par each other and 25 cm × 25 cm was significantly

Table 6. Effect of age of seedlings and crop geometry on number of leaves per plant of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Number of leaves per plant**					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**
Age of seedlings						
8 days seedlings	48.50[b]	89.22[b]	136.80[a]	125.00	102.90[a]	47.94
15 days seedlings	67.22[a]	107.90[a]	137.60[a]	134.10	99.06[ab]	53.22
22 days seedlings	40.22[c]	80.06[c]	133.10[ab]	119.60	101.00[a]	39.17
29 days seedlings	31.17[d]	66.78[d]	132.20[b]	114.80	91.56[b]	46.56
CD (P = 0.05)	3.31**	6.63**	4.44*	NS	7.64*	NS
Sem ±	1.13	2.26	1.51	4.769	2.61	3.40
Spacing (cm^2)						
20 cm × 20 cm	47.17b	86.96[a]	133.50[b]	123.80	94.71[b]	49.42[a]
25 cm × 25 cm	50.04a	89.83[a]	139.90[a]	127.50	110.80[a]	50.71[a]
30 cm × 30 cm	43.13c	81.21[b]	131.30[b]	118.80	90.33[b]	40.04[b]
CD (P = 0.05)	2.86**	5.74*	3.82**	NS	6.62**	8.63*
Sem ±	0.977	1.96	1.31	4.130	2.26	2.94
CV %	7.23	7.88	3.37	11.59	7.93	21.82
Grand mean	46.78	86.00	134.90	123.39	98.63	46.72

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

different with others. Highest average number of leaves per plant was observed in 25 cm × 25 cm (139.90) in 60 DAT and lowest number of leaves per plant was observed in 30 cm × 30 cm at 105 DAT.

Higher numbers of leaves per plant (60 DAT) causes high LAI (75 DAT) ultimately the more photosynthesis thus more dry matter production (90 DAT) and ultimately more yield. There was highly significant positive correlation (r = 0.755) between numbers of leaves per plant at 60 DAT and LAI at 75 DAT. This indicates that there was significant positive correlation (r = 0.656*) between the number of leaves per plant at 60 DAT and yield (t/ha) (Appendix 16).

4.1.4 Interaction effects of age of seedlings and crop geometry on number of leaves per plant

There was significant effect on different age of seedlings with respect to different crop geometry at 30 DAT and 75 DAT (Appendix 13). At 30 DAT, 15 days seedlings with 25 cm × 25 cm had significantly higher number of leaves per plant as compared with other crop geometry followed by 20 cm×20 cm and 30 cm × 30 cm respectively (figure 4).

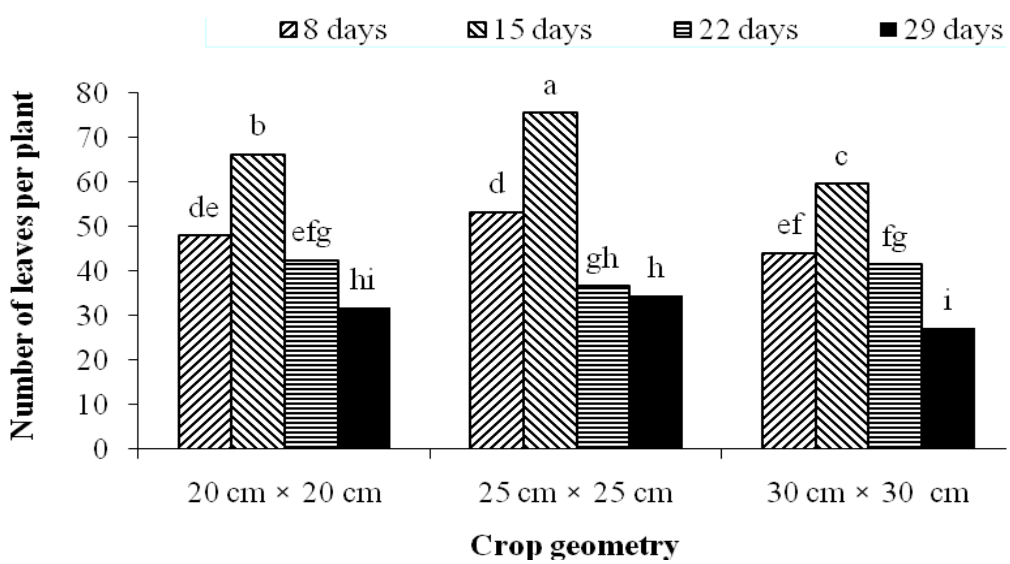

Figure 4. Interaction effects of age of seedlings and crop geometry on number of leaves per plant at 30 days after transplanting of rice under SRI at Shivanagar VDC,

Chitwan, 2008. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

At 75 DAT, 25 cm × 25 cm with 15 days seedlings had significantly higher number of leaves per plant as compared with other age of seedlings but at par with 20 cm×20 cm crop geometry and statistically different with 30 cm × 30 cm crop geometry (figure 5).

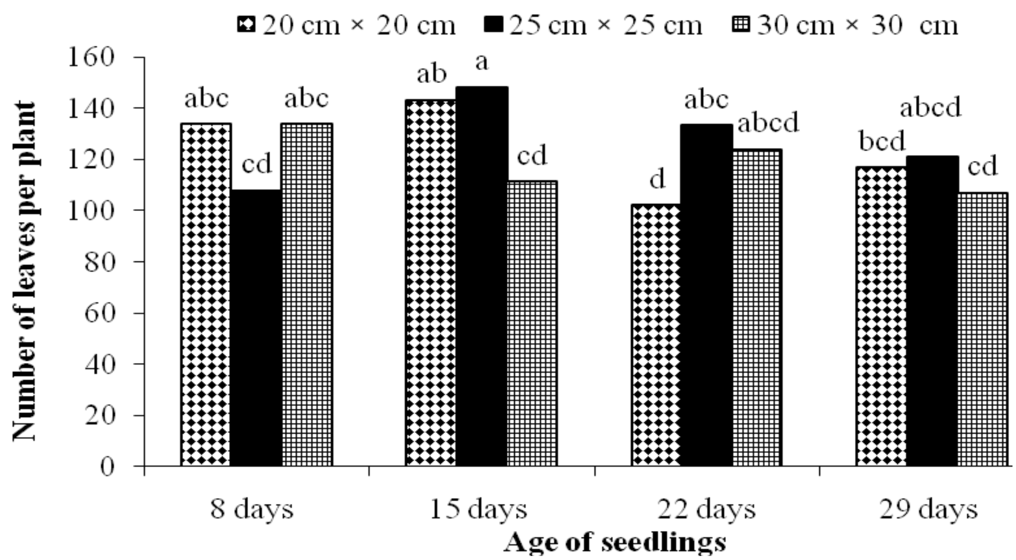

Figure 5. Interaction effects of age of seedlings and crop geometry on number of leaves per plant at 75 days after transplanting of rice under SRI at Shivanagar VDC, Chitwan, 2008. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

4.1.5 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. The observed result showed that the average leaf

Table 7. Effect of age of seedlings and crop geometry on leaf area index (LAI) of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Leaf area index (LAI)**					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**
Age of seedlings						
8 days seedlings	1.78^{ab}	1.62^{ab}	2.05^{ab}	2.16^{b}	2.00	0.93
15 days seedlings	2.11^{a}	1.92^{a}	2.43^{a}	2.76^{a}	2.14	0.99
22 days seedlings	1.66^{b}	1.51^{b}	1.91^{b}	1.92^{b}	1.94	0.83
29 days seedlings	1.44^{b}	1.31^{b}	1.66^{b}	2.04^{b}	1.81	0.82
CD (P = 0.05)	0.3786*	0.3443*	0.4350*	0.2713**	NS	NS
Sem ±	0.1291	0.1174	0.1483	0.09250	0.1366	0.09369
Spacing (cm^2)						
20 cm × 20 cm	1.97^{a}	1.80^{a}	2.27^{a}	2.49^{b}	2.19^{b}	1.08^{a}
25 cm × 25 cm	2.11^{a}	1.93^{a}	2.43^{a}	2.78^{a}	2.55^{a}	1.09^{a}
30 cm × 30 cm	1.16^{b}	1.05^{b}	1.33^{b}	1.41^{c}	1.18^{c}	0.51^{b}
CD (P = 0.05)	0.3279**	0.2981**	0.3767**	0.2349**	0.3470**	0.2380**
Sem ±	0.1118	0.1017	0.1285	0.08010	0.1833	0.08114
CV %	22.18	22.18	22.12	12.45	20.78	31.49
Grand mean	1.75	1.59	2.01	2.22	1.98	0.89

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

area index increased from 30 DAT (1.75%) to 75 DAT (2.22%) and declined towards maturity mainly due to leaf senescence (0.89%). It was observed that the response of LAI on age of seedlings was significantly different at 30, 45, 60 and 75 DAT but significantly not different at 90 and 105 DAT (Appendix). Among the age of seedlings, the highest LAI was obtained from that of 15 days of seedlings in 30, 45, 60, 75, 90 and 105 DAT as compared to all other age of seedlings (Table 7). The LAI of 30, 45 and 60 DAT, 15 days ages seedlings were found significantly different with 22 and 29 days seedling but at par with 8 days seedlings. Similarly 8 days of seedlings were again at par with 22 and 29 days of seedlings. The LAI of 75 DAT, 15 days of seedlings were significant with 8, 22 and 29 days of seedlings. In 15 days of seedling higher LAI obtained were 2.11 and (30 DAT), 1.92 (45 DAT), 2.43 (60 DAT), 2.76 (75 DAT), 2.14 (90 DAT) and 0.99 (105 DAT). Likewise lower LAI obtained 1.44 (30 DAT), 1.31 (45 DAT), 1.66 (60 DAT), 2.04 (75 DAT), 1.81 (90 DAT) and 0.82 (105 DAT) in 29 days of seedlings.

