EFFECT OF WEED CONTROL METHODS ON RICE CULTIVARS UNDER THE SYSTEM OF RICE INTENSIFICATION (SRI)

SHARAD PANDEY

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THESIS
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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF WEED CONTROL METHODS ON RICE CULTIVARS UNDER THE SYSTEM OF RICE INTENSIFICATION (SRI)"** submitted in the partial fulfillment for the Master of Science in Agriculture with major in **AGRONOMY** of Postgraduate Program. Institute of Agriculture and Animal Science, Rampur, is a record of original research carried out by **Mr. SHARAD PANDEY**, Id. No. **R-2007-AGR-04-M**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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

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The thesis attached hereto, entitled **“EFFECT OF WEED CONTROL METHODS ON RICE CULTIVARS UNDER THE SYSTEM OF RICE INTENSIFICATION (SRI)”** prepared and submitted by **Mr. SHARAD PANDEY,** in partial fulfillment of the requirements for the degree of Master of Science in Agriculture (Agronomy), is here by accepted.

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Sharad Pandey

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ACRONYMS

%	Percent
@	At the rate of
^0C	Degree Celsius
ANOVA	Analysis of variance
B:C	Benefit cost ratio
CBS	Central Bureau of Statistics
CD	Critical difference
cm	Centimeter
CV	Coefficient of variance
DADO	District Agriculture Development Office
DAP	Di-ammonium phosphate
DAT	Days after transplanting
DMRT	Duncan's multiple range test
FAO	Food and Agriculture Organization
FYM	Farm yard manure
GDP	Gross domestic product
gm	Gram
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
LSD	Least significance difference
m	Meter
MOAC	Ministry of Agriculture and Co-operatives
NARC	Nepal Agriculture Research Council
NMRP	National Maize Research Program
No.	Number
NPK	Nitrogen, phosphorus and potash
NRRP	National Rice Research Program
NS	Non-significant
P	Probability
r	Correlation
R^2	Coefficient of determination
RCBD	Randomized complete block design
RH	Relative humidity
RSTL	Regional Soil Testing Laboratory
SEm (±)	Standard error of mean
SRI	System of rice intensification
t ha^{-1}	Tonne per hectare
TGW	Thousand grain weight
$ZnSO_4$	Zinc sulphate

ABSTRACT

Name: Sharad Pandey
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A field experiment was conducted to study the effect of weed control methods on rice cultivars under the system of rice intensification (SRI) at a farmer's field, Shivanagar-3, Chitwan, Nepal during rainy season of 2008. The experiment was laid out in two factorial randomized complete block designs (RCBD) with three replications. First factor had eight weed control method [Unweeded check; one hand weeding at 21 DAT; two hand weedings at 21 and 42 DAT; chemical weed control (Pyrazosulfuron-ethyl @ 0.015 a. i. kg/ha); chemical weeding supplemented with one hand weeding at 21 DAT; one soil-aerating weeding at 14 DAT; two soil-aerating weedings at 14 and 28 DAT; and three soil-aerating weedings at 14, 28 and 42 DAT] and second factor had two rice variety (Ram and Sabitri) having sixteen treatment combinations. It was evident that among weed control treatments, three soil-aerating weedings at 14, 28 and 42 DAT was best for controlling weeds which contributed to the highest plant height and also higher number of tillers per plant and moderately higher leaf area index. Similarly, three soil-aerating weedings at 14, 28 and 42 DAT produced significantly higher number of effective tillers per square meter (282.67), panicle weight (3.92 gm), number of grains per panicle (184.54), lower sterility (7.36%), and higher grain yield (6.53 t ha^{-1}). Ram produced significantly higher grain yield (5.19 t ha^{-1}) due to significantly higher number of effective tillers per square meter (265.25), comparatively moderate number of grains per panicle (167.68), and significantly lower sterility (8.33%). There was significantly higher benefit-cost ratio with three soil-aerating weedings at 14, 28 and 42 DAT planting variety Ram and can be used most beneficially

for rice production under the system of rice intensification (SRI) practices where there are assured facilities of irrigation and drainage.

Narendra Kumar Chaudhary	Sharad Pandey
Major Advisor	Author

शोध-सार

नामः शरद पाण्डे
सत्र तथा भर्ना वर्षः प्रथम, २०६४
मुख्य विषयः बाली विज्ञान
मुख्य सल्लाहकारः नरेन्द्र कुमार चौधरी

दर्ता नं.: आर-२००७-एजीआर-०४-एम
उपाधिः कृषि स्नातकोत्तर
विभागः बाली विज्ञान

एस. आर. आई. प्रणालीमा झारपातको नियन्त्रण र जातहरुले पार्ने प्रभाव अध्ययनका लागी किसानको खेत, शिवनगर-३, चितवनमा २०६५ सालको बर्षे मौसममा अनुसन्धान गरिएको थियो । उक्त अनुसन्धानमा २ वटा तत्वलाई फ्याक्टोरीयल रेन्डोमाईज्ड कम्प्लिट ब्लक डिजाईन प्रयोग गरि तेहेऱ्याईएको थियो । उक्त परिक्षणमा ८ वटा झारपात नियन्त्रण गर्ने तरीकाहरु [झारपात नगोड्ने, बेर्ना सारेको २१ दिनपछि एकपटक हातले झारपात गोड्ने, बेर्ना सारेको २१ र ४२ दिनपछि २ पटक हातले गोडमेल गर्ने, रासायनीक तरीकाले झारपात गोडमेल (पाईराजोसल्फुरोन-ईथायल @ ०.०१५ प्रभावकारी तत्व कि.ग्रा. प्रति हेक्टर) गर्ने, रासायनीक तरिका साथ साथै वेर्ना सारेको २१ दिन पछि एक पटक हातले झारपात गोडमेल गर्ने, वेर्ना सारेको १४ दिन पछि एक पटक माटोमा हावा खेल्ने गरि गोडमेल गर्ने, वेर्ना सारेको १४ र २८ दिन पछि २ पटक माटोमा हावा खेल्ने गरि गोडमेल गर्ने, वेर्ना सारेको १४, २८ र ४२ दिनमा ३ पटक माटोमा हावा खेल्ने गरि गोडमेल गर्ने] र धानका २ जातहरु (राम र सावित्री) समावेश गरिएको थियो । यस अध्ययनको नतिजा अनुसार झारपात नियन्त्रण गर्न वेर्ना सारेको १४, २८ र ४२ दिनमा ३ पटक माटोमा हावा खेल्ने गरि गोडमेल गर्नु सवैभन्दा उत्तम पाइयो जसबाट वोटको उचाइ, प्रति बोट सराको संख्या र पात क्षेत्रफल सुचांक सवैभन्दा वढी पाइयो । तथ्याङ्कीय दृष्टिकोणले तिन पटक माटोमा हावा खेल्ने गरि गोडमेल गर्दा प्रति वर्ग मिटर प्रभावकारी सरा(२८२.६७), वालाको तौल (३.९२ ग्रा.), प्रति वालामा दानाको संख्या (१८४.५४), न्यून बाझोपन प्रतिशत (७.३६) र बढी धान उत्पादन (६.५३ टन प्रति हेक्टर) पाइयो । जातहरु मध्ये राम जातको धानले वढी उत्पादन (५.१९ टन प्रति हेक्टर) दियो । जसमा तथ्याङ्कीय आधारले प्रभावकारी सरा प्रति वर्ग मिटर (२६५.२५), मध्यम दाना संख्या (१६७.६८) प्रति वाला र कम वाझोपन प्रतिशत (८.३३) पाइयो । कुल आम्दानी, खुद नाफा र फाइदा लगानी अनुपात पनि तथ्याङ्कीय हिसावले प्रभावकारी देखियो । यसर्थ, वेर्ना सारेको १४, २८ र ४२ दिनमा ३

पटक माटोमा हावा खेल्ने गरि गोडमेल गरि झारपातको नियन्त्रण गर्ने तरिका र राम जातको धानलाइ सिचाई तथा निकाशको राम्रो व्यवस्था मिलाएर एस. आर. आई. प्रणालीबाट धान खेती गर्दा सवैभन्दा उत्तम हुन्छ।

नरेन्द्र कुमार चौधरी
मुख्य सल्लाहकार

शरद पाण्डे
लेखक

1 INTRODUCTION

Rice (*Oryza sativa* L. var. *Indica*) is the most important cereal crops in agriculture and economy of Nepal. It is grown in about 1.55 million ha of cultivable land producing 4.30 million tonnes of rice with an average productivity of 2.78 t ha^{-1}. The crop is grown in all major agro-ecological regions of Nepal i.e. Terai and Inner-Terai, Hills and Mountains that include approximately 71%, 24.9% and 4.1% respectively of the total rice production area in the country (MOAC, 2007/08). It shares 20% to the agricultural gross domestic product (AGDP) and accounts 53% of the total food grain production and covers more than 50% of the agricultural production area. It meets more than 50% of the total calories requirement of the Nepalese people (NARC, 2007). The main diet of the Nepalese people is rice. Rice is cultivated in the diverse eco-climatic ranges of Nepal at differing altitudes, topography and climate in flooded, deep water, waterlogged land, drought, problematic soil and with weed infestation, disease and pests (Basnet, 2000). Therefore, rice is the main crop of Nepal.

The food grain production of the country is deficit by 0.17 million tonnes as compared to her requirement for the fiscal year 2006/07 (NARC, 2007). Rice is said to be on the front line to fight against the world's hunger and poverty. Increasing rice production can solve this food-deficit problem and save millions of rupees now spent by the Government every year on bringing grains into food-deficit areas. The performance of SRI raises the hope among policy makers, development workers and farmers for solving this national problem and to enhance food security in remote areas where modern inputs are costly and difficult to obtain.

Father Henri de Laulanie first synthesized the elements of the system of rice intensification (SRI) in 1983-84. The main elements of SRI are: (1) early transplanting of young seedlings, 8-12 days old, (2) transplanting single seedlings with wide spacing, 25x25 cm^2 or more depending upon soil fertility status, (3) mechanical weeding with a rotary push weeder that aerates the soil as well as it controls weeds, (4) water management in such a way that there is no continuously standing water during the vegetative growth phase, and (5) reliance on compost as far as possible, with supplemental or no use of chemical fertilizer. Proponents of SRI have reported that these practices appear to work synergistically for higher yield than conventional rice production systems (ATS, 1992; Randriamiharisoa and Uphoff, 2002).

Thousands of farmers in Madagascar have been benefited from SRI techniques since then, with at least doubled rice yield only by changing certain common practices (Laulanié, 1993). It is reported that where initial production is low, with effective use of SRI practices, 50-300% yield increase is possible (Uphoff *et al.*, 2002).The ability of these practices to achieve more productive phenotypes from most rice genotypes, in a wide variety of circumstances, has now been documented in countries like Bangladesh, Bhutan, China, Cuba, Gambia, India, Indonesia, Iraq, Iran, Myanmar, Nepal, and Vietnam (Husain *et al*., 2004; Sinha and Talati, 2005; Ceesay *et al.*, 2007; Kabir and Uphoff, 2007; Sato and Uphoff, 2007; Satyanarayana *et al*., 2007; Uphoff, 2007). SRI claims to capitalize on previously immobilized capacities for productive root growth and tillering by providing a more favorable environment for rice plants to manifest such potential, although this system remains controversial in some quarters (Sheehy *et al*., 2004; McDonald *et al*., 2006).

Weeds are at present the major biotic constraint to increased rice production worldwide. The importance of their control has been emphasized in the past by various authors (De Datta and Baltazar, 1996; Labrada, 1996; Zhang, 1996). Weed infestation is regarded as one of the major causes of low crop yields throughout the world and can cause 50-60% reduction in grain yield under puddled conditions and 91% yield reduction in non-puddled conditions (Ali and Sankaran, 1984). Similarly, yield loss due to uncontrolled weed growth in transplanted rice has been calculated as 17-47% and 14-93% in upland rice (Rangit, 1999). In Nepal, 70-80% yield loss in upland conditions and 20-40% yield loss in lowland conditions was reported by Upadhyaya (1998). Season-long weediness depleted 35 N, 15 P_2O_5 and 45 K_2O kg/ha from the soil while the rice crop under a weed-free environment up to maturity removed 60, 26 and 80 kg/ha N, P_2O_5 and K_2O, respectively (Singh *et al*., 1999).