Furthermore, it was observed that the response of LAI on different crop geometry was found significantly different at 30, 45, 60, 75, 90 and 105 DAT (Table 7). The observed result showed that (Table 7) the LAI among the different crop geometry, the highest LAI was obtained from that of 25 cm × 25 cm in 30, 45, 60, 75, 90 and 105 DAT and lowest was observed in wider spacing 30 cm × 30 cm as compared to all other crop geometry. Similar result was reported by Nayak *et al*. (2003) in a field experiment conducted in Bhuvaneshwor during wet season where LAI was lower at wider spacing of (20 × 15) cm^2 compared to (15 × 15) cm^2The LAI of 30, 45, 60 and 105 DAT, the crop geometry 25 cm × 25 cm found significant with 30 cm × 30 cm but at par with 20 cm×20 cm. LAI of 75 and 90 DAT were significant with each other. There was significant positive correlation (r = 0.678*) between leaf area index and total dry matter production at 90 DAT (Appendix 16).

4.1.6 Interaction effects of age of seedlings and crop geometry on LAI

There was significant effect on different age of seedlings with response to different crop geometry at 75 DAT and 90 DAT (Appendix 14).

At 75 DAT, 15 days seedlings with 25 cm × 25 cm had significantly higher number of leaves per plant as compared with other crop geometry followed by 20 × 20 cm and 30 cm × 30 cm respectively (figure 6).

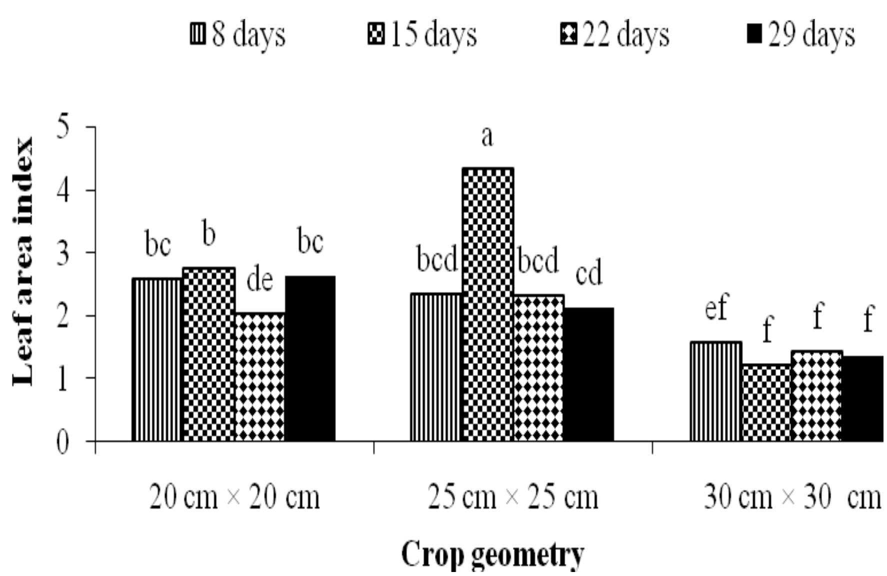

Figure 6. Interaction effects of age of seedlings and crop geometry on leaf area index (LAI) at 75 days after transplanting (DAT) of rice under SRI at Shivanagar VDC, Chitwan, 2008. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

At 90 DAT, 25 cm × 25 cm with 15 days seedlings had significantly higher number of leaves per plant as compared with other age of seedlings but at par with 22 and 29 days of seedlings and statistically different with 8 days of seedlings (figure 7).

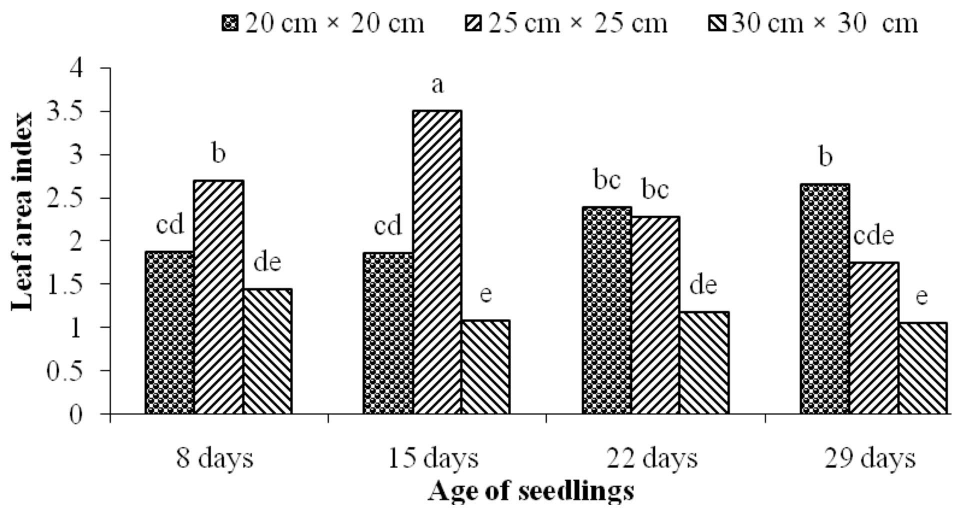

Figure 7. Interaction effects of age of seedlings and crop geometry on leaf area index (LAI) at 90 days after transplanting (DAT) of rice under SRI at Shivanagar VDC, Chitwan, 2008. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

4.1.7 Dry matter production

The first prerequisite for high yield is a high production of total dry matter per unit area. 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 dry matter produced is distributed among different parts of the plants, which determine magnitude of the economic yield (Arnon, 1972).

The result showed that response of dry matter production/plant on both factors age of seedling and plating pattern were significant at 60, 75 and 90 DAT but non significant in 30 DAT (age of seedlings) and 45 DAT (crop geometry) (Table 8). The average dry matter production per plant increased from 30 DAT (14.74 g) to 90 DAT (137.63 g).

Table 8. Effect of age of seedlings and crop geometry on total dry matter production per plant (g) of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Dry matter production per plant (g)**				
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
Age of seedlings					
8 days seedlings	14.74	31.41[ab]	64.32[ab]	108.50[ab]	141.30[b]
15 days seedlings	16.03	33.77[a]	70.15[a]	116.10[a]	177.60[a]
22 days seedlings	14.52	29.86[ab]	58.35[bc]	104.50[ab]	123.60[c]
29 days seedlings	13.68	26.14[b]	52.52[c]	99.49[b]	107.90[d]
CD (P = 0.05)	NS	5.147*	8.693**	11.71*	14.44**
Sem ±	0.6957	1.755	2.946	3.993	4.924
Spacing (cm^2)					
20 cm × 20 cm	14.26[b]	29.51	60.17[b]	110.2[a]	136.40[b]
25 cm × 25 cm	17.23[a]	32.62	68.75[a]	113.2[a]	149.10[a]
30 cm × 30 cm	12.75[b]	28.75	55.08[b]	98.06[b]	127.40[b]
CD (P = 0.05)	1.767**	NS	7.482**	10.14*	12.51**
Sem ±	0.6025	1.520	2.551	3.458	4.265
CV %	14.16	17.38	14.41	11.18	10.73
Grand mean	14.74	30.29	61.33	107.15	137.63

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

It was observed that the response of dry matter production per plant on age seedlings was significantly different at 45, 60, 75 and 90 DAT but non significantly different at 30 DAT (Appendix 9). Among the age of seedlings, the highest dry matter production per plant was obtained from that of 15 days seedlings in 30, 45, 60, 75, 90 DAT as compared to all other age of seedlings (Table 8). The dry matter production per plant of 30, 45 and 75 DAT, 15 days age seedlings was found significantly different with 29 days seedling but at par with 8 and 22 days of seedlings. Similarly 8 days seedlings were again at par with 22 and 29 days seedlings. Dry matter production per plant of 90 DAT, 15 days seedlings were significant with 8, 22 and 29 days seedlings respectively. In 30 days seedling higher dry matter production per plant obtained were 16.03 g, 33.77 g (45 DAT), 70.15 g (60 DAT), 116.10 g (75 DAT), 177.60 g (90 DAT) in 15 days seedlings and lower dry matter production per plant obtained was 13.68 g (30 DAT), 26.14 g (45 DAT), 52.52 g (60 DAT), 99.49 g (75 DAT) and 107.90 g (90 DAT) in 29 days seedlings.

Furthermore, it was observed that the response of dry matter production per plant on different crop geometry was significantly different at 30, 60, 75 and 90 DAT (Appendix 9). The observed result showed that (Table 8) the dry matter production per plant among the different crop geometry, the highest was obtained from that of 25 cm × 25 cm in 30, 45, 60, 75 and 90 DAT as compared to all other crop geometry. Dry matter production per plant of 30, 60 and 90 DAT, the crop geometry 25 cm × 25 cm found significant with 30 cm × 30 cm and 20 cm×20 cm. In 75 DAT, crop geometry 25 cm × 25 cm found significant with 30 cm × 30 cm but at par with 20 cm×20 cm. This might be due to higher leaf area index (LAI) at 25 cm × 25 cm in all growth stages of crop thus higher total dry matter production per plant was observed in 25 cm × 25 cm. There was highly significant positive correlation (r = 0.878) between total dry matter production at 90 DAT and yield (t/ ha) (Appendix 16).

4.2 Yield attributing parameters as influenced by age of seedlings and crop geometry

4.2.1 Effective tiller per meter square

Substantial differences were observed in the effective tiller per square meter for the age of seedlings and crop geometry from the analyzed data (Table 9). Both age of seedlings and crop geometry significantly influenced the effective tillers per square meter and also the interaction effect found significant that influence the effective tiller per square meter (Appendix 15). The effective tillers ranged from 210.6 to 266.1 among the combination of different age of seedlings and crop geometry (spacing), and the average effective tiller per square meter obtained in the experiment was 246.79.

It was observed (Table 9) that the response of effective tiller per square meter on age of seedlings was found. Significant result was obtained on effective tiller with response to age of seedling by NARC (2005) and reported that younger seedlings obtained significantly higher number of effective tillers than older seedlings. Effective tillers obtained from 15 days of seedlings were significantly higher than 29 days of old seedlings but at par with 8 and 22 days of seedlings. Among the age of seedlings, 15 and 8 days of seedling produced higher number of effective tillers per square meter as compared to 22 and 29 days of seedling. Comparatively higher numbers of effective tillers per square meter (264.9) was observed in 15 days of seedlings and lowest tillers numbers (217.7) in 29 days of seedlings. 15 days old seedlings recorded maximum number of effective tillers per square meter (264.9) as compared to other age of seedlings. The reduction in effective tillers with old seedlings was attributed to the lower productive tillers per plant in rice. The similar findings were in conformity with results of Krishna and Biradarpatil (2009).

Statistically it was observed that the number of effective tiller per square meter was found significantly different with response to crop geometry (Table 9). Among the different crop geometry, significantly the highest effective tiller per square meter was obtained from that of 25 cm × 25 cm (266.1) which was significantly higher than 30 cm × 30 cm (210.6) but at par with 20 cm × 20 cm (263.8). The increase in the productive tillers per plant might be due to the better spacing provided to the plants by planting in square method. This might have facilitated better utilization of resources by the plants converting majority of the tillers into productive tillers (Gani *et al.,* 2002; Sarath and Thilak, 2004). There was significant positive correlation (r = 0.618*) between effective tiller per square meter and yield (t/ ha) (Appendix 16).

4.2.2 Interaction effects of age of seedlings and crop geometry on effective tiller per meter square

There was significant effect on different age of seedlings and different crop geometry with respect to effective tiller per square meter (Appendix 15). 8 days of seedlings with 25 cm × 25 cm showed highest effective tiller per square meter and found best combination with respect to other rest and was significant with 29 days of seedlings with 30 cm × 30 cm. Similarly in 15 days of seedlings with 25 cm × 25 cm found higher number of effective tiller and was significantly different with 30 cm × 30 cm but at par with 8 days of seedlings with combination of 25 cm × 25 cm.

Similar trend was carried out at Agricultural Research Station, Gangavati during rabi season of 2004 to 05 under SRI having seedlings of different ages viz., 8, 12, 16 and 25 old, were transplanted with different spacing in square pattern according to the treatments i.e. 20 x 20, 30 x 30 and 40 x 40 cm and observed that interaction between the age of seedlings and spacing for productive tillers per plant was found to be significant. The treatment combination of 12 days with 30 x 30 cm recorded significantly higher productive tillers per plant (20.80) compared to all other interactions. (Krishna and Biradarpatil, 2009).

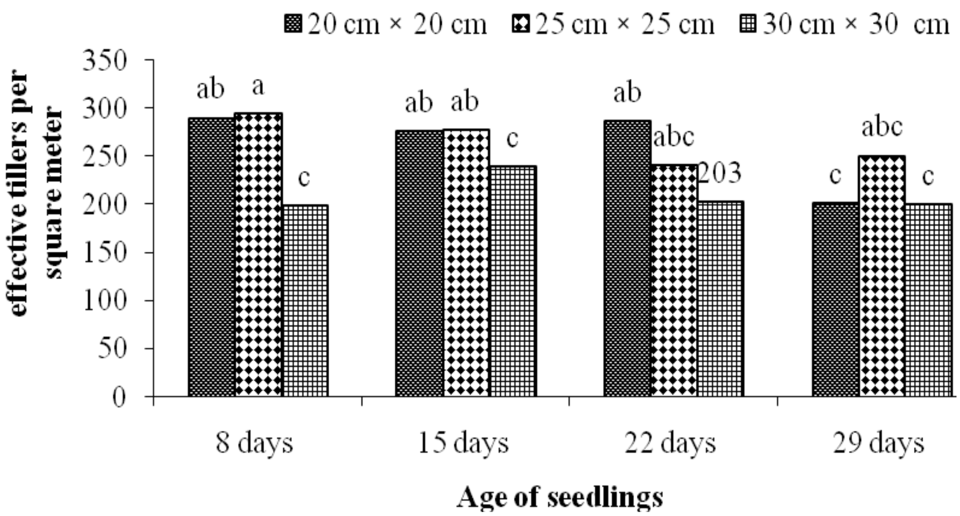

Figure 8. Interaction effects of age of seedlings and crop geometry on number of effective tillers per square meter of rice under SRI at Shivanagar VDC, Chitwan, 2008. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5% level of significance.

4.2.3 Panicle length

The average panicle length was 26.113. Panicle length was not significantly influenced by the factor age of seedlings but was significantly influenced by crop geometry statistically (Table 9). Comparatively higher panicle length was observed in 15 days of seedlings, 26.70 and lowest panicle length in 29 days of seedlings, 25.74.

Panicle length having 25 cm × 25 cm (26.58) differed significantly with 30 cm × 30 cm (25.66) but at par with 20 cm × 20 cm (26.10) and latter two were at par with each other. There was significant positive correlation (r = 0.662*) between length of panicle and yield (t/ha) (Appendix 16).

Table 9. Effect of age of seedlings and crop geometry on yield attributing characters of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatment	**Effective tillers m^{-2}**	**Per panicle length (cm)**	**Per panicle weight (gm)**	**No. of grains Per panicle**	**Sterility percentage**	**1000 grain weight (gm)**
Age of seedlings						
8 days seedlings	261.00[a]	26.26	3.54	142.4[b]	11.80	22.48
15 days seedlings	264.90[a]	26.70	3.57	157.7[a]	11.30	22.84
22 days seedlings	243.60[ab]	25.75	3.43	129.0[c]	11.96	22.06
29 days seedlings	217.70[b]	25.74	3.24	116.5[d]	12.13	21.93
CD (P = 0.05)	27.18*	NS	NS	11.79**	NS	NS
Sem ±	9.267	0.2741	0.1269	4.021	1.080	0.3221
Spacing (cm^2)						
20 cm × 20 cm	263.80[a]	26.10	3.44	135.8[b]	11.98	22.56
25 cm × 25 cm	266.10[a]	26.58	3.49	147.5[a]	10.36	22.35
30 cm × 30 cm	210.60[b]	25.66	3.41	125.9[b]	13.06	22.07
CD (P = 0.05)	23.54**	NS	NS	10.21**	NS	NS
Sem ±	8.026	0.2373	0.1099	3.482	0.9351	0.2790
CV %	11.27	3.15	11.04	8.84	27.45	4.33
Grand mean	246.79	26.11	3.44	136.41	11.80	22.33

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5 % level of significance.

4.2.4 Panicle weight

The analysis of data (Table 9) showed that the average panicle weight of panicles in the experiment was (3.444). Both the factor age of seedlings and crop geometry did not significantly influence the panicle weight. Average panicle weight obtained in the experiment was 3.444. Comparatively higher panicle weight was observed in 15 days of seedlings, 3.572 and lowest panicle weight in 29 days of seedlings, 3.238.

In the case of different crop geometry, comparatively higher panicle weight was recorded in 25 cm × 25 cm (3.486) and lowest panicle weight in 30 cm × 30 cm (3.409). There was highly significant positive correlation (r = 0.780**) between panicle weight and yield (t/ha) (Appendix 16).

4.2.5 Grains per panicle

Substantial differences were observed in the number of grains per panicle for the age of seedlings and crop geometry from the analyzed data (Table 9). The grains per panicle ranged from 116.5 to 157.7 among the combination of different age of seedlings and crop geometry (spacing), and the average number of grains obtained in the experiment was 136.406. Age of seedlings highly significantly influence the number of grains per panicle. Number of grains per panicle of different age of seedlings differed significantly among each other. Comparatively highest number of grains per panicle was observed in 15 days of seedlings, 157.7 and significantly higher than other.