When rice fields are not flooded continuously and plants are widely spaced as recommended under SRI, weeds get a better chance to grow. Therefore, more weeding is required with SRI management. The higher amount of labor for weeding is one of the most criticized aspects of SRI. So, effort must be made to eliminate weeds and minimize their competition with rice plants by using less labour for effective weed control methods. With SRI, the amount of labor required makes manual weeding twice as expensive as in conventional rice production, and if farmers use hired labour, they are often careless when removing weed and often leave the roots of the weed in the soil, so that weed emerge again within a few days. This creates problems for the crop and makes weed management expensive. Weed control helps to enhance the production environment, thereby allowing more of the inherent capacity of the plant to express itself in higher yields than otherwise would not occur. Therefore, it is essential to control weeds in rice fields for the greater utilization of growth factors by the crop to get higher yield

One way to reduce weeding efforts is by transplanting in rows which allows the use of simple tools for weeding like rotator weeder which on one hand control weeds and one the other hand this also increase soil aeration, which is an important aspect in SRI management. Weeding is necessary with SRI and can actively enhance yield through soil aeration which stimulates root growth and soil biological activity. The issue of weeding is always important because it entails costs as well as benefit and which requires proper study for optimum number of weeding required.

There are at least three main kinds of weeding: (1) manual weed control, (2) chemical weed control using herbicides, and (c) mechanical weed control using the rotating hoe. Tefy Saina (1992) advises using mechanical weed control "early and often." This means starting 10-12 days after transplanting with a first weeding, and then at every 10-12 days interval until the canopy has closed enough so that further weeding becomes difficult and plants shade out further weed growth. By using a mechanical hand weeder (rotary hoe), the cost of weeding can be reduced to less than under conventional methods, even when doing three weedings instead of just one.

Viewing these facts, a field experiment was conducted at a farmer's field at Shivanagar-3, Chitwan during the rainy season of 2008 to study the "Effect of weed control methods on rice cultivars under the system of rice intensification (SRI)" with the following objectives:

1. To evaluate the effectiveness of different weed control method on growth and development of rice under system of rice intensification (SRI) practices.
2. To explore the cost-effectiveness of weed control method for SRI practices.
3. To identify the suitability of rice cultivars with SRI practices under Chitwan condition.

2 LITERATURE REVIEW

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

In 1983 after two decades of experimenting Fr. Henri de Laulaníe, a Jesuit priest in Madagascar, synthesized the “système de riziculture intensive” (French) and “system of rice intensification” (English). Under the pressures from a drought and shortages of rice seeds, he started to experiment at his agricultural school near Antsirabe (1500 m elevation). The experiments initially focused on transplanting very young rice seedlings of just 10-15 days old in a fairly wide spacing (25x25 cm^2) of single seedlings. A square planting pattern was used to facilitate mechanized weeding. The rice was not grown in flooded paddies, but in moist soil, with intermittent irrigation. Under such conditions Laulaníe observed tremendous increases in tillering and rooting as well as number of panicles and panicle sizes, contributing to spectacular grain yields.

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

2.2 System of Rice Intensification

(Laulanié, 1993a; Laulanié, 1993b; Uphoff, 2001; Stoop *et al*., 2002; Uphoff *et al*., 2002; Stoop, 2003; Uphoff, 2003; Horie *et al*., 2005) described the system of rice intensification and suggested that SRI represents an integrated and agro-ecologically sound approach to irrigated rice (*Oryza sativa* L. var. *Indica*) cultivation, which may offer new opportunities for location-specific production systems of small farmers.SRI is a designer innovation that efficiently uses scarce land, labour, capital and water resources, protects soil and groundwater from chemical pollution, and is more accessible to poor farmers than input-dependent technologies that require capital and logistical support (Uphoff, 2004). SRI methods can lead to superior phenotypes and agronomic performance for a diverse range of rice genotypes (Tao *et al.*, 2002; Lin *et al*., 2005, Lin *et al*., 2006).

2.3 Principles of system of rice intensification (SRI)

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

2.3.1 Transplanting of single seedling per hill

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

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

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

Transplanting rice seedlings at a younger stage has been supported by many researchers (Ota, 1975; Yamamoto *et al*., 1995; Horie *et al*., 2005). This practice captures the benefit of the early phyllochron stages (less than four leaves) having higher potential to produce more tillers per plant (Katayama, 1951).

SRI methods give highest yield when young seedlings are transplanted, less than 15 days old and preferably only 8–12 days, i.e., before the start of the fourth phyllochron (Stoop *et al*. 2002). This preserves plants' potential for tillering and root growth that is compromised by later transplanting (Uphoff, 2001; Randriamiharisoa and Uphoff, 2002; Horie *et al*., 2005).

In general, uprooting causes stress to the seedling which could be minimized when the endosperm remains attached (Sakai and Yosida, 1957; Ota, 1975; Hoshikawa *et al*., 1998). In conventional management, it has been reported that around 40-60% of the roots remain in the soil during pulling up from the nursery. Pruning up to 60% of the root during transplanting significantly decreased subsequent root and shoot dry matter accumulation (Ros *et al*., 1998).Therefore, it may be suggested that SRI practices lead to increased shoot and root dry matter accumulation by protecting root system during transplanting.

2.3.3 Transplanting of seedlings into a muddy field

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

Seedlings are transplanted into a muddy field rather than flooded with standing water. During the vegetative growth phase, paddy soil is kept moist but never continuously saturated because flooding creates hypoxic soil conditions that cause rice roots to degenerate. Under continuous flooding, up to three-fourths of roots degrade by the flowering stage (Kar *et al.*, 1974). The SRI recommends maintaining 1–3 cm of standing water on the field after panicle initiation

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

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

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

Long duration varieties perform better with wider spacing than short duration varieties (Baloch *et al*., 2002). This is in agreement with the recent findings of Stoop (2005) who suggested that long-duration varieties will perform better under SRI management.

2.3.5 Intermittent irrigation during vegetative growth stage

It was reported that 25-50% water could be saved by intermitted irrigation without any adverse effect on rice yield (Ramamoorhy *et al*., 1993; Tajima, 1995). Growth is not harmed when plants are exposed to limited water condition during their vegetative stage (Boonjung and Fukai, 1996). Plant adopts osmotic adjustment at the vegetative stage which contributes the mostly noticeable mechanism of dehydration tolerance in the rice plant (Steponkus *et al*., 1980). But, any drought stress at later stages in plants which are not exposed to such drying treatment can cause great loss especially when plants are in the early reproductive phase (Kobata and Takami, 1981). Thus intermittent drying in the vegetative stage may not only induce root growth into deeper soil layers but could also help the plant to develop xenomorphic characteristics. Intermittent drying also improves soil, stimulates tiller development and alters sink-source relationships.

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

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

Numerous studies conducted on the manipulation of depth and interval of irrigation, to save on water use without any yield loss, have demonstrated that continuous submergence is not essential for obtaining high yields (Guerra *et al.*, 1998). Impounding of 2.5 cm of irrigation water, irrigation after formation of hairline cracks showed considerable water saving besides better root environment in SRI (Thiagarajan *et al.*, 2002). Rice plants grown conventionally but under well-drained soil conditions can give a yield 5-10% higher than if flooded, and sometimes more (Ramasamy *et al.*, 1997; Lin *et al.*, 2005).

There is an evident to indicate that intermittent irrigation may increase root mass during vegetative stages (Baba, 1997) and stimulates more root activity, and hence more cytokinin content. This favorable condition can be achieved by maintaining higher rates of cytokinin production at a later growth stage, first by following intermittent irrigation during the vegetative stage and then by maintaining shallow flooding during the reproductive phase.

2.3.6 Addition of organic manure instead of chemical fertilizer

The incorporation of organic manure into the soil can bring beneficial effects to root growth by improving the physical, chemical and biological environments in which root grow (Sidiras *et al.*, 2001; Yang *et al.*, 2004). Under continuous water logging condition, there is significant decrease in root growth (Sahrawat, 2000), whereas under intermittent irrigation, the incorporation of organic matter improves root morphological characteristics and root activity of rice plant. It has the effect of increasing root density, active absorption area, root oxidation ability and nutrient uptake (Yang *et al*., 2004).

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

2.3.7 Manual or mechanical weed control without herbicidal use

To control weeds, use of a mechanical weeder is recommended, starting after 10 days after transplanting, with additional weedings every 10–12 days until the canopy closed. One or two weedings is usually sufficient to control most weeds Soil aeration appears to stimulate the growth of aerobic bacteria and fungi and associated organisms in the soil food web. Planting in a square pattern allows farmers to weed in perpendicular directions, which achieves more and better soil aeration. These practices are all known to have positive effects on yield (Horie *et al*., 2005). However, additional weedings are seen to boost yield by 0.5–1.0 tonnes.

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

There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by two to three fold compared to current yield levels (Abu, 2002; Uphoff, 2005). Husain *et al*. (2004) document a 30% yield advantage for SRI in Bangladesh and Namara *et al*. (2003) show an even larger benefit (44%) in Sri Lanka.

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

2.5 The relation of SRI and extensive root system of rice

SRI produces vigorous plants with larger root systems (Doberman, 2004; Stoop, 2005). The main compound which influences plant growth and development through root activity was cytokinin (Richmond and Lang, 1957). The phytohormone that is mainly synthesized in the roots is cytokinin which has a significant effect on tiller bud formation (John *et al*., 1993; Bangerth *et al*., 2000). It mobilizes plant nutrients (Li *et al*., 1992), delays leaf senescence, regulates chloroplast development, and determines sink-source relationships (Hutchinson and Kietber, 2002). High efficient photosynthetic performance of super high-yielding rice cultivars is largely due to the increased cytokinin content in their roots (Shu-Qing *et al*., 2004) contributing to higher grain yield. Root quantity and cytokinin content are enhanced in the rice plant at later growth stages. This results in increased grain yield per plant due to enhanced physiological efficiency of the plant (San-oh *et al*., 2006). In general, root activity and root quantity (Lee, 1980; Jiang *et al*., 1985) responsible for increasing the physiological efficiency of rice plants.

2.6 The weed flora in the field of rice

The dominant weeds under puddle conditions were *Echinochloa cursgallli*, *Cyperus deformis*, *Eclipta prostrate*, *Ammannis balifera* and *Marsilea quadrifoli*a whereas *Echinochloa colona*, *Cyperus iria*, *Eclipta prostrate* were dominant under non-puddled condition (Ali and Sankaran, 1984).

2.7 The effect of weed on yield of rice

Weeds are at present the major biotic constraint to increased rice production worldwide. The importance of their control has been emphasized in the past by various authors (De Datta and Baltazar, 1996; Labrada, 1996; Zhang, 1996).

The occurrence of weeds has become a serious problem and they limit the yield and quality of crops. It is often stated that some weeds cause total crop failure and that weeding practices are absolutely essential (De Datta and Haque, 1982). Unchecked weed compete with rice plants for light, nutrients and moisture resulting reduction of grain yield up-to 80 % (Sinha Babu *et al*. 1992; Behera and Jha, 1992).

Estimation of yield losses caused by competition from weeds ranges from 30-100% (Dobermann and Fairhurst, 2000). Yield loss in rice crop due to weed range from 10-50 % (Singh and Singh, 1993). Unchecked weed growth caused 53% reduction in grain yield in puddled conditions, and 91% yield reduction in non-puddled conditions (Ali and Sankaran, 1984). In lowland or puddled conditions, broad-leafed weed are the main problem. Maximum grain yield (64 q/ha) was obtained in weed-free plots and minimum (35 q/ha) in weedy plots. Weed-free condition at early stage of growth was found more important than at later stages for getting higher yield of rice (Thapa and Jha, 1999). The loss in grain yield caused by weeds varies from 30-50% (Singh *et al.*, 1991; Brar *et al.*, 1995). The yield loss occurs 25-30% due to unchecked weed growth (Upadhyay and Gogoi, 1993) in transplanted rice.