Statistically it was observed that the factor crop geometry was highly significant within the treatments from the analyzed data (Table 9). Among the different crop geometry, significantly the highest number of grains per panicle was obtained from that of 25 cm × 25 cm (147.5) which was significant with the rest of two crop geometry. The lowest number of grains per panicle was observed in 30 cm × 30 cm (125.9) but at par with

20 cm×20 cm (135.8). There was highly significant positive correlation (r = 0.910**) between grains per panicle and yield (t/ha) (Appendix 16).

4.2.6 Sterility percentage

Udaykumar, (2005) reported that the plants in SRI method had better partitioning of dry matter, which lead to increase in the number of filled spikelets and decrease in the spikelet sterility. The average sterility percentage in research experiment was 11.801% and it ranged from 10.36 to 13.06% (Table 9) depending upon the combination of different age of seedlings and different crop geometry. Statistical analysis of the data indicated that the sterility percentage was not significantly difference among the factor age of seedlings and crop geometry. The higher sterility was observed in 29 days of seedlings (12.13%) followed by 22 days of seedlings (11.96%) and lower sterility was observed in 15 days of seedlings (11.30%) which was not significantly different among each other.

The sterility percentage was not significantly influenced by the crop geometry. Comparatively higher sterility percentage was observed in 30 cm×30 cm (13.06%) followed by 20 cm × 20 cm (11.98%) and lowest sterility percentage was observed in 25 cm × 25 cm (10.36%). There was negative correlation (r = -0.481) between sterility percentage and yield (t/ha) (Appendix 16).

4.2.7 Thousand grain weight

The average thousand grain weight in research experiment was 22.328 gm and it ranged from 21.93 to 22.84 gm (Table 9) depending upon the combination of different age of seedlings and different crop geometry. Statistical analysis of the data indicated that the thousand grain weight was not significantly difference among the factor age of seedlings and crop geometry. The higher thousand grain weight was observed in 15 days of seedlings (12.84 gm) followed by 8 days of seedlings (12.48 gm) and lower grain weight was observed in 29 days of seedlings (21.93 gm) which was not significant among each others.

Faruk *et al.* (2009) also reported that 1000-grain weight was unaffected by age of seedling and their interactions.

Comparatively higher grain weight was observed in 20 cm×20 cm (22.56 gm) followed by 25 cm × 25 cm (22.35 gm) and lowest grain weight was observed in 30 cm × 30 cm (22.07 gm). The better seed quality with seed produced from wider spacing might be due to higher test weight values which indicate the better food reserves in the seeds produced and might be resulted in better yield in SRI (Table 9). These results are in conformity with Nandisha and Mahadevappa (1984) and Manonmani and Jacqulin (1995). There was highly significant positive correlation (r = 0.714*) between thousand grain weight and yield (t/ha) (Appendix 16).

4.3 Yield as influenced by age of seedling and crop geometry

4.3.1 Grain yield

Substantial differences were observed in the grain yield production (t ha^{-1}) for the age of seedlings and crop geometry (Table 10) from the analyzed data. Both age of seedlings and crop geometry significantly influenced the grain yield but their interaction did not influence the grain yield. The similar findings were in conformity with results of Krishna and Biradarpatil (2009) where seedling age and plating pattern were found significant and interaction effects found were non significant. The obtained rice grain yield ranged from 4.42 t ha^{-1} to 6.59 t ha^{-1} among the different age of seedling and crop geometry (spacing), and the average grain yield obtained in the experiment was 5.66 t/ha.

A perusal of data in Table indicates that 15 days of seedlings yielded highest (6.59 t/ha) and 29 days seedlings yielded lowest (4.42 t/ha). The reduction in grain yield due to 29 days seedlings than 15 days was 32.96% and the reduction was significant. One week older and one week younger seedlings than 15 day seedlings also resulted significantly different lower grain yield and the reduction was to the extent of 15.77% and 7.71%

respectively. Significantly highest rice grain yield recorded with 15 days of old seedlings might be attributed by significantly higher numbers of effective tillers per square meter and higher numbers of grains per panicles. Similar findings had been reported by (Singh *et al*., 2004) in which seedling age is known to influence the grain yield. Further, Pasuquin *et al* (2008) on SRI reported that transplanting seedlings as young as about 14 days old generated higher crop performance than transplanting 21 to 23 day old seedlings. Mchugh (2002) reported that the findings of Madagascar that 8 to 15 day old seedlings transplanted produced the highest yield, whereas in Sumatra the highest yields were obtained with 10 day old transplanted seedlings. In North Sumatra, a 15 day old seedling crop out yielded a 21 day old one (Makarim *et al*., 2002). There were indications that the longer stay of seedlings in the nursery may have affected seedling growth pattern in response to high seedling competition (Mandel *et al*., 1984).

Similarly, the different crop geometry also affected grain yield significantly (Table 10). Among the different crop geometry, significantly the highest grain yield was recorded 25 cm × 25 cm (6.04 t/ha) as compared to 20 cm×20 cm (5.57 t/ha) and 30 cm × 30 cm (5.37 t/ha). The grain yield thus obtained from 20 cm×20 cm and 30 cm × 30 cm was at par with each other (Table 10). The difference in lowest grain yield and highest grain yield due to reduction in number of hills per unit area was 11.17% and the reduction was significant. The reduction in grain yield due to 20 cm×20 cm as compared to 25 cm × 25 cm was 7.87% and the reduction was significant. Maximum yield obtained under crop geometry of 25 cm × 25 cm was due to the significantly higher numbers of grains per panicle as compared to rest of the crop geometry which was in accordance with the findings (Uphoff and Fernandes, 2002) and was advised to most of the farmers. Menete *et al*. (2008) on SRI reported that wider plant spacing (0.3 m) decreased grain yields by 11.5% (6.2–5.5 t/ha) than at closer spacing (0.2 m) and added that increasing plant spacing very readily results in decreased yields, although rice plants can compensate to a considerable extent by increasing per-plant productivity. Still, a factor increase in plant spacing results in a square factor decrease in plant density, and therefore necessitates very high gains in per-plant productivity. Thus, the optimum level of plant population coupled with better yield parameters might have resulted in higher seed yield/ha under 25 x 25 cm spacing.

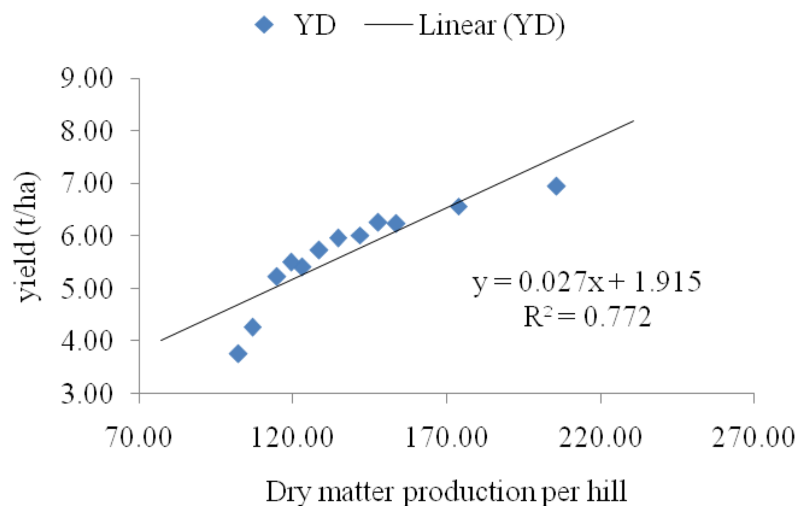

Figure 9. Relationship between dry matter production per plant (g) and grain yield of rice under SRI at Shivanagar VDC, Chitwan, 2008

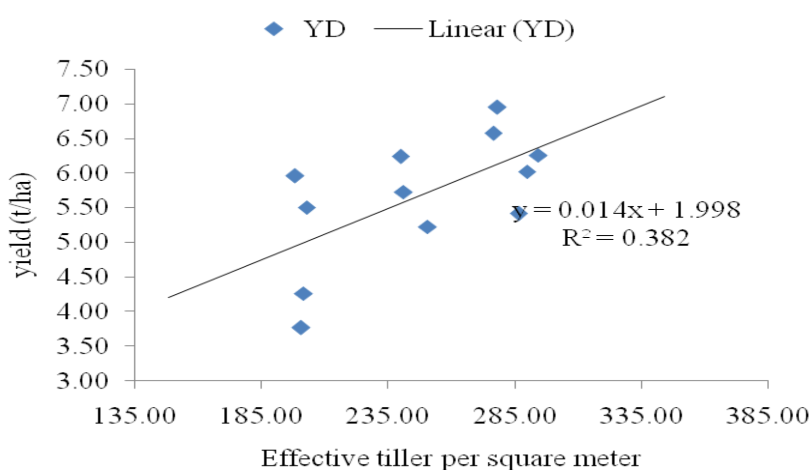

Figure 10. Relationship between effective tillers per square meter and grain yield of rice under SRI at Shivanagar VDC, Chitwan, 2008

Table 10. Effect of age of seedlings and crop geometry on grain yields, straw yields, harvest index and grain straw ratio of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Grain straw ratio
Age of seedlings				
8 days seedlings	6.08[b]	6.43[b]	48.53[a]	0.94[a]
15 days seedlings	6.59[a]	7.05[a]	48.50[a]	0.94[a]
22 days seedlings	5.55[c]	6.01[bc]	47.75[a]	0.92[a]
29 days seedlings	4.42[d]	5.74[c]	42.54[b]	0.75[b]
CD (P = 0.05)	0.4648**	0.5061**	2.376**	0.08744*
Sem ±	0.1585	0.1726	0.8101	0.02981
Spacing (cm^2)				
20 cm × 20 cm	5.57[b]	6.33[ab]	46.08	0.87
25 cm × 25 cm	6.04[a]	6.58[a]	47.66	0.92
30 cm × 30 cm	5.37[b]	6.02[b]	46.73	0.89
CD (P = 0.05)	0.4025**	0.4383*	NS	NS
Sem ±	0.1372	0.1494	0.7015	0.02582
CV %	8.41	8.20	5.19	9.79
G rand mean	5.66	6.31	46.83	0.89

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5 % level of significance.

4.3.2 Straw yield

Rice straw is the major crop by product that feeds the livestock during the fodder deficit period. In, Nepal, total production of rice straw was 2.8 million tones (APROSC, 1986).

Substantial differences were observed in the straw yield production (t/ha) for the age of seedlings and crop geometry (Table 10) from the analyzed data. Both age of seedlings and crop geometry significantly influenced the straw yield but their interaction did not influence the straw yield. The obtained rice straw yield ranged from 5.74 t/ha to 7.05 t/ha among the different age of seedlings and crop geometry (spacing), and the average straw yield obtained in the experiment was 6.31 t/ha.

Statistically it was observed that the factor age of seedlings was highly significant within the treatments from the analyzed data. Among the age of seedlings, the highest straw yield was obtained from that of 15 days of young seedlings, a straw yield of 7.05 t/ ha as compared to all other age of seedlings. Similarly the lowest straw was obtained from 29 days of old seedlings, a straw yield of 5.74 t/ha which was at par with 22 days of old seedlings, a straw yield of 6.01 t/ha (Table 10). Similar kind of result was observed by Faruk *et al.* (2009) where straw yield were significantly different among different age of seedling (2, 3, 4 and 5 weeks).

Statistically it was observed that the factor crop geometry was significant within the treatments. Among the different crop geometry, significantly the highest straw yield was obtained from that of 25 cm × 25 cm, a straw yield of 6.58 t ha^{-1}, which was par to 20 cm×20 cm, a straw yield of 6.33 t ha^{-1} and in 30 cm × 30 cm, a lowest straw yield of 6.02 t ha^{-1} which was par with 20 cm×20 cm (Table 10).

4.3.3 Harvest index (HI)

According to the data presented in the table, the average value of harvest index in the experiment was 46.827% and ranged from 42.54 to 58.53% in the case of age of seedling and 46.08 to 47.66 % in the case of crop geometry.

Harvest index (HI) was significantly different among the age of seedlings but it was not significantly among the crop geometry (Table 10). Comparatively highest harvest index was obtained with 8 days of young seedlings (48.53%) followed by 15 days of young seedlings (48.50%) and 22 days of old seedlings (47.75%) which was at par with each other. The lowest harvest index was obtained from 29 days of old seedlings (42.54%). This was due to higher biomass production in younger seedlings (8, 15, 22 days) than 29 days of seedlings.

Similar trend on harvest index (HI) was observed by Pasuquin *et al.* (2008) on SRI having 7, 14, and 21 days of seedlings which was conducted in dry season 2003.

No significant difference in harvest index was observed in the different crop geometry of 25 cm × 25 cm which was the higher (47.66%) than others followed by 30 cm × 30 cm (46.73%) respectively. The lowest harvest index (HI) was observed in 20 cm × 20 cm of (46.08%). There was an increasing trend in harvest index with the increasing spacing (.20 m to .25 m).

Similar results were evaluated in harvest index by Jayawardena and Abeysekera (2002) having an experiment in two locations with 2 hybrid varieties of rice under six spacing to yield responses and reported that 25 cm × 25 cm and 30 cm×30 cm was not significant different in both locations.

4.3.4 Interaction effects of age of seedlings and crop geometry on harvest index

There was significant effect on different age of seedlings and different crop geometry with respect to harvest index (Appendix 15). 22 days of seedlings with 30 cm ×

30 cm showed highest harvest index and found best combination with respect to other but at par with other combination and was significant with the combination of 29 days of seedlings with 20 cm × 20 cm and 30 cm × 30 cm.

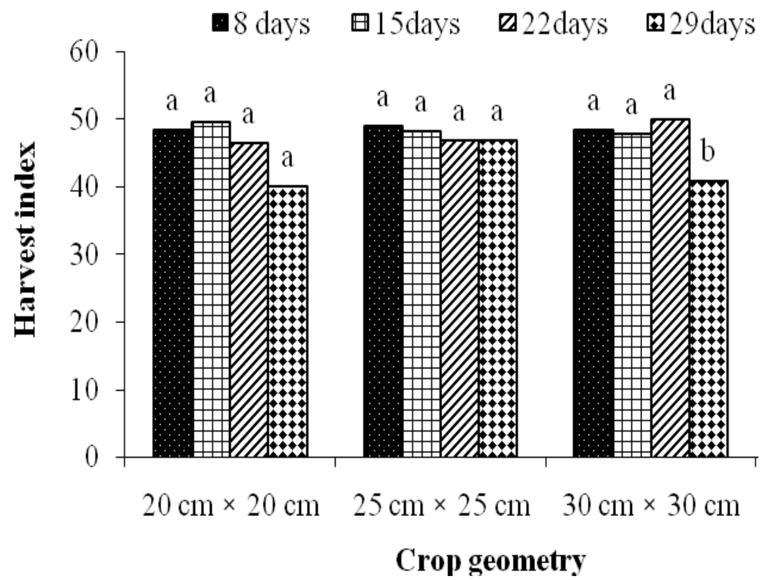

Figure 11. Interaction effects of age of seedlings and crop geometry on harvest index of rice under SRI at Shivanagar VDC, Chitwan, 2008.

4.3.5 Grain straw ratio

Grain straw was highly significantly differently among the age of seedlings but it was not significantly differently among the crop geometry. Similar grain straw ratio was obtained with 8 days of young seedlings (0.9444) and by 15 days of young seedlings (0.9444) followed by 22 days of old seedlings (0.9200) which was par with each other. The lowest grain straw ratio was obtained from 29 days of old seedlings (0.7489).

Grain straw ratio of 25 cm × 25 cm was the higher (0.9150) followed by 30 cm×30 cm (0.8867) and 20 cm×20 cm of (0.8667) which was non significant.

4.4 Economic analysis

4.4.1 Cost of cultivation

Cost of cultivation was similar for all treatments (Table 11).

Table 11. Effect of age of seedlings and crop geometry on cost of production, net return, net return and B: C ratio under SRI at Shivanagar VDC, Chitwan, 2008

Treatment	Economic analysis			
	Cost of cultivation Rs./ha('000)	Gross return Rs./ha ('000)	Net return Rs./ha('000)	B C ratio
Age of seedlings				
8 days seedlings	44.58	156.30[b]	111.70[b]	3.51[b]
15 days seedlings	44.58	169.60[a]	125.00[a]	3.80[a]
22 days seedlings	44.58	143.10[c]	98.54[c]	3.21[c]
29 days seedlings	44.58	117.20[d]	72.65[d]	2.63[d]
LSD(P-0.05)		10.63**	10.63**	0.2395**
SEm±		3.625	3.625	0.08165
Spacing				
20 cm × 20 cm	44.58	144.60[b]	100.00[b]	3.24[b]
25 cm × 25 cm	44.58	156.00[a]	111.40[a]	3.50[a]
30 cm × 30 cm	44.58	139.10[b]	94.540[b]	3.12[b]
LSD(P-0.05)		9.208**	9.208**	0.2074**
SEm±		3.140	3.140	0.07071
CV%		7.42	10.66	7.43
Grand mean		146.56	101.98	3.29

SRI, System of Rice Intensification; DAT, days after transplanting; NS, non significant; VDC; village development committee. Treatment means separated by Duncan's Multiple Range Test (DMRT) and columns represented with same letter (s) are not significantly different among each other at 5 % level of significanc

4.4.2 Gross return

The gross return per hectare was significantly influenced by the age of seedlings and crop geometry but the interaction effect did not influence the gross return. The observed result showed that the average gross return was Rs 146.56 thousands/ha and it ranged from Rs 117.20 to 169.60 thousands/ha (Table 11).

Statistically it was observed that the gross return with response of age of seedlings was highly significant between the treatments from the analyzed data (Table 11). Among the age of seedlings, the highest gross return was obtained from that of 15 days of young seedlings, (Rs 169.60 thousands/ha) as compared to all other age of seedlings. Likewise, 15 days of seedlings was significantly difference with 8 days of seedlings (156.30 thousand/ha), 22 days of seedlings (143.10 thousand/ha) and 29 days of seedlings (117.20) which obtained lowest gross return in old age seedlings. The higher gross return per hectare was due to higher grain yield.