2.8 The effect of manual weeding on yield of rice

The first weeding operation is done 3-4 weeks after transplanting and need 25-34 labors/ha depending on the weed density. The second weeding is generally done 15-30 days after first weeding and usually required 12-15 labors/ha. The second weeding operation is needed to pull out the weeds, which escaped the first weeding (Moddy, 1998).

The hand removal of early emerged grassy weeds and sedges along with the broad leaved species allowed lower accumulation of dry matter and these resulted in better crop growth which in turn smothered the weed growth in comparison to others treatment. These resulted in maximum weed control efficiency under other treatments (Gogoi, 1998). Increasing the frequency of hand weeding from one to two doubled the yield and also reported weed free period between 0 to 49 days after transplanting resulted in highest yield for transplanted rice (Ahmed, 1982).

Hand weeding is the most common and effective methods of weed control in rice but it is being difficult and uneconomical day-by-day due to high wages and non-availability of labours at peak period of farm operation (Singh *et al*., 1999). A large portion of the total labor is required for hand weeding, however, hand weeding is common in areas where labor is easily available and costs are low. Otherwise, chemical weed control is recommended (Silveira Filho and de Aquino, 1983). Hand weeding is generally not a very efficient method. Probably 10-20% or more of the plants with 10 cm or more growth is left in the field after weeding. On an average the efficiency of this method is not more than 70% (Moody, 1998).

2.9 The mode of action of sulfonylurea herbicide

Pyrazosulfuron ethyl is a new highly active sulfonylurea herbicide that has been widely used for weed control in a variety of crops and vegetables. The sulfonylurea herbicides are highly active herbicides that have been in commercial use since 1982. The mode of action of the sulfonylurea (Chaleff, 1984; LaRossa, 1984) herbicides is the inhibition of acetolactate synthase (ALS). ALS a key enzyme required in the biosynthesis of essential amino acids, valine and isoleucine, in plants. This results in rapid inhibition of plant cell division and growth, although the symptoms of drying weeds may not appear till 7-20 days after application (Gupta, 1998).

Because of the high herbicidal activity of sulfonylureas, they are effective at low dose of application (Hay, 1990). They exhibit extremely low acute and chronic mammalian toxicities in comparison with most other herbicides (Brown *et al.*, 1990; Levitt, 1991). Therefore, the use of sulfonylurea herbicides is increasing steadily worldwide.

2.10 The effect of herbicidal application on yield of rice

In rice, the conventional method of weed control i.e. hand weeding is very laborious, expensive and inefficient. Chemical weed control can be considered as a better alternative (Singh and Singh, 1993). Use of chemical to control weed has been found effective and economical (Pilai, 1977; Singh and Mani, 1981). Chemical weeding is easier, time–saving and economical as compared to hand weeding alone (Brar and Mishra, 1989). Herbicidal weed control methods offer an advantage to save labour and money, as a result, regarded as cost effective method of weed control (Ahmed *et al.*, 2000).

Herbicides gave significant control of weeds when applied one day after transplanting (Sharma *et al.*, 1994). In South Korea and China, rice is treated with herbicides by 70% and 90% respectively. Moreover, 90 % rice herbicides being applied are pre- emergence and farmer prefer granular herbicides 4-6 days after transplanting (Moddy, 1982). Herbicide use moves the agro-ecosystem to low species diversity with new problem weeds appearing, so that there is a need for an ecological approach to weed control instead of relying totally on chemical control methods (Moody, 1992).

2.11 The effect of herbicide followed by one hand weed control on yield of rice

It seems possible that weeds grown at early stages can be reduced to a minimum by pre-emergence application of herbicide and removal of late emerged weeds by supplemental hand wedding (Sharma *et al*., 1999).

The combination of herbicides and manual weed control has significant effect on controlling weed of rice field (Moody and De Datta, 1986; Singh *et al*., 2005).

2.12 The effect of mechanical weed control on yield of rice

With SRI, weeding is done manually using a mechanical hand weeder (rotating hoe or cono-weeder) with no herbicide use. This returns the weeds to the soil as green manure. Moreover, weeding for SRI becomes less hard in successive years as skill is gained in the methods and as better implements is developed. Giving up herbicides has a health benefit for all concerned persons like the farm worker and the consumer and there is no pollution of the environment and ground water.

The pronounced effect of the increased number of rotary weeding indicates that weed control is the key factor, and it should also increase the aeration in the field (Fernandes and Uphoff, 2002).

In experiments conducted during 2001/02, Senthilkumar (2003) compared the use of rotary weeder (five times with ten-day intervals from 20 days after transplanting until booting stage) with the conventional hand weeding (three times) for wet season, and chemical weeding and two times hand weeding for dry season. In both the seasons, mechanical weed control significantly increased grain yields. Weeder use alone increased the plant height and enhanced the grain yield by 10.9% as compared to manual weeding.

Vijayakumar *et al*. (2006a) also found significant yield increase of 9.7% (20 x 20 cm^2 plant density) and 11.1% (25 x 25 cm^2 plant density) due to weeder use when compared to conventional weeding (herbicide + hand weeding) with 14-day-old seedlings and limited irrigation. Additional weeding can add as much as t ha^{-1} to the yield, which substantially increases the profitability of SRI (Uprety, 2005). Several analyses have shown that additional weeding beyond the first two can add 0.5 to 2.5 t ha^{-1} to final yield. In one Madagascar community, farmers who did not do mechanical weeding got 6.0 t ha^{-1}, farmers who did one or two weedings got 7.5 t ha^{-1}, but the farmers who weeded three times averaged 9.2 t ha^{-1}, and the farmers who were weeding four times got 11.8 t ha^{-1} (Uphoff, 2003).

2.13 The growth of weed under SRI condition

The field dries up and as a consequence of alternate dry and wetting, an aggressive flush of both terrestrial and aquatic weeds come up in the early stage of crop growth (Sharma *et al*., 1999). Frequent aerobic condition of soil and high temperature favor the growth of grassy weeds (Sharma *et al*., 1995).

3 MATERIALS AND METHODS

The details of the experimental materials used and methods adopted during the course of experimentation are described in this chapter.

3.1 Description of experimental site

3.1.1 Location

The experiment was conducted at a farmer's field, Shivanagar-3, Chitwan, Nepal during June to November 2008. The site is located at 3 km west from Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan district which is situated 10 km west of Bharatpur, the district headquarter. The altitude of the site is about 256 meter asl. Geographically, it is located at 27^0 $37'$ North latitude and 84^0 $25'$ East longitudes. The experiment was conducted on land preceding hybrid maize planting.

3.1.2 Physico-chemical characteristics of experimental soil

Composite samples were taken randomly from different spots at 0-15 cm to record the initial physico-chemical characteristics of the experimental soil. The soil samples were air-dried, grounded up and sieved through 2 mm sieve and subjected to tests on their properties. Total nitrogen was determined by Kjeldhal method (Jackson, 1967), available phosphorus by Olsen's method (Olsen *et al.*, 1954), and available potassium by Flame Photometer method. Organic matter was determined by Walkey and Black method, pH (1:2 soil water suspension) by Beckman Glass Electrode pH meter, and soil texture by Hydrometer method. Physico-chemical characteristics of experimental soil are presented in Table 1.

From the soil analysis, sand (61%) was dominant in the physical properties of soil compared to silt (30%) and clay (9%). On the other hand, chemical properties like organic matter (2.1%), total nitrogen (0.09%) and available phosphorus (26 kg/ha) were recorded in lower amount, and potassium (119 kg/ha) in higher amount in the upper (0-15 cm) soil layer with reference to soil testing report. Soil pH (6.1) 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).

Table 1. Physico-chemical characteristics of soil at the experimental site

S. No.	Properties	Average content	Rating
1	Physical properties		
	Sand	61%	
	Silt	30%	
	Clay	9%	
2	Chemical properties		
	Soil pH	6.1	Acidic
	Soil organic matter (%)	2.1.	Low
	Total nitrogen (%)	0.09	Low
	Available phosphorus(kg/ha)	26	Low
	Available potassium kg/ha	119	Medium
3	Texture	Sandy loam	

According to Khatri Chettri (1991), total nitrogen, available phosphorus, and organic matter of the experimental field were indicative of lower soil fertility, while available potassium indicated medium soil fertility (Jaishy, 2000).

3.1.3 Climatic condition during experimental period

The experimental site enjoys sub-tropical type of weather conditions with cool winters, hot summers, and a distinct rainy season with annual rainfall of 1919.5 mm (NMRP, 2000). 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, relative humidity and sunshine hours recorded during rice growing period at National Maize Research Program (NMRP), Rampur, Chitwan, are presented in Figure 1. Weekly average data on temperature, relative humidity, total rainfall and sunshine hours are given in Appendix 2.

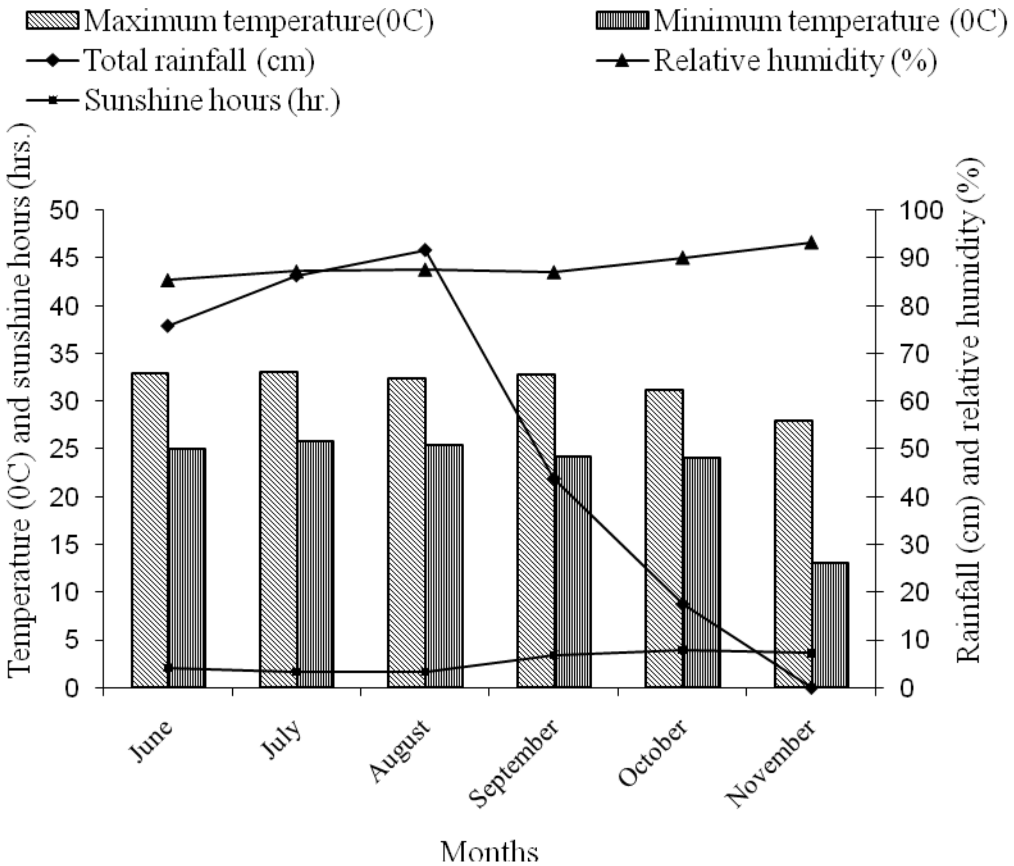

Figure 1. Weather condition during the course of experimentation at farmer's field, Shivanagar-3, Chitwan, Nepal from June to November 2008 (Source: NMRP, 2008)

During the crop cycle, the average maximum (33.23, 33.16, 32.53, 33.10, 31.35, 28.09 and 24^0C) and minimum (25.08, 25.75, 25.55, 24.31, 24.93, 13.77 and 11.98^0C) 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 29.25^0C, 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 25-30^0C. The average temperature during the period of booting to heading (September to October) and ripening (October to November) was 28.42 and 24.53^0C, respectively. Such level of temperature is suitable for the rice crop because it requires temperature of 26.5 to 29.5^0C at booting and 20 to 25 ^{0}C at ripening stage (Singh, 2004).