Similarly it was observed that the factor crop geometry was highly significant which affect the gross return within the treatments from the analyzed data. Among the different crop geometry, significantly the highest gross return was obtained from that of 25 cm × 25 cm (156 thousands/ha) as compared to 20 cm×20 cm (144.60 thousands/ha) and 30 cm × 30 cm (139.10). The gross return thus obtained from 20 cm×20 cm and 30 cm × 30 cm crop geometry was at par with each other (Table 11). The high yield recorded in the 25 cm × 25 cm was the cause of higher gross return per hectare.

4.4.3 Net return

The net return per hectare was significantly influenced by the age of seedlings and crop geometry but the interaction effect did not influence the net return. The observed result showed that the average net return was Rs 101.98 thousands/ha and it ranged from Rs 72.65 to 125 thousands/ha (Table 11).

Statistically it was observed that the net return with response of age of seedlings was highly significant between the treatments from the analyzed data (Table 11). Among the age of seedlings, the highest net return was obtained from that of 15 days of young seedlings, (Rs 125 thousands/ha) as compared to all other age of seedlings. Likewise, 15 days of seedlings was significantly difference with 8 days of seedlings (111.70 thousand/ha), 22 days of seedlings (98.54 thousand/ha) and 29 days of seedlings (72.65) which obtained lowest net return in old age seedlings. Higher net return per hectare in 15 days of seedlings was due to higher grain yield. It was observed that the factor crop geometry was highly significant which affect the net return within the treatments from the analyzed data. Among the different crop geometry, significantly the highest net return was obtained from that of 25 cm × 25 cm (111.40 thousands/ha) as compared to 20 cm×20 cm (100 thousands/ha) and 30 cm × 30 cm (94.54). The net return thus obtained from 20 cm×20 cm and 30 cm × 30 cm crop geometry was at par with each other (Table 11).

4.4.4 B: C 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). On the other hand, minimum BC ratios of 1.5 for the agricultural sector have been fixed for any enterprises to be economically viable. Therefore, any crop enterprises must maintain a 1.5 BC ratio to be economically sustainable (Bhandari, 1993).

Gross return per hectare and net return per hectare, B: C ratio was significantly influenced by age of seedlings and crop geometry but interaction effect did not influence it (Table 11). Thus, the analyzed data revealed that the average benefit cost ratio was above 2 (3.29) and it ranged from 3.12 to 3.80. The significantly higher BCR was observed in 15 days of seedlings (3.80) than the others, followed by 8 days of seedlings (3.51), 22 days of seedlings (3.21) and lowest in 29 days of seedlings (2.63) respectively. Significantly higher B:C in 15 days of seedlings was due to high yield ultimately which ultimately cause the high gross return and net return per hectare.

Similarly, on the other hand, it was observed that the factor crop geometry was highly significant which affect the BCR within the treatments from the analyzed data. Among the different crop geometry, significantly the highest B:C ratio was obtained from that of 25 cm × 25 cm (3.50) as compared to 20 cm×20 cm (3.24) and 30 cm × 30 cm (3.12). The BC ratio thus obtained from 20 cm×20 cm and 30 cm × 30 cm crop geometry was at par with each other (Table). Higher B:C ratio in 25 cm × 25 cm was due to high yield.

Thus it is clear from the present investigation that, 15 days old seedling (3.80) and 25 x 25 cm spacing results in higher benefit cost ratio (3.50) as compared to rest other treatments.

5 SUMMARY AND CONCLUSIONS

A field experimentation to determine the productivity and economic viability of rice under different planting pattern and age of seedling through System of Rice of Intensification were carried out during rainy season of 2008 in farmers' field of Shivanagar VDC of Chitwan. The seedlings of different ages viz., 8, 15, 22 and 29 old, were transplanted and tested with different spacing in square pattern according to the treatments i.e. 20 x 20, 25 x 25 and 30 x 30 cm in two factorial RCBD with three replications. The soil of experimental site was sandy loam in texture having 63%, 29%, 8% sand, silt, and clay respectively with soil PH 6.3. The soil was low in organic matter content (2.1%), medium in total nitrogen (0.11%), low in available phosphorus (26 kg/ha) and low in available potassium (107 kg/ha). The experimental site received total rainfall of 1573.92 mm from transplanting to harvesting of crop with the maximum temperature and relative humidity ranged from 24 to 33.23^{o}C and 83.53 to 97.55^{o}C. The results of the experiments are summarized below:

No significant differences were observed for plant height due to age of the seedlings and planting patterns from 30 DAT to 105 DAT. The increment in plant height was prominent (53.62%) between 30 DAT and 50 DAT. However, plant height with 8 days old seedlings (99.45 cm) and wider spacing of 30 cm x 30 cm (99.04) recorded highest plant height at 105 DAT. There was non significant positive correlation (r = 0.276) between plant height at 105 DAT and yield.

The number of tillers per plant varied significantly due to age of the seedlings at different growth stages of the crop growth. The increment in the average number of tillers per plant was remarkably high in the period between 30 DAT (12.86) to 45 DAT (26.57) (106.60%). Among the age of seedlings and different crop geometry the highest number of tillers per plant was obtained from that of 15 days of young seedlings and crop geometry of 25 cm × 25 cm in 15, 30, 45, and 60 DAT. Highest numbers of tiller per plant recorded at 60 DAT (38.11) in 15 days of seedlings and 32.48 in 25 cm × 25 cm causes the higher number of leaves per plant (60 DAT). The higher number of leaves produced high LAI (75 DAT) ultimately the more photosynthesis, more dry matter production (90 DAT) and thus ultimately more yield. This indicates that there was highly significant positive correlation between the maximum tillering stage (60 DAT) and yield (r = 0.948**).

Number of leaves per plant was found significant at 30, 45, 60 and 90 DAT expect 75 and 105 DAT. The observed result showed that average number of leaves per plant increase up to 60 DAT (134.903 cm) and thereafter decreased. Highest numbers of leaves per plant was observed in 15 days of seedlings at 30, 45, 60, 75 and 105 DAT except 90 DAT. Similarly, highest number of leaves per plant was obtained from crop geometry of 25 cm × 25 cm at 30, 45, 60, 75, 90 and 105 DAT in all crop growth stage. There was significant effect of age of seedlings and crop geometry on numbers of leaves at 30 DAT and 75 DAT. At 30 DAT, 15 days seedlings with 25 cm × 25 spacing cm had significantly higher number of leaves per plant as compared with other crop geometry.

The observed result showed that the response of age of seedling and plating pattern on LAI were found significant at 30, 45, 60 and 75, 90 and 105 DAT but non significant at 90 and 105 DAT in case of age of seedling. However, LAI with 15 days seedlings and wider spacing of 25 cm x 25 cm recorded higher LAI at all observed date from 30 DAT and 105DAT. There was significant positive correlation (r = 0.678*) between leaf area index and total dry matter production at 90 DAT.

Significant result was found in dry matter production per plant response to age of seedlings and plating patterns at 60, 75 and 90 DAT but non significant in 30 DAT (age of seedlings) and 45 DAT (planting pattern). The average dry matter production per plant increased from 30 DAT (14.74 gm) to 90 DAT (137.63 gm). Highest dry matter production per plant was obtained from 15 days of young seedlings and 25 cm × 25 cm in 30, 45, 60, 75, 90 DAT as compared to all others. Significantly higher dry matter production under 15 days seedlings at 90 DAT resulted into higher yield attributing characters and yield. There was highly significant positive correlation (r = 0.878) between total dry matter production at 90 DAT and yield (t ha^{-1}).

Significant differences in effective tillers per square meter and numbers of grains per panicle were observed in age of seedling and planting pattern. Per panicle length, per panicle weight, sterility percentage and thousand grain weight were not influenced by both the age of seedling and crop geometry. Comparatively higher effective tiller per square meter (264.9) was observed in 15 days of seedlings and lowest tiller in 29 days of seedlings (217.7). Similarly, highest effective tiller per square meter (266.1) was obtained from that of 25 cm×25 cm which was significantly more than 30 cm × 30 cm (210.6) but at par with 20 cm × 20 cm (263.8). There was significant positive correlation (r = 0.618*) between effective tiller per square meter and yield (t ha^{-1}). Age of seedlings and crop geometry was found highly significant that influence the number of grains per panicle. 15 days of seedlings (157.70) and 25 cm×25 cm (147.50) produced higher number of grains per panicle which was significantly higher than others. There was highly significant positive correlation (r = 0.910**) between grains per panicle and yield (t ha^{-1}).

The grain yield of rice differed significantly with the different age of seedlings (8, 15, 22 and 29) and different crop geometry (20, 25 and 30 cm). 15 days of seedlings yielded highest (6.59 t ha^{-1}) and 29 days seedlings yielded lowest (4.42 t ha^{-1}) and the reduction in grain yield due to 29 days seedlings than 15 days was 32.96% and the reduction was significant. Similarly highest grain yield was obtained from that of 25 cm ×

25 cm (6.04 t ha^{-1}) and lowest in 30 cm × 30 cm (5.37 t ha^{-1}) and 20 and 30 cm crop geometry yield was at par.

Age of seedlings and crop geometry significantly influenced the straw yield. Significantly the highest straw yield was obtained from 15 days of young seedlings, a lowest straw yield of 7.05 t ha^{-1} was obtained from 29 days of seedlings, a straw yield of 5.74 t ha^{-1} which was at par with 22 days of old seedlings (6.01 t ha^{-1}). Similarly higher straw yield was obtained from that of 25 cm × 25 cm (6.58 t ha^{-1}), which was par to 20 cm×20 cm (6.33 t ha^{-1}) in different crop geometry. Significantly higher harvest index was obtained with 8 days of young seedlings (48.53%) and lower harvest index was obtained from 29 days of old seedlings (42.54%). But crop geometry did not influence the harvest index. Similar pattern was observed in grain straw ratio.

Gross return, net return and B:C ratio were found significantly different in 15 days of seedlings and 25 cm × 25 cm crop geometry and found more profitable. Highest B:C ratio (3.80) was recorded in 15 days of seedlings and 25 cm × 25 cm crop geometry (3.50).

CONCLUSIONS

Under the present day constraints of lower production and the results from experiments clearly revealed that younger seedlings transplanted in 15 days old with a plant density of 25 cm × 25 cm with SRI technique resulted into maximum production with good economic returns of rice. Thus the above SRI technique can be extended to a larger rice growing area consisting of small landholding farmers and thereby maximizing total production of rice, ultimately contributing to national food security.

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APPENDICES

Appendix 1. Weekly meteorological data of cropping season (June to November) during 2008 at Shivanagar VDC, Chitwan, Nepal, 2008

Months	**Standard week**	**Temperature ^{0}C**		**Relative humidity**	**Total rainfall**	**Sunshine hours**
		Maximum	Minimum	(%)	(mm)	(Hrs.)
June	01-07	34.31	23.59	63.90	71.43	8.14
	08-14	33.87	25.60	89.00	85.86	4.75
	15-21	32.01	25.13	100.1	87.71	3.60
	22-28	33.31	26.04	44.80	85.57	2.58
	29-30	31.20	25.00	80.80	96.00	0.87
July	01-07	33.56	25.99	72.10	88.57	3.93
	08-14	34.00	25.31	112.6	83.86	5.13
	15-21	32.14	25.60	153.9	90.14	1.50
	22-28	32.97	25.79	84.40	88.14	3.62
	29-31	33.10	26.50	8.40	85.00	2.39
August	01-07	33.37	25.43	142.1	86.86	4.08
	08-14	33.41	26.03	105.5	83.71	4.25
	15-21	32.41	25.74	74.60	88.43	2.54
	22-28	31.21	25.40	104.4	92.71	2.36
	29-31	31.80	24.57	31.30	86.00	3.59
September	01-07	32.96	24.04	94.10	86.71	7.83
	08-14	33.93	25.07	13.10	85.57	7.90
	15-21	33.34	24.86	60.50	83.71	6.51
	22-28	32.69	23.49	33.00	91.00	6.38
	29-30	31.30	23.50	18.00	88.00	4.81
October	01-07	32.20	23.39	56.20	88.57	6.51
	08-14	31.60	21.07	31.10	92.43	7.48
	15-21	31.84	41.74	0.00	85.29	9.36
	22-28	30.27	16.76	0.00	88.86	8.32
	29-31	30.10	17.33	0.00	95.33	7.41
Novermber	01-07	29.89	16.51	0.00	91.43	7.59
	08-14	29.19	14.84	0.00	97.14	7.47
	15-21	27.26	13.76	0.00	97.14	6.44
	22-28	26.33	11.30	0.00	96.29	6.90
	29-30	27.1	9.05	0.00	84.50	7.45

Appendix 2. Details of various cultural operations in the experimental plot of rice under SRI from May to November, 2008 at Shaivanagar VDC., Chitwan

S.N.	Particular operations	Date (D-M-Y)
1.	Nursery bed preparation (4 raised dry bed)	
a.	29 days of seedling	29-05-2008
b.	22 days of seedling	07-06-2008
c.	15 days of seedling	14-06-2008
d.	8 days of seedling	21-06-2008
2.	Soaking of seed	
a.	29 days of seedling	29-05-2008
b.	22 days of seedling	07-06-2008
c.	15 days of seedling	14-06-2008
d.	8 days of seedling	21-06-2008
3.	Seed sowing in nursery bed	
a.	29 days of seedling	31-05-2008
b.	22 days of seedling	05-06-2008
c.	15 days of seedling	12-06-2008
d.	8 days of seedling	19-06-2008
4.	Fertilizer application (50:45:45 kg NPK/ha + FYM)	20-06-2008
5.	Main field preparation	26-06-2008
6.	Transplanting	28-06-2008
7.	Gap filling after 5 days after transplanting	03-07-2008
8.	Weeding (3 times, from 15 DAT with 15 days of interval)	13-07-2008 to 12-08-2008
9.	Irrigation (6 times, 7 days of interval)	12-07-2008 to 17-08- 2008
12.	Nitrogen top-dressing	
a.	First top-dressing (25 kg N/ha)	02-08-2008
b.	Second top-dressing (25 kg N/ha)	17-08-2008
13.	Cypermathrin spraying 25%	25-09-2008
14.	Harvesting	
15.	Threshing, cleaning and weighing	

Appendix 3. General cost of cultivation (Rs. /ha) of irrigated rice under SRI during May-November, 2008 at Shivanagar, Chitwan, Nepal, 2008

S.N.	**Particulars**			**Rice**	
I	**Variable cost**	Unit	Quantity	Rate (Rs.)	Total (Rs.)
A.	**Nursery raising (100 m^2)**				
1.	Cost of seed	kg	7	27	189
2.	Land preparation (3 ploughings) through disc harrow	Min.	5	13	65
3.	Seed bed preparation	Labor	1	150	150
4.	Vermi-compost	Kg	5	20	100
5.	Sanjeewani	Kg	0.2	90	18
6.	Bavistein	gm	20	65	65
7.	Cost of uprooting of seedlings	Labor	1	150	150
B.	**Transplanting field (1 ha)**				
1.	3 Ploughings (planking and puddling with disc harrow)	Hours	3	780	2,340
2.	Bund making and digging	Labor	5	200	1,000
3.	Fertilizer @ 100:45:45 NPK kg/ha				
	Urea	Kg	179.12	23	4,120
	DAP	Kg	97.83	42	4,109
	MOP	Kg	75.00	24	1,800
	FYM	tonne	6	1000	6,000
4.	Sanjeewani	Kg	20	85	1,700
5.	Application of fertilizer	Labor	1	150	150
6.	Hand weeding (3 times)	labor	90	150	13,500
7	Transplanting of seedling	Labor	30	150	4,500
8.	Irrigation	month	3	1,050/ha/yr	263
9.	Labor for irrigation	Labor	2	150	300
10.	Cypermathine	ml	100	100	100
11.	Spraying of cypermathine	Labor	1	150	150
12.	Harvesting	Labor	30	150	4,500
13	Threshing	Labor	10	150	1,500
14.	Cleaning, drying and storage	Labor	7	150	1,050
	Sub Total				**41,819**
II	**Interest on variable cost@ 12% for 6 months**				2,509
III	**Fixed cost (government tax)**	month	6	500/ha/yr	250
	Grand total				**44,578**

Appendix 4. Rating chart of soil values to determine the fertility of experimental soil

Nutrients	Low	Medium	High
Available 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
pH	<6.0 (Acidic)	6.0-7.5 (Neutral)	>7.5 (Alkaline)

Source: (Khattri Chettri, 1991 and Jaishy, 2000)

ANALYSIS OF VARIANCE OF RICE DATA UNDER SRI

Appendix 5. Mean squares from ANOVA of plant height (cm) as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	**df ¶**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**
Replication	2	3.477	0.309	11.630	16.436	33.923	22.766
Factor A	3	34.380	35.730	21.509	31.928	28.762	55.145
Factor B	2	4.613	5.112	2.983	7.018	45.663	55.430
AB	6	12.119	11.321	11.667	12.996	16.864	10.183
Error	22	12.964	14.437	32.848	22.034	33.692	25.544

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 6. Mean squares from ANOVA of tillers per plant as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	df ¶	15 DAT	30 DAT	45 DAT	60 DAT
Replication	2	0.083	11.714	4.488	47.481
Factor A	3	13.237**	55.734**	320.988**	359.456**
Factor B	2	1.563**	38.048*	52.674**	58.481**
AB	6	0.150	4.674	2.101	8.093
Error	22	0.115	9.841	4.704	8.987

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 7. Mean squares from ANOVA of number of leaves per plant as influenced by different age of seedlings with respect to crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	df ¶	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT
Replication	2	5.778	293.396	29.694	613.799	147.438	5.778
Factor A	3	2122.870**	2690.315**	64.988*	615.093	221.951*	51.167
Factor B	2	144.882**	231.438*	237.694**	231.465	1398.813**	363.799*
AB	6	61.002**	15.558	20.093	859.947*	139.701	107.826
Error	22	11.444	45.979	20.619	204.685	61.119	261.278