The total rainfall received during the growing 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 growing period of rice.

3.2 Experimental details

3.2.1 Field layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications and 16 treatment combinations. The dimensions of the individual plot were 3.50 m length and 3 m breadth (10.5 m^2 area). There was a bund accounting to 0.5 m width between plots and a border having 1 m width. Each replication was separated by 1 m bund. The crop geometry of rice was 25×25 cm^2 (hill to hill and row to row spacing) with one seedling per hill and 12 rows in each plot having 14 plants in each row. The 7^{th} to 11^{th} rows were treated as the net plot rows for harvesting, and the remaining 2^{nd} to 5^{th} rows were used for biometrical observations.

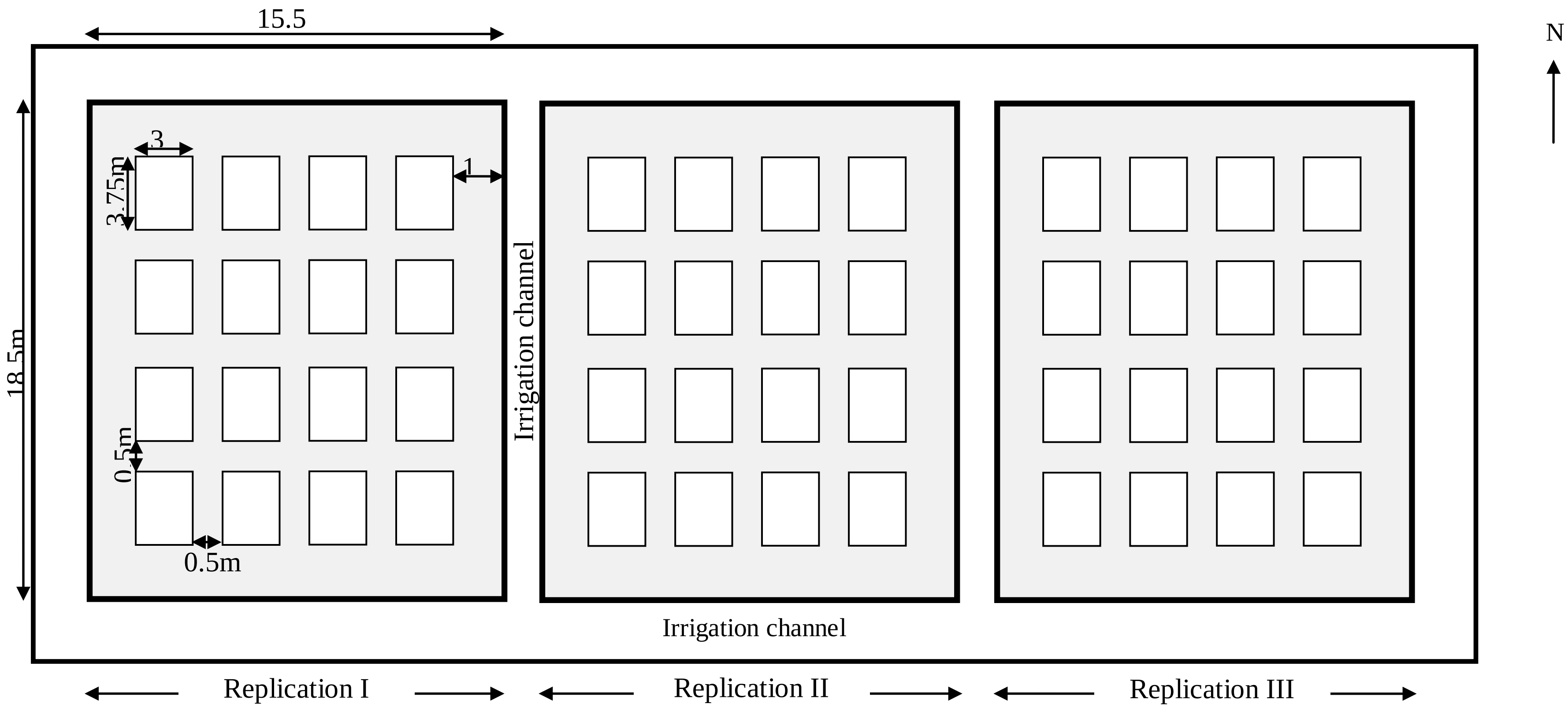

Figure 2. Field layout of the experimental site at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

3.2.2 Treatment details

The experimental trial consisted of 16 treatments with factor A having 8 weed control method, i.e., 1) Unweeded check , 2) One hand weeding at 21 days after transplanting, 3) Two hand weedings at 21 and 42 days after transplanting, 4) Chemical weeding (Pyrazosulfuron ethyl @ 0.15 a.i. kg /ha), 5) Chemical weeding supplemented with one hand weeding, 6) One soil-aerating weeding @ 14 days after transplanting, 7) Two soil-aerating weedings at 14 and 28 days after transplanting, 8) Three soil-aerating weedings at 14, 28 and 42 days after transplanting; and factor B having 2 rice varieties, i.e., 1) Ram (OR-367-SP-11), and 2) Sabitri. Detailed description of the treatment combinations is given in Table 2.

Note:

Soil aerating weeding refers to weeding done by push pull rotatory weeder.

Table 2. Details of the treatment combinations in the experiment during May to December 2008 at farmer's field, Shivanagar-3, Chitwan, Nepal

Treatment	**Treatment combinations**	**Symbol**
T_1	Ram + Unweeded check	V_1 W_1
T_2	Ram + One hand weeding at 21 DAT	V_1 W_2
T_3	Ram + Two hand weedings at 21 and 42 DAT	V_1 W_3
T_4	Ram + Chemical weeding	V_1 W_4
T_5	Ram + Chemical weeding supplemented with one hand weeding at 21 DAT	V_1 W_5
T_6	Ram + One soil-aerating weeding at 14 DAT	V_1 W_6
T_7	Ram + Two soil-aerating weedings at 14 and 28 DAT	V_1 W_7
T_8	Ram + Three soil-aerating weedings at 14, 28 and 42 DAT	V_1 W_8
T_9	Sabitri + Unweeded check	V_2 W_1
T_{10}	Sabitri + One hand weeding at 21 DAT	V_2 W_2
T_{11}	Sabitri + Two hand weeding at 21 and 42 DAT	V_2 W_3
T_{12}	Sabitri + Chemical weeding	V_2 W_4
T_{13}	Sabitri + Chemical weeding supplemented with one hand weeding at 21 DAT	V_2 W_5
T_{14}	Sabitri + One soil-aerating weeding at 14 DAT	V_2 W_6
T_{15}	Sabitri + Two soil-aerating weedings at 14 and 28 DAT	V_2 W_7
T_{16}	Sabitri + Three soil-aerating weedings at 14, 28 and 42 DAT	V_2 W_8

3.3 Description of tested variety

3.3.1 Characteristics of rice variety

3.3.1.1 Ram

The first variety used in the experiment was Ram. The variety Ram (OR-367-SP-11) was released on 5 May 2006. It is a high yielding variety recommended for farmers to cultivate in Siwalik valley of Makwanpur, Chitwan and Nawalparasi and similar environment, and central Terai under rainfed and irrigated condition as main season rice in Rice-Wheat-Maize, Rice-Lentil-Maize and Rice-Wheat cropping pattern. The variety Ram developed from the cross parents: Masuli/IR-20 was originated in India. Farmers preferred this variety due to its earliness, medium fine grain type, higher yield and less prone to disease and insects, high milling recovery, good cooking quality, tolerance to lodging, tolerance to drought and foliar diseases. It has a yield of 4.0-7.2 kg/ha and maturity period of 130-137 days from seeding (NARC, 2006).

3.3.1.2 Sabitri

The second variety used in the experiment was Sabitri. It was released in 1972 and is a popular rice variety in central and western Terai. It was derived from the cross of IR 1561-228-1/IR 1737//CR94-13. It has slender and medium-sized grains. The milling and cooking qualities are acceptable. It has field resistance to blast and bacterial blight. In the Terai and similar environments, it is gradually replacing Mansuli because it is higher-yielding, blast-resisitant, and matures at 140-145 days, about a week earlier than Mansuli. It has semi-dwarf plant height and produces about 4.0-5.0 t/ha of an average grain yield (NRRP, 1997).

3.4 Cultivation practices

Date-wise details of the various cultural practices recorded for rice production under SRI practices from seedbed preparation to harvesting are presented in Appendix 1.

3.4.1 Layout of field

The field was ploughed using a disc harrow through tractor. The layout of the field was done by making 48 plots manually by digging, weeding and pulverizing soils. Bunds and water channels were well maintained.

3.4.2 Raising of seedlings

Two nursery beds, one each for Ram and Sabitri variety, of 3 m length, 1.5 m breadth, and 15 cm height were prepared for raising seedlings. Solarization was done on these beds before sowing seeds, using transparent plastic sheets of 300 gauge thickness for 3 weeks. Rice seeds were sown on 20th June 2008 (6th Ashad 2065) with a seed rate of 5 kg per hectare. The nursery bed was fertilized using vermi-compost (6 t ha^{-1}) and zinc sulphate (25 $ZnSO_4$ kg/ha through Sanjewani, 21% $ZnSO_4$). The seed was treated with Bavistin at the rate of 2 gm/kg of seed. Pregerminated seeds were sown on the solarized nursery beds. Frequent irrigation was done through a hand watering jar to maintain a moist soil condition and to prevent from drought.

3.4.3 Land preparation

The experimental plots were prepared after manual digging 2-3 times, and weeds were removed. Vermi-compost was incorporated to the soil before 5 days of transplanting in each experimental plot. Required amount of chemical fertilizers were applied as mentioned on fertilizer management.

3.4.4 Transplanting and gap filling

Ten-day-old seedlings were transplanted with one seedling per hill, maintaining 25 cm×25 cm row to row and plant to plant distance on 29th June 2009. Gap filling of 2% was done frequently after transplanting of rice seedlings to maintain the plant population in the experimental field.

3.4.5 Fertilizer management

The fertilizer recommendation used in this experiment was 10 t ha^{-1} of well-decomposed FYM, 100:45:45 NPK kg/ha, and $ZnS0_4$ @ 25 kg/ha. In this practice (total of 100 kg N/ha), 50 kg N/ha was applied before puddling, and the remaining half dose of nitrogen was split into two equal halves and top-dressed at tillering and panicle initiation stages, respectively. Whole doses of phosphorus @ 45 kg/ha, potash @ 45 kg/ha, and zinc @ 25 kg/ha were applied as basal fertilizer. The available source of fertilizers were urea (46% N), DAP (18% N and 46% P_2O_5), MOP (60% K_2O), and Sanjewani (21% $ZnSO_4$).

3.4.6 Weed management

The weed control method was done according to the above-mentioned treatment for individual experimental plots.

3.4.7 Irrigation management

Irrigation was provided only to maintain the field in moist soil condition but not flooded condition. The detail of irrigation schedule is given in Appendix 1.

3.4.8 Insect-pest management

Insect damage was observed during heading and milking stage of crop growing period. Spraying of Cypermathin 25 EC @ 1 ml/liter of water at these phenological stages was done.

3.4.9 Harvesting and threshing

The crop from the net plot area was harvested manually with the help of sickle. Harvested plants were left in-situ in the field for 5 days for sun drying. Threshing was done manually, and grains were obtained by winnowing and were weighed at 12% moisture content.

3.5 Observation noted during experimental period

3.5.1 Observation for growth contributing characteristics of rice

3.5.1.1 Plant height (cm)

The plant height were measured from 20 hills, separated for phenological recording, at an interval of 15 days starting from 25th day after transplanting and ending with 120 days after transplanting (physiological maturity). It was measured from base to tip of the longest leaf of the main tiller.

3.5.1.2 Number of leaves and number of tiller per plant

Number of leaves and number of tillers per plant were counted from the sample of five hills of each plot at 15-day intervals during growth analysis, and mean values were calculated. The main stem was also included to calculate the total number of tillers per plant.

3.5.1.3 Leaf area index (LAI)

Leaf area (cm^2) of the functional leaves was obtained at 15-day intervals from five hills which were selected randomly from the samples for growth analysis, i.e., drawn for dry matter accumulation study. After that, leaves were separated from the plant, and leaf area was measured by automatic leaf area meter at central laboratory of IAAS. Then leaf area /unit plant sample was recorded to find leaf area index by the following formula:

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

3.5.1.4 Weed density and weed dry weight

The total number of weeds from 1 m^2 area (weed density) of each net plot was recorded at 21, 42, 93 days after transplanting and harvesting stage with the help of quadrant. The whole sample was dried in an oven at 70 ^{O}C until constant weight was achieved for dry weight. The weed density and weed dry weight were expressed as number of weed/m^2 and gm/m^2, respectively.

3.5.1.5 Root length and root volume

The longest root of each plant was measured from five hills of each plot at 15-day intervals and the mean was measured. Similarly, the roots from five hills were submerged in a jar containing water and the volume of water displaced by the roots was treated as root volume (1 ml= 1 cm^3).

3.5.2 Growth analysis

Plant samples were taken from the five hills of sampling rows at an interval of 15 days from 25 to 100 DAT. At the time of sampling, plants were taken from an area of 0.3125 m^2 (25 cm x 25 cm x 5). Plants from each hill were taken by digging to a depth of 25 cm from a distance of 10 cm from all sides by using a small shovel. These plant samples were further separated into roots, leaves, stems and panicles. The leaf sheath and the developing inflorescence before onset of heading were retained as part of the stem. Dry matter deposition was determined by drying plant organs at a temperature of 70^0C in a hot-air oven until constant weight.

3.5.3 Observation for yield contributing characteristics of rice

3.5.3.1 Number of effective tiller per square meter

Observations regarding the effective tillers per square meter were recorded within each net plot from two randomly selected places with the help of a quadrate (1 m x 1 m) just before harvesting the crop, and the average values were used to obtain the effective tillers per square meter.

3.5.3.2 Length and weight of panicle

The length and weight of panicles were taken from five hills of each net plot by random selection just before harvesting, and means were calculated.

3.5.3.3 Number and weight of grains per panicle

Panicle was weighed in an electronic balance by taking the panicles from five hills of each net plot just before harvesting. At the same time, numbers of filled and unfilled grains were counted to determine the number of filled grains per panicle.

3.5.3.4 Thousand grain weight (Test weight)

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

3.5.3.5 Sterility percentage

Total unfilled grains per panicle were obtained in the panicles from five hills and this information was used to calculate sterility percentage as per the following formula.

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

3.5.4 Observation for grain yield, straw yield and harvest index of rice

3.5.4.1 Grain yield and straw yield

Grain yield and straw yield were taken at harvesting stage of crop growth from each net plot consisting of five rows. The crop was dried, threshed, cleaned and again sun-dried to maintain 12% moisture content, and final weight was taken. The grain yield per hectare was computed for each treatment from the net plot yield. The straw yield per hectare was obtained by deducting the grain yield from the total dry matter yield. Dicky Johns Multi-grain Moisture Meter was used to record the moisture percentage of the grain. Finally, grain yield was adjusted to 12% moisture using the formula suggested by Paudel (1995).

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

Where MC is the moisture content in percentage of the grains.

3.5.4.2 Harvest index

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

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

3.6 Economic analysis for rice production

3.6.1 Cost of cultivation

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

3.6.2 Gross return

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

3.6.3 Net return

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

3.6.4 B: C ratio

This was calculated by using the following formula from the procedure given by Bhandari (1993).

Benefit cost ratio = Gross return / Cost of cultivation

3.7 Statistical analysis

All the recorded data were tabulated according to treatment-wise under three replications. The data entry was done to develop an ANOVA table. When the null hypothesis was rejected, Duncan’s Multiple Range Test (DMRT), a mean separation technique, was applied to identify the most efficient treatment. A simple correlation and regression analysis was done between selected parameters (Gomez and Gomez, 1984). Regarding the software programs used, Microsoft Word 2007 was used for word processing; Microsoft Excel for tables and graphs; and MSTAT-C was for running statistical 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 course of investigation were analyzed and are presented in this chapter with the help of tables as well as figures. The evaluation of results suggests certain explanations based on the available evidences. The observed variations in the various characteristics of rice are considered to infer some cause-and-effect relationships that may be further evaluated for improvement in our understanding and production of rice.

4.1 Effect of weed control method and variety on growth-contributing characteristics of rice under SRI practices

4.1.1 Root length

Rice seedling starts with a radicle (seminal root), mesocotyl root, and nodal roots. However, the rice root system is basically composed of nodal or adventitious roots (Yoshida, 1981). The root system of rice is typically fibrous, which is a basic outcome of the general growth habit, constituted by a series of individual tillers, with associated root systems. Thus, the root system of rice crop is a large number of individuals' roots with relatively low lateral branching rather than diffuse branching of a single primary root. Nutrient uptake by plants depends either on the increment of the nutrient ion to the absorbing root surface or on the roots' ability to reach the zone of nutrient availability (Reddy and Reddi, 2002). Thus, capacity of the plant to absorb water and nutrients is closely related to the total length of the root system (Yoshida, 1981). Rice root systems play an important role in uptake of water and nutrients from soil (Yang *et al.* 2004).

The mean root length in the experiments (Table 3) across all trials indicated that this parameter increased up to 85 DAT and thereafter declined. The root length ranged from 10.30 to 21.23 cm depending on the weed control method and variety used. The most intensive increase in root length was between 25 to 40 DAT.

4.1.1.1 Effect of weed control method on root length

At 25 DAT, the longest root length (11.23 cm) was recorded with three soil-aerating weedings and the shortest length was at unweeded check plot (9.42 cm). The next longest root length was with two soil-aerating weedings (10.64 cm), followed by chemical weeding supplemented with one hand weeding (10.52 cm), two hand weedings (10.38 cm), and one soil-aerating weeding (10.29 cm). The same trend of root length for three soil-aerating weedings having longest root growth was also observed at 40, 55 and 100 DAT. This parameter was significantly influenced by both weed control method and variety, but the interaction effect of weed control method and variety on root length was non-significant. At 40 DAT, the treatment with three soil-aerating weedings produced the longest root length (16.82 cm) while unweeded check plot had the shortest root length (14.65 cm). There was no significant difference among three soil-aerating weedings (16.82 cm), chemical weeding supplemented with one hand weeding (16.80 cm), two soil-aerating weedings (16.62 cm), two hand weedings (16.34 cm), and chemical weeding (16.18 cm).

At 55 DAT, the treatment with three soil-aerating weedings had produced the longest root length (19.98 cm), while unweeded check plot produced the shortest root length (16.77 cm). There was no significant difference in root length among three soil-aerating weedings (19.98 cm), chemical weeding supplemented with one hand weeding (19.85 cm), and two soil-aerating weedings (19.25 cm).

At 70 DAT, the longest root length (20.42 cm) was recorded in the plots with two hand weedings and the shortest root length at unweeded check (18.45 cm). The root length did not differ significantly among two hand weedings (20.42 cm), three soil-aerating weedings (20.31 cm), chemical weeding supplemented with one hand weeding (19.63 cm), and two soil-aerating weedings (19.62 cm).

At 85 DAT. the longest root length (22.55 cm) was recorded at two hand weedings, and the shortest root length at unweeded check (19.06 cm). There was no significant difference in terms of root length among two hand weedings (22.55 cm), chemical weeding supplemented with one hand weeding (22.18 cm), three soil-aerating weedings (21.62 cm), two soil-aerating weedings (21.52 cm), and one soil-aerating weeding (21.46 cm).

At 100 DAT, three soil-aerating weedings (20.25 cm) produced the longest root length, but this did not differ significantly with two soil-aerating weedings (19.12 cm), and one soil-aerating weeding (18.80 cm).

4.1.1.1.1 Manual weed control

At 25 DAT, there was no significant difference between two hand weedings (10.38 cm) and one hand weeding (9.82 cm). The same relationship was observed at 55 and 100 DAT. There was significant difference in terms of root length with two hand weedings as compared to one hand weeding and unweeded check treatment at 40, 70 and 85 DAT. The increment in root length resulting from two hand weedings over one hand weeding, and unweeded check treatment was 10.2% and 11.5%, 9.1% and 10.7%, and 9.1% and 18.3%, respectively at 40, 70 and 85 DAT.

Table 3. Variation of root length (cm) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Root length (cm)[a]					
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Weed control method						
Unweeded check	9.42^{c}	14.65^{c}	16.77^{d}	18.45^{b}	19.06^{c}	18.25^{c}
One HW at 21 DAT	9.82^{bc}	14.83^{c}	17.98^{c}	18.71^{b}	20.66^{b}	18.32^{c}
Two HWs at 21 and 42 DAT	10.38^{abc}	16.34^{ab}	18.19^{bc}	20.42^{a}	22.55^{a}	19.34^{abc}
CW	10.13^{bc}	16.18^{ab}	18.58^{bc}	19.27^{ab}	20.82^{b}	19.01^{bc}
CW + one HW at 21 DAT	10.52^{ab}	16.80^{a}	19.85^{a}	19.63^{ab}	22.18^{ab}	19.51^{ab}
One SAW at 14 DAT	10.29^{abcF}	15.53^{b}c	18.00^{c}	18.81^{b}	21.46^{ab}	18.80^{bc}
Two SAWs at 14 & 28 DAT	10.64^{ab}	16.62^{ab}	19.25^{ab}	19.62^{ab}	21.52^{ab}	19.12^{bc}
Three SAWs at 14, 28 & 42 DAT	11.23^{a}	16.82^{a}	19.98^{a}	20.31^{a}	21.62^{ab}	20.25^{a}
LSD(P-0.05)	0.94	1.01	1.07	1.14	1.48	0.98
SEm (±)	0.33	0.35	0.37	0.40	0.51	0.34
Variety						
Ram	10.64^{a}	16.46^{a}	19.03^{a}	20.00^{a}	21.86^{a}	19.58^{a}
Sabitri	9.97^{b}	15.48^{b}	18.12^{b}	18.79^{b}	20.60^{b}	18.58^{b}
Grand mean	10.30	15.97	18.57	19.40	21.23	19.07
LSD(P-0.05)	0.58	0.62	0.66	0.70	0.90	0.60
CV%	7.75	5.34	4.89	5.00	5.90	4.37
SEm (±)	0.20	0.21	0.23	0.24	0.31	0.21

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil-aerating weeding)

4.1.1.1.2 Chemical weed control

There was no significant difference in terms of root length between chemical weeding supplemented with one hand weeding over chemical weeding and unweeded check between 25 to 100 DAT except at 55 DAT. At 55 DAT, the increment in root length due to chemical weeding supplemented with one hand weeding with chemical weeding and unweeded check was 6.8% and 18.4%, respectively.

4.1.1.1.3 Mechanical weed control

There was no significant difference among three soil-aerating weedings, two soil-aerating weedings, and one soil-aerating weeding at 25 and 85 DAT. Also at 40 DAT, there was no significant difference in root length between three soil-aerating weedings (16.82 cm) and two soil-aerating weedings (16.62 cm), and also between two soil-aerating weedings (16.62 cm) and one soil-aerating weeding (15.55 cm). Here, three soil-aerating weedings (16.82 cm) was significantly different from one soil-aerating weeding (15.53 cm) and unweeded check (14.65 cm). The same trend of root length was also observed at 70 DAT.

AT 55 DAT, three soil-aerating weedings (19.98 cm) was at par with two soil-aerating weedings (19.25 cm), but had a significant difference as compared to one soil-aerating weeding (18.00 cm) and unweeded check (16.77 cm). At 100 DAT, three soil-aerating weedings (20.25 cm) was significantly different from two soil-aerating weedings (19.12 cm) and one soil-aerating weeding (18.80 cm), but the latter two treatments were at par with each other.

4.1.1.2 Effect of variety on root length

The variety Ram had performed considerably better, in terms of root length, as compared to the variety Sabitri in conjunction with SRI method of crop management at all growth stages. The increment in root length of the variety Ram as compared to Sabitri was 6.7%, 6.3%, 5%, 6.4%, 6.1% and 5.4%, respectively, at 25, 40, 55, 70, 85 and 100 DAT.

Thus, on the basis of above results, it can be decided that root length was increased up to 85 DAT, and thereafter declined. Klepper (1992) reported that the general pattern of root development over the life of the crop shows a shift from a heavy investment in roots during seedling establishment and early vegetative growth in the first part of crop growth period to a heavy investment in reproductive organs during the latter part of crop growth period. This may explain roots reaching a plateau during grain filling stage.

Use of three soil-aerating weedings brought significant growth in root length between 25 to 100 DAT except at 70 and 85 DAT. The variety Ram had performed considerably better in terms of root length as compared to the variety Sabitri in conjunction with SRI method of crop management at all growth stages. This might be due to the reason that mechanical weed control results in better soil aeration and greater root development which would support greater tillering as well as more grain filling during the reproductive stage (Uphoff, 1999). Incorporation of weed with mechanical weeder increased the root activity which stimulated the new cell division in roots by pruning of some upper roots encouraged deeper root growth thereby increased the shoot: root ratio (Uphoff, 2001). This was in accordance with other literature data that partial excision of roots of wheat seedlings resulted in an increase in the growth rate of the remaining root system (Hunt, 1975; Vysotskaya *et al.*, 2001). The capacity of the plant to absorb water and nutrients is closely related to the total length of the root system (Yoshida, 1981) which subsequently increases higher assimilation which will favor higher yield attributes and yield.

4.1.2 Root volume

The architecture of the root system is also well known to be a major determinant of root functions in the acquisition of soil resources such as nutrients and water (Yamauchi *et al*., 1996; Fitter, 2002; Wang *et al*., 2006).

The appraisal of these data (Table 5) showed that increment in root volume was most prominent between 25 to 40 DAT, i.e., 110.1%, and thereafter it gradually declined at later stages of crop growth due to the death of older roots as well as retardation in growth process. On average, root volume ranged from 25.41 to 143.88 $cm^3/0.31\ m^2$ depending on weed control method and variety used. This was significantly influenced by both weed control method and variety and also by an interaction effect between weed control method and variety at 25 DAT while at the rest of crop growth stages this interaction effect in terms of root volume had no significant difference.

4.1.2.1 Effect of weed control method on root volume

At 25 DAT, the highest root volume (28.83 $cm^3/0.31\ m^2$) was recorded with three soil-aerating weedings, and the lowest root volume (20.83 $cm^3/0.31\ m^2$) at unweeded check plot. There was no significant effect in root volume among two soil-aerating weedings (28.33 $cm^3/0.31\ m^2$), one soil-aerating weeding (27.99 $cm^3/0.31\ m^2$), two hand weedings (27.17 $cm^3/0.31\ m^2$), and chemical weeding supplemented with one hand weeding (24.33 $cm^3/0.31\ m^2$).

At 40 DAT, three soil-aerating weedings produced the highest root volume (62.83 $cm^3/0.31\ m^2$), and the lowest root volume was recorded at unweeded check (42.00 $cm^3/0.31\ m^2$). The three soil-aerating weedings was statistically at par with two hand weedings (62.50 $cm^3/0.31\ m^2$) and two soil-aerating weedings (59.00 $cm^3/0.31\ m^2$).

At 55 DAT, three soil-aerating weedings still produced the highest root volume (109.17 $cm^3/0.31\ m^2$), and the lowest root volume was recorded at unweeded check (40.00

cm^3/0.31 m^2). Chemical weeding supplemented with one hand weeding (107.50 cm^3/0.31 m^2) and two soil-aerating weedings (105.61 cm^3/0.31 m^2) did not differ significantly in terms of root volume.

At 70 DAT, the highest root volume (173.33 cm^3/0.31 m^2) was found with two hand weedings, and the lowest root volume at unweeded check treatment (93.33 cm^3/0.31 m^2). The treatment two hand weedings differed significantly with all other weed control method. At 85 DAT, the highest root volume (164.58 cm^3/0.31 m^2) was recorded at three soil-aerating weedings, and the lowest root volume (93.75 cm^3/0.31 m^2) was at unweeded check. The three soil-aerating weedings did not differ significantly from chemical weeding supplemented with one hand weeding (164.58 cm^3/0.31 m^2), two hand weedings (164.58 cm^3/0.31 m^2), and two soil-aerating weedings (159.38 cm^3/0.31 m^2).

At 100 DAT, the highest root volume (130.00 cm^3/0.31 m^2) was produced by two soil-aerating weedings, and the lowest root volume (91.67 cm^3/0.31 m^2) from unweeded check. Two soil-aerating weedings (130.00 cm^3/0.31 m^2) was at par with two hand weedings (128.37 cm^3/0.31 m^2), two soil-aerating weedings (118.33 cm^3/0.31 m^2) and chemical weeding supplemented with one hand weeding (118.33 cm^3/0.31 m^2).

4.1.2.1.1 Manual weed control

There was significant effect in root volume between two hand weedings and one hand weeding from 40 to 100 DAT, but at 25 DAT, there was no significant difference in root volume between two hand weedings (27.17 cm^3/0.31 m^2) and one hand weeding (23.33 cm^3/0.31 m^2). The increment in root volume due to two hand weedings as compared to one hand weeding and unweeded check from 40 to 100 DAT was 42.1% and 48.8%, 19.6% and 154.2%, 65.1% and 85.7%, 27.9% and 73.3%, and 30.5% and 40%, respectively.

4.1.2.1.2 Chemical weed control

There was no significant difference in root volume between chemical weeding supplement with one hand weeding and chemical weeding at 25 DAT, but there was significant difference in root volume between them at crop growth stages from 40 to 85 DAT. The increment in root volume due to chemical weeding supplemented with one hand weeding over chemical weeding and unweeded check treatment between 40 to 85 DAT was 13.3% and 28.2%, 13.16% and 168.8%, 11.3% and 49.1%, and 16.2% and 75.6%, respectively.

4.1.2.1.3 Mechanical weed control

There was no significant difference in root volume among three soil-aerating weedings (28.33 cm^3/0.31 m^2), two soil-aerating weedings (28.33 cm^3/0.31 m^2), and one soil-aerating weeding (27.99 cm^3/0.31 m^2) at 25 DAT. At 40 DAT, three soil-aerating weedings (62.83 cm^3/0.31 m^2) and two soil-aerating weedings (59.00 cm^3/0.31 m^2) were at par, and two soil-aerating weedings (59.00 cm^3/0.31 m^2) and one soil-aerating weeding (53..33 cm^3/0.31 m^2) had also non-significant differences, but three soil-aerating weedings (62.83 cm^3/0.31 m^2) was significantly different with one soil-aerating weeding (53.33 cm^3/0.31 m^2). The same trend of root volume was observed at 100 DAT.

At 55 DAT, there was no significant difference in root volume between three soil-aerating weedings (109.11 cm^3/0.31 m^2) and two soil-aerating weedings (105.61 cm^3/0.31 m^2), but there was a significant difference between three soil-aerating weedings (109.11 cm^3/0.31 m^2) and one soil-aerating weeding (90.83 cm^3/0.31 m^2). The same trend of root volume was also observed at 85 DAT. At 70 DAT, there was a significant difference in volume root among three soil-aerating weedings (162.50 cm^3/0.31 m^2), two hand weedings (105.83 cm^3/0.31 m^2), and one soil-aerating weeding (116.67 cm^3/0.31 m^2), but the latter two treatments were at par with each other.

4.1.2.2 Effect of variety on root volume

There was significant difference in the root volume between the two varieties evaluated, i.e., Ram and Sabitri, at 25, 40, 55 and 85 DAT, but these were at par at 70 and 100 DAT. The increment in the root volume of the variety Ram as compared to Sabitri at 25, 40, 55 and 85 DAT was 26.8%, 40.3%, 5.4% and 4.1%, respectively.

4.1.2.3 Interaction effect of weed control method and variety on root volume

There was a significant interaction effect between weed control method and variety in the root volume at 25 DAT (Table 4). The variety Ram had comparatively higher root volume than Sabitri with all weed control method. The interaction effect of two hand weedings with the variety Ram resulted significantly the highest root volume while the interaction effect of chemical weeding with Sabitri resulted significantly in the lowest root volume. The earlier treatment was at par with three soil-aerating weedings with the variety Ram followed by two soil-aerating weedings with the variety Ram, chemical weeding with the variety Ram, one soil-aerating weeding with the variety Ram, three soil-aerating weedings with Sabitri, one soil-aerating weeding with Sabitri, one hand weeding with the variety Ram, chemical weeding supplemented with one hand weeding and the variety Ram and two soil-aerating weedings with Sabitri.

Thus, on the basis of result on Table 5, it can be stated that root volume was increasing between 25 to 40 DAT and thereafter it gradually decreased. The three soil-aerating weedings brought significant increase in the root volume between 25 to 100 DAT except 70 and 85 DAT. The same trend of this treatment was also seen in root length. There was significant difference in the root volume between the two varieties evaluated, i.e., Ram and Sabitri, at 25, 40, 55 and 85 DAT, but these varieties were at par at 70 and 100 DAT.

Table 4. Interaction effect of weed control method and variety of rice on root volume (cm^3/0.31 m^3) under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatments	Root volume (cm^3/0.31m^3)[a]	
	25 DAT	
	Varieties	
	Ram	Sabitri
Weed management		
Unweeded check	21.00[cd]	20.65[cd]
One HW at 21 DAT	26.15[abc]	20.50[cd]
Two HWs at 21 and 42 DAT	33.50[a]	20.83[cd]
CW	30.00[ab]	15.00[d]
CW + one HW at 21 DAT	26.00[abc]	22.65[bc]
One SAW at 14 DAT	29.32[ab]	26.67[abc]
Two SAWs at 14 & 28 DAT	30.65[a]	26.00[abc]
Three SAWs at 14, 28 & 42 DAT	30.65[a]	27.00[abc]
LSD(P-0.05)	6.68	
SEm (±)	2.31	

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

Table 5. Variation of root volume ($cm^3/0.31\ m^3$) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Root volume ($cm^3/0.31m^3$) [a]					
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Weed control method						
Unweeded check	20.83^{d}	42.00^{c}	40.00^{e}	93.33^{f}	93.75^{d}	91.67^{c}
One HW at 21 DAT	$23.33b^{cd}$	44.00^{c}	85.00^{d}	105.00^{e}	127.08^{c}	98.33^{c}
Two HWs at 21 and 42 DAT	$27.17^{ab}c$	62.50^{a}	101.67^{b}	173.33^{a}	162.50^{a}	128.33^{a}
CW	22.50^{cd}	47.50^{c}	95.00^{c}	125.00^{d}	141.66^{b}	115.00^{b}
CW + one HW at 21 DAT	24.33^{abcd}	53.83^{b}	107.50^{ab}	139.17^{c}	164.58^{a}	118.33^{ab}
One SAW at 14 DAT	27.99^{ab}	55.33^{b}	90.83^{c}	116.67^{d}	137.50^{b}	111.67^{b}
Two SAWs at 14 & 28 DAT	28.33^{ab}	59.00^{ab}	105.61^{ab}	125.83^{d}	159.38^{a}	118.33^{ab}
Three SAWs at 14, 28 & 42 DAT	28.83^{a}	62.83^{a}	109.17^{a}	162.50^{b}	164.58^{a}	130.00^{a}
LSD(P-0.05)	4.72	5.31	5.64	10.01	7.52	11.45
SEm (±)	1.64	1.84	1.95	3.47	2.60	3.97
Variety						
Ram	28.41^{a}	55.99^{a}	94.23^{a}	132.29^{a}	146.77^{a}	116.95^{a}
Sabitri	22.41^{b}	50.76^{b}	89.46^{b}	127.91^{a}	140.99^{b}	110.95^{a}
Grand mean	25.41	53.37	91.85	130.10	143.88	113.95
LSD(P-0.05)	2.89	3.25	3.45	6.13	4.61	7.01
CV%	15.76	8.44	5.21	6.52	4.43	8.52
SEm (±)	1.00	1.13	1.20	2.12	1.60	2.43

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.3 Plant height

Plant height is one of the important growth parameters of any crop plant as it determines or modifies the yield contributing characters and finally shapes the grain yield. For the ideal rice variety, the height of the plant should be medium type (Reddy and Reddi, 1997).

The analyzed data presented in Table 7 revealed that, on an average across all trials, plant height increased up to 100 DAT, and its value ranged from 37.69 to 100.63 cm, depending on weed control method and variety used. The increment in plant height was most intensive (31.8%) between 40 and 55 DAT. Plant height was significantly influenced by all weed control methods between 25 and 100 DAT, while varieties also influenced this parameter significantly between 25 and 100 DAT, except at 55 DAT and 100 DAT, respectively. The interaction effect between weed control method and variety was significant at 25 and 100 DAT only.

4.1.3.1 Effect of weed control method on plant height

At 25 DAT, three soil-aerating weedings had produced significantly taller plants (38.74 cm), while the unwedded check plots produced significantly shorter plants (35.64 cm). The same pattern was observed at 55 DAT and 85 DAT. At 40 DAT, chemical weeding supplemented with one hand weeding produced significantly taller plants (50.42 cm), while unweeded check produced significantly shorter plants (44.53 cm). The same pattern was also found at 70 and 100 DAT.

4.1.3.1.1 Manual weed control

At 25 DAT, two hand weedings (37.78 cm) had no significant difference in plant height as compared with one hand weeding (36.33 cm). The same pattern of plant height was observed at 40, 55 and 85 DAT. But at 70 DAT, two hand weedings (79.68 cm) had a significant influence on plant height as compared to one hand weeding (78.02 cm) and the same trend of plant height was observed at 100 DAT. Two hand weedings had increased plant height by 2.1% and 8.2%, and 1.9% and 6.5% over one hand weeding and unweeded check plots at 70 and 100 DAT, respectively.

4.1.3.1.2 Chemical weed control

Chemical weeding supplemented with one hand weeding (38.61 cm) produced no significant difference in plant height as compared with chemical weeding treatments (37.58 cm) at 25 DAT. The same trend of plant height was observed at 55, 85 and 100 DAT. There was a significant difference in plant height between chemical weeding supplemented with one hand weeding and chemical weeding at 40 and 70 DAT. The increment in plant height with chemical weeding supplemented with one hand weeding over chemical weeding and unweeded check was 6.8% and 13%, and 4.1% and 11.7%, respectively, at 40 and 70 DAT.

4.1.3.1.3 Mechanical weed control

At 25 DAT, there was no significant difference in plant height among three soil-aerating weedings (38.74 cm), two soil-aerating weedings (38.52 cm) and one soil-aerating weeding (38.33 cm). There was no significant difference in plant height at 40 DAT between three soil-aerating weedings (48.82 cm) and two soil-aerating weedings (47.30 cm), while the latter treatment was at par with one soil-aerating weeding (46.47 cm). At 55 DAT, three soil-aerating weedings (66.78 cm) had a significant difference in terms of plant height from two soil-aerating weedings (62.72 cm) and one soil-aerating weeding (61.99 cm), but the latter two treatments were non-significant from each other. The same trend of plant height was noticed between 70 to 100 DAT.

4.1.3.2 Effect of variety on plant height

At 25 DAT, the variety Ram (39.25 cm) showed significantly taller plants as compared to the variety Sabitri (36.13 cm) in conjunction with SRI methods of crop management in all treatments, and the increment in plant height was 8.6%. The same trend of plant height was also seen at 40, 70 and 90 DAT with the increased plant height of 3.9%, 2.3% and 2%, respectively. The variety Ram was statistically at par with Sabitri in terms of plant height at 55 DAT and 100 DAT.

4.1.3.3 Interaction effect of weed control method and variety on plant height

There was significant interaction effect between weed control method and variety for plant height at 25 and 100 DAT (Table 6). AT 25 DAT, the variety Ram was comparatively taller than Sabitri with all weed control methods, and the same trend was noticed at 100 DAT.

At 25 DAT, the interaction effect of chemical weeding supplemented with one hand weeding with the variety Ram had resulted significantly taller plants, while the interaction effect of unweeded check with the variety Sabitri resulted in significantly shorter plants. The chemical weeding supplemented with one hand weeding produced tallest plants followed by two soil-aerating weedings, one soil-aerating weeding, three soil-aerating weedings, and two hand weedings.

At 100 DAT, the interaction effect of three soil-aerating weedings with the variety Sabitri produced taller plants, while the interaction effect of unweeded check plot with the variety Sabitri produced shorter plants. The interaction effect of three soil-aerating weedings with the variety Ram produced the second taller plants, which was at par with chemical weeding supplemented with one hand weeding, two soil-aerating weedings, chemical weeding, and two hand weedings.

Table 6. Interaction effect of weed control method and variety of rice on plant height (cm) under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatments	Plant height (cm)[a]			
	25 DAT		100 DAT	
	Variety			
	Ram	Sabitri	Ram	Sabitri
Weed control method				
Unweeded check	37.85^{cde}	33.43^{g}	95.01^{f}	94.23^{f}
One HW at 21 DAT	36.67^{def}	35.99^{ef}	99.85^{de}	98.58^{e}
Two HWs at 21 and 42 DAT	38.28^{abcde}	37.27^{cde}	101.39^{bcde}	100.85^{cde}
CW	40.75^{ab}	34.41^{fg}	102.09^{bcd}	99.60^{de}
CW + one HW at 21 DAT	41.00^{a}	36.21^{ef}	102.95^{bc}	100.06^{de}
One SAW at 14 DAT	40.00^{abc}	36.66^{def}	101.09^{cde}	100.35^{cde}
Two SAWs at 14 & 28 DAT	40.00^{abc}	37.04^{def}	102.45^{bcd}	100.15^{cde}
Three SAWs at 14, 28 & 42 DAT	39.41^{abcd}	38.06^{bcde}	103.95^{b}	107.41^{a}
LSD(P-0.05)	2.42		2.46	
SEm (±)	0.84		0.85	

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

Thus, it can be described that plant height increased up to 100 DAT and the increment was higher (31.8%) between 40 and 55 DAT. Use of three soil-aerating weedings brought significant increase in plant height between 25 to 100 DAT except 40 and 70 DAT. There was significant positive correlation (r = 0.874**) between plant height at 100 DAT and grain yield (Appendix 16). At 25 DAT, the variety Ram produced significantly taller plants as compared to the variety Sabitri in combination with SRI methods of crop management in all treatments. The same trend of plant height was also seen at 40, 70 and 90 DAT, but the variety Ram did not differ significantly with the variety Sabitri in plant height at 55 DAT and 100 DAT. Mechanical weeding could enhance plant height by better soil aeration and incorporation of weeds as a green manure increased the organic carbon content of the soil (Vijayakumar *et al*., 2006).

Table 7. Dynamics of plant height (cm) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Plant height (cm)[a]					
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Weed control method						
Unweeded check	35.64[c]	44.53[d]	59.75[c]	73.66[e]	83.06[c]	94.62[d]
One HW at 21 DAT	36.33[bc]	48.10[bc]	61.89[bc]	78.02[d]	86.59[b]	99.21[c]
Two HWs at 21 and 42 DAT	37.78[ab]	48.10[bc]	63.00[b]	79.68[bc]	88.07[b]	101.12[b]
CW	37.58[ab]	47.23[bc]	62.79[b]	79.07[cd]	87.64[b]	100.85[bc]
CW + one HW at 21 DAT	38.61[a]	50.42[a]	63.26[b]	82.31[a]	89.18[b]	101.51[b]
One SAW at 14 DAT	38.33[a]	46.47[cd]	61.99[bc]	78.46[cd]	87.28[b]	100.72[bc]
Two SAWs at 14 & 28 DAT	38.52[a]	47.30[bc]	62.72[bc]	78.96[cd]	88.27[b]	101.30[b]
Three SAWs at 14, 28 & 42 DAT	38.74[a]	48.82[ab]	66.78[a]	81.21[ab]	92.15[a]	105.68[a]
LSD(P-0.05)	1.71	1.99	2.74	1.62	2.60	1.74
SEm (±)	0.59	0.69	0.95	0.56	0.90	0.60
Variety						
Ram	39.25[a]	48.52[a]	63.46[a]	79.80[a]	88.64[a]	101.10[a]
Sabitri	36.13[b]	46.72[b]	62.09[a]	78.04[b]	86.92[b]	100.15[a]
Grand mean	37.69	47.62	62.77	78.92	87.78	100.63
LSD(P-0.05)	1.05	1.21	1.68	0.99	1.59	1.06
CV%	3.85	3.54	3.70	1.74	2.51	1.47
SEm (±)	0.36	0.42	0.58	0.34	0.55	0.37

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.4 Number of tillers per plant

Tillering plays a vital role in determining rice grain yield since it is closely related to number of panicle per unit ground area. Too few tillers result in too few panicles, but excess tillers enhance high tiller mortality, small panicles, poor grain filling, and consequent reduction in grain yield (Peng *et al.*, 1994).

The mean value of the number of tillers per plant in the experiment for all treatments (Table 8) indicated that the number of tillers per plant increased up to 70 DAT and thereafter gradually declined. The decrease in the number of tillers per plant was attributed to the death of some of the last tillers as a result of their failure in competition for light and nutrients (Fageria, *et al*., 1997b). Another explanation for this effect is that during the panicle initiation stage of crop growth period, competition for assimilates exists between developing panicles and young tillers. Eventually, growth of many young tillers is suppressed, and they may senesce without producing seed (Dofing and Karlsson, 1993). Tillers production occurred in the initial stage of crop growth period. The potential of tillers production differs with variety because it is genetically controlled behavior.

The increase in number of tillers per plant between 25 and 40 DAT was remarkable (98.8%). The highest average number of tillers per plant was recorded at 70 DAT (23.8). The number of tillers per plant was significantly influenced by weed control method and also by variety at all dates of observation except at 100 DAT. There was no significant effect of interaction between weed control method and variety in terms of number of tillers per plant.

4.1.4.1 Effect of weed control method on number of tillers per plant

At 25 DAT, the highest number of tillers per plant was produced at two hand weedings (9.83), which was significantly higher than unweeded check plots (7.36), but two hand weeded plots was at par in terms of numbers of tiller per plant with three soil-aerating weedings (9.11) There was no significant differences in the number of tillers per plant among chemical weeding supplemented with one hand-weeding (8.98), two soil-aerating weedings (8.83), one soil-aerating weeding (8.11), and one hand weeding (7.44).

At 40 DAT, the highest number of tillers per plant was observed for two hand weedings (19.63). This treatment was significantly higher than unweeded check plot (14.67), but was non-significant as compared to three soil-aerating weedings (18.20), two soil-aerating weedings (17.57), chemical weeding supplemented by one hand weeding (17.0.), one soil-aerating weeding (16.97), and one hand weeding (16.63). At 55 DAT, chemical weeding supplemented by one hand weeding (26.67) had significantly higher number of tillers per plant than unweeded check (15.03), but it was not significantly different from two hand weedings (25.00) or three soil-aerating weedings (24.90).

At 70 DAT, two hand weedings (32.97) produced significantly higher number of tillers per plant than unweeded check (18.63), and unweeded check was at par with one hand weeding (18.93). At 85 DAT, three soil-aerating weedings (22.69) produced significantly higher number of tillers per plant than unweeded check (15.45), but it was at par with two hand weedings (21.60) and chemical weeding supplemented with one hand weeding (20.71). Unweeded check was statistically at par with two soil-aerating weedings (17.92), one soil-aerating weeding (17.57), chemical weeding (17.23), and one hand weeding (16.51).

At 100 DAT, the highest number of tillers per plant was produced at three soil-aerating weedings compared to unweeded check plot (13.56), but was at par with chemical weeding supplemented with one hand weeding (18.70). There was no significant difference in terms of number of tillers per plant among two soil-aerating weedings (18.33), two hand weedings (18.10), and chemical weeding (17.60).

4.1.4.1.1 Manual weed control

The highest significant number of tillers per plant was observed at two hand weedings (9.83) at 25 DAT as compared to one hand weeding (7.44) and unweeded check (7.36). The increment in number of tillers per plant was 32.1% and 33.6%, respectively. The same trend of number of tillers per plant was found at 40 and 70 DAT. The increment in number of tillers per plant with two hand weedings as compared to one hand weeding and unweeded check was 22.4% and 66.3%, 30.8% and 39.8%, 26.6% and 33.5%, respectively, at 55, 85 and 100 DAT.

4.1.4.1.2 Chemical weed control

There was no significant difference between chemical weeding supplemented by one hand weeding and chemical weeding in terms of the number of tillers per plant at 25, 40 and 100 DAT. Chemical weeding supplemented by one hand weeding produced significantly higher number of tillers per plant as compared to chemical weeding and unweeded check treatment at 55 and 85 DAT. The increment was 13.6% and 77.4%, and 20.2% and 34.1%, respectively.

4.1.4.1.3 Mechanical weed control

There was no significant difference in number of tillers per plant among three soil-aerating weedings, two soil-aerating weedings, and one soil-aerating weeding at 25 and 40 DAT. Three soil-aerating weedings had a significant effect on the number of tillers per plant as compared to two soil-aerating weedings and one soil-aerating weeding, while the latter two treatments were at par with each other at 55 to 85 DAT.

4.1.4.2 Effect of variety on number of tillers per plant

The variety Ram had significantly higher number of tillers per plant as compared to Sabitri in conjunction with SRI methods of crop management during 25 to 100 DAT. The increment in the number of tillers per plant of the variety Ram over Sabitri was 8.2%, 8.3%, 9%, 8.6%, 13.8% and 16.3%, respectively, from 25 to 100 DAT.

Thus, form the above results, it can be described that use of two hand weedings brought significant increment in number of tillers per plant at the early stage of crop growth, but at the later stage three soil-aerating weedings produced significant increment which ultimately resulted them higher number of effective tillers per square meter. According to Vijayakumar *et al.* (2006), mechanical weeding not only helped in reducing the weed competition, but also improved root growth by increasing soil aeration and root pruning which ultimately resulted in increased number of tillers per plant (Shad, 1986). The variety Ram had significantly higher number of tillers per plant as compared to the variety Sabitri in conjunction with SRI methods of crop management during 25 to 100 DAT.

Table 8. Dynamics of tiller formation per plant as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Number of tillers per plant [a]					
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Weed control method						
Unweeded check	7.36[c]	14.67[c]	15.03[e]	18.63[e]	15.45[b]	13.56[c]
One HW at 21 DAT	7.44[c]	16.63[bc]	20.43[d]	18.93[e]	16.51[b]	14.30[c]
Two HWs at 21 and 42 DAT	9.83[a]	19.63[a]	25.00[ab]	32.97[a]	21.60[a]	18.10[ab]
CW	8.56[b]	14.96[c]	23.47[bc]	23.26[c]	17.23[b]	17.60[ab]
CW + one HW at 21 DAT	8.98[ab]	17.03[bc]	26.67[a]	26.17[b]	20.71[a]	18.70[ab]
One SAW at 14 DAT	8.11[bc]	16.97[bc]	21.27[cd]	21.23[d]	17.57[b]	15.40[bc]
Two SAWs at 14 & 28 DAT	8.83[ab]	17.57[ab]	21.77[cd]	22.77[cd]	17.92[b]	18.33[ab]
Three SAWs at 14, 28 & 42 DAT	9.11[ab]	18.20[ab]	24.90[ab]	26.50[b]	22.69[a]	18.97[a]
LSD(P-0.05)	0.96	2.17	2.76	1.87	2.58	3.07
SEm (±)	0.33	0.75	0.96	0.65	0.59	1.06
Variety						
Ram	8.86[a]	17.63[a]	23.28[a]	24.82[a]	19.92[a]	18.14[a]
Sabitri	8.19[b]	16.28[b]	21.35[b]	22.80[b]	17.50[b]	15.60[b]
Grand mean	8.53	16.96	22.32	23.81	18.71	16.87
LSD(P-0.05)	0.59	1.33	1.69	1.15	1.58	1.88
CV%	9.54	10.86	10.49	6.67	11.67	15.41
SEm (±)	0.20	0.46	0.59	0.40	0.55	0.65

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.5 Number of leaves per plant

Leaves are the primary sites for carbon fixation (Photosynthesis) and the synthesis of nitrogenous compounds (Krishman *et al*., 1998). The main principle of agronomy is harvesting as much solar energy as possible and converting solar energy into chemical energy by photosynthesis (Reddy and Reddi, 2002). In general, up to 14 leaves are found in rice plant. The first 4 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 the generative organs (Ustimenko Bakumovsky, 1983).

The data presented in Table 9 showed that number of leaves per plant across all treatments increased from 25 to 70 DAT, and thereafter gradually decreased due to senescence of older leaves. The average number of leaves per plant ranging from 32.2 to 90.0 depended on weed control method and variety used. The increment in the number of leaves per plant between 25 to 40 DAT was much higher (66.3%) as compared to the period between 40 to 55 DAT (44.7%).

Weed control method significantly influenced the number of leaves per plant from 25 to 100 DAT while the variety significantly influenced them from 25 to 55 DAT. The number of leaves per plant was non-significant from 70 to 100 DAT and the interaction effect of weed control method and variety was also non-significant.

4.1.5.1 Effect of weed control method on number of leaves per plant

At 25 DAT, the two hand weedings (40.57) produced significantly higher number of leaves per plant than unweeded check plot (27.57). The same trend of number of leaves per plant was also found at 70 DAT. At 40 DAT, the numbers of leaves per plant was significantly higher at three soil-aerating weedings (61.60) than unweeded check treatment

(45.63), and the same trend of number of leaves per plant was also observed at 85 and 100 DAT. At 55 DAT, chemical weeding supplemented with one hand weeding produced higher number of leaves per plant (95.87) than unweeded check (49.17).

4.1.5.1.1 Manual weed control

At 25 DAT, two hand weedings (40.57) produced significantly higher number of leaves per plant over one hand weeding (28.59) and unweeded check (27.57), and the increment was 41.9% and 47.1%, respectively. The same trend of number of leaves per plant was also observed at 70 DAT. There was significant difference in the number of leavers per plant between two hand weedings (55.30) and one hand weeding (50.19) at 40 DAT. The same trend of number of leaves per plant was recorded during the crop growth period between 55, 85 and 100 DAT.

4.1.5.1.2 Chemical weed control

In chemical weeding, both the chemical weeding (31.03) and chemical weeding supplemented by one hand weeding (32.77) were at par with each other in terms of number of leaves per plant at 25 DAT. There was significant effect of chemical weeding supplemented by one hand weeding (57.60) in terms of number of leaves per plant with chemical weeding supplemented by one hand weeding (57.60) over chemical weeding (52.97) and unweeded check (45.63) at 40 DAT and the same trend of number of leavers per plant was recorded from 55 to 100 DAT. The increment in the number of leaves per plant was 8.7% and 26.2%, 21.4% and 95%, 7.2% and 32%, 18% and 51.4%, and 9.2% and 45.6%, respectively from 40 to 100 DAT. At 55 DAT, chemical weeding supplemented by one hand weeding had produced significantly higher number of leaves per plant (95.87) over all other treatments.

4.1.5.1.3 Mechanical weed control

At 25 DAT, the number of leaves per plant did not differ significantly between one soil-aerating weeding (31.00) and two soil-aerating weedings (31.00), and only three soil-aerating weedings (34.97) differed significantly with them. The same trend of number of leavers per plant was observed at 40 and 85 DAT.

There was no significant difference in the number of leaves per plant between three soil-aerating weedings (69.10) and two soil-aerating weedings (66.83) but both significantly differed with one soil-aerating weeding (52.78) at 100 DAT. Three soil-aerating weedings differed significantly from two soil-aerating weedings and one soil-aerating weeding in terms of number of leaves per plant at 55 and 70 DAT. The increment in the number of leaves per plant at three soil-aerating weedings over two soil-aerating weedings, one soil-aerating weeding and unweeded check were 14.6%, 4.5%, 78.3% and 11.4%, 23%, 44.3%, respectively at 55 and 70 DAT.

4.1.5.2 Effect of variety on number of leaves per plant

The variety Ram produced significantly higher number of leaves per plant than the variety Sabitri under different method of weed control from 25 to 55 DAT and the values were 32.94, 54.43 and 78.18, respectively. The variety Ram did not differed significantly in the number of leaves per plant with the variety Sabitri from 70 to 100 DAT.

Thus, on the basis of the results, it can be stated that number of leaves per plant increased from 25 to 70 DAT, and thereafter gradually decreased. Use of two hand weedings, brought significant increase in the number of leaves per plant at the early stage of crop growth, but at the later stage three soil-aerating weedings brought significant increment which was important for higher LAI that ultimately result more photosynthesis. This indicated the close relationship between the number of leaves per plant at 70 DAT and LAI at 70 DAT (r = 0.834**) and likewise, highly significant positive correlation (r = 0.726**) was recorded between them and yield (t ha^{-1}) (Appendix 16).

Table 9. Dynamics of leaves formation per plant as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Number of leaves per plant[a]					
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Weed control method						
Unweeded check	27.57[e]	45.63[f]	49.17[g]	69.90[f]	51.87[f]	46.78[d]
One HW at 21 DAT	28.59[de]	50.19[e]	72.53[f]	79.83[e]	64.00[e]	48.22c[d]
Two HWs at 21 and 42 DAT	40.57[a]	55.30[c]	85.63[c]	118.00[a]	85.53[b]	65.67[ab]
CW	31.03[cd]	52.97[d]	79.00[d]	86.10[d]	66.54[e]	62.39[b]
CW + one HW at 21 DAT	32.77[bc]	57.60[b]	95.87[a]	92.30[c]	78.54[c]	68.10[a]
One SAW at 14 DAT	31.00[cd]	51.37[de]	73.23[f]	82.07[e]	70.58[d]	52.78[c]
Two SAWs at 14 & 28 DAT	31.00[cd]	53.46[cd]	76.53[e]	90.60[c]	73.63[d]	66.83[ab]
Three SAWs at 14, 28 & 42 DAT	34.97[b]	61.60[a]	87.67[b]	100.89[b]	95.67[a]	69.10[a]
LSD(P-0.05)	2.44	2.08	1.69	3.21	3.15	4.78
SEm (±)	0.84	0.72	0.59	1.11	1.09	1.65
Variety						
Ram	32.94[a]	54.43[a]	78.18[a]	90.82[a]	74.23[a]	61.31[a]
Sabitri	31.44[b]	52.60[b]	76.73[b]	89.10[a]	72.36[a]	58.88[a]
Grand mean	32.19	53.51	77.45	89.96	73.30	60.10
LSD(P-0.05)	1.49	1.28	1.03	1.97	1.93	2.93
CV%	6.42	3.30	1.85	3.03	3.64	6.74
SEm (±)	0.52	0.44	0.36	0.68	0.67	1.01

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.6 Leaf area index

The leaves of a plant are normally its main organs of photosynthesis and the total area of leaves per unit area of land surface called leaf area index (LAI) has therefore been proposed by Watson, as the best measure of the capacity of a crop for producing dry matter and called it as productive capital (Arnon, 1972). Fageria *et al*. (1997a) reported that optimum LAI for upland rice is about 2–3 at 85–100 days after transplanting. The variations in LAI are an important physiological parameter that determines crop yield (Evans and Wardlaw, 1976). The leaf area index (LAI) is a determinant of dry matter production, and hence increased total dry matter production results in increased