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 8. Mean squares from ANOVA of leaves area index (LAI) of rice as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	**df ¶**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**
Replication	2	0.010	0.008	0.012	0.230	0.460	0.222
Factor A	3	0.702*	0.580*	0.926*	1.250**	0.167	0.059
Factor B	2	3.193**	2.666**	4.217**	6.425**	6.039**	1.305**
AB	6	0.114	0.095	0.150	1.166**	1.011**	0.055
Error	22	0.150	0.124	0.198	0.077	0.168	0.079

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 9. Mean squares from ANOVA of dry matter production per plant (g) as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	**df ¶**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
Replication	2	13.703	0.989	206.512	255.475	1108.636
Factor A	3	8.538	92.390*	519.824**	443.864*	8076.177**
Factor B	2	62.239**	50.476	573.072**	770.118*	1433.294**
AB	6	1.669	2.669	125.746	16.762	316.282
Error	22	4.356	27.722	78.087	143.532	218.252

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 10. Mean squares from ANOVA of yield attributes as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	**df ¶**	**Effective tillers m^{-2}**	**Per panicle length (cm)**	**Per panicle weight (gm**	**No. of grains Per panicle**	**Sterility percentage**	**1000 grain weight (gm)**
Replication	2	202.370	1.091	0.516	622.452	37.889	3.394
Factor A	3	4162.491*	1.912	0.204	2819.879**	1.152	1.548
Factor B	2	11833.240**	2.514*	0.018	1399.652**	22.016	0.740
AB	6	2024.668*	0.739	0.090	208.262	20.274	0.207
Error	22	772.938	0.676	0.145	145.506	10.492	0.934

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 11. Mean squares from ANOVA of grain yield, straw yield, harvest index and grain straw ratio as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	**df ¶**	**Grain yield**	**Straw yield**	**Harvest index**	**Grain straw ratio**
Replication	2	0.795	0.265	19.203	0.022
Factor A	3	7.794**	2.942**	74.840**	0.080**
Factor B	2	1.443**	0.972*	7.569	0.007
AB	6	0.251	0.142	15.615*	0.018
Error	22	0.226	0.268	5.906	0.008

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 12. Mean squares from ANOVA of gross return, net return and B:C ratio as influenced by different age of seedlings with respect to different crop geometry under SRI at Shivanagar VDC, Chitwan, 2008

Source	**df ¶**	**Gross return Rs./ha ('000)**	**Net profit Rs./ha('000)**	**B C ratio**
Replication	2	354.763	354.763	0.179
Factor A	3	4493.456**	4493.456**	2.258**
Factor B	2	885.621**	885.622**	0.447**
AB	6	119.065	119.065	0.060
Error	22	118.282	118.282	0.060

¶ Degree of freedom; * Significance at 0.05 level of significance; ** Significance at 0.01 level of significance; FA, age of seedling; FB, spacing

Appendix 13. Interaction effects of age of seedlings and crop geometry on number of leaves per plant at 30 and 75 days after transplanting (DAT) of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Crop geometry**					
Age of seedlings	Leaves per plant at 30 DAT			Leaves per plant at 75 DAT		
	20 cm × 20 cm	25 cm × 25 cm	30 cm × 30 cm	20 cm × 20 cm	25 cm × 25 cm	30 cm × 30 cm
8 days seedlings	48.00^{de}	53.33^{d}	44.17^{ef}	133.7^{abc}	107.7^{cd}	133.Z^{abc}
15 days seedlings	66.33^{b}	75.67^{a}	59.67^{c}	143.0^{ab}	148.2^{a}	111.2^{cd}
22 days seedlings	42.50^{efg}	36.67^{gh}	41.50^{fg}	102.0^{d}	133.2^{abc}	123.7^{abcd}
29 days seedlings	31.83^{hi}	34.50^{h}	27.17^{i}	116.7^{bcd}	121.2^{abcd}	106.7^{cd}

Appendix 14. Interaction effects of age of seedlings and crop geometry on leaf area index (LAI) at 75 and 90 days after transplanting (DAT) of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Crop geometry**					
Age of seedlings	Leaf area index (LAI) at75 DAT			Leaf area index (LAI) at 90 DAT		
	20 cm × 20 cm	25 cm × 25 cm	30 cm × 30 cm	20 cm × 20 cm	25 cm × 25 cm	30 cm × 30 cm
8 days seedlings	2.573^{bc}	2.347^{bcd}	1.573^{ef}	1.870^{cd}	2.690^{b}	1.437^{de}
15 days seedlings	2.747^{b}	4.327^{a}	1.213^{f}	1.860^{cd}	3.497^{a}	1.073^{e}
22 days seedlings	2.023^{de}	2.323^{bcd}	1.423^{f}	2.380^{bc}	2.277^{bc}	1.177^{de}
29 days seedlings	2.623^{bc}	2.133^{cd}	1.370^{f}	2.650^{b}	1.747^{cde}	1.047^{e}

Appendix 15. Interaction effects of age of seedlings and crop geometry on effective tillers per square meter and harvest index of rice under SRI at Shivanagar VDC, Chitwan, 2008

Treatments	**Crop geometry**					
Age of seedlings	Effective tillers per square meter			Harvest index (HI)		
	20 cm × 20 cm	25 cm × 25 cm	30 cm × 30 cm	20 cm × 20 cm	25 cm × 25 cm	30 cm × 30 cm
8 days seedlings	290.0^{ab}	294.4^{a}	198.5^{c}	48.29^{a}	49.03^{a}	48.27^{a}
15 days seedlings	276.7^{ab}	278.1^{ab}	240.0^{bc}	49.51^{a}	48.12^{a}	47.86^{a}
22 days seedlings	286.7^{ab}	241.1^{abc}	203.0^{c}	46.48^{a}	46.78^{a}	49.98^{a}
29 days seedlings	201.7^{c}	250.7^{abc}	200.7^{c}	40.05^{b}	46.74^{a}	40.82^{b}

Appendix 16. Correlation coefficient among growth characters, yield attributing characters and yield of rice 2008

	MT	NL@60	LAI@60	LAI@75	LAI@90	DM@75	DM@90	ET	PL	PW	GPP	SP	TGW	YD
PH@105	0.271	0.160	-0.152	-0.259	-0.395	0.016	0.291	0.012	0.156	0.223	0.230	0.512	0.276	0.292
MT		0.670(*)	0.678(*)	0.598(*)	0.457	0.821(**)	0.962(**)	0.599(*)	0.756(**)	0.729(**)	0.954(**)	-0.394	0.770(**)	0.948(**)
NL@60			0.733(**)	0.755(**)	0.666(*)	0.757(**)	0.696(*)	0.496	0.863(**)	0.427	0.763(**)	-0.551	0.516	0.656(*)
LAI@60				0.836(**)	0.846(**)	0.964(**)	0.689(*)	0.832(**)	0.772(**)	0.380	0.741(**)	-0.538	0.635(*)	0.583(*)
LAI@75					0.876(**)	0.761(**)	0.678(*)	0.530	0.860(**)	0.419	0.649(*)	-0.596(*)	0.439	0.455
LAI@90						0.730(**)	0.475	0.526	0.668(*)	0.253	0.550	-0.604(*)	0.247	0.332
DM@75							0.809(**)	0.834(**)	0.783(**)	0.479	0.853(**)	-0.479	0.767(**)	0.743(**)
DM@90								0.570	0.835(**)	0.682(*)	0.899(**)	-0.319	0.710(**)	0.878(**)
ET									0.591(*)	0.406	0.643(*)	-0.441	0.595(*)	0.618(*)
PL										0.446	0.812(**)	-0.488	0.529	0.662(*)
PW											0.679(*)	-0.380	0.572	0.780(**)
GPP												-0.459	0.738(**)	0.910(**)
SP													-0.249	-0.481
TGW														0.714(**)

*Significant at the 0.05 level (2-tailed); **significant at the 0.01 level (2-tailed); PH@105, plant height; MT, maximum tillering stage per hill; NL@60, Number of Leaves per plant at 60 DAT; LAI@60, Leaf Area Index at 60 DAT; LAI@75, Leaf Area Index at 75 DAT; LAI@90, Leaf Area Index at 90 DAT; DM@75, Total Dry matter production at 75 DAT; DM@90, Total Dry Matter production at 90 DAT; ET, Effective Tiller; PL, Panicle Length; PW, Panicle Weight; GPP, Grain Per Panicle; SP, Sterility Percentage; TGW, Thousand Grain Weight; YD, Yield (t ha^{-1}).

BIOGRAPHICAL SKETCH

Mr. Keshav Bahadur Karki, was born on 26th July 1979 in Dullu-9, Dailekh as eldest son of Mrs. Kastura Devi and Mr. Junga Bahadur Karki. His school education was completed in 1995 from Dipendra Police School, Sanga, Kavre. He joined Institute of Agriculture and Animal Science in Paklihawa, Bhairawa, Rupendhi and completed the intermediate level in agriculture science in the year 1998. Then he joined Institute of Agriculture and Animal Science, Rampur, Chitwan and completed a Bachelor's degree of Agriculture with a major in Extension Education in 2003. After his graduation he worked on BDS-MaPS project at the designation of "Agri-Enterprise Officer," funded by USAID. Then he enrolled in a Post-Graduate Program for a Master of Science degree in Agriculture at the same university in 2007 with a major in Agronomy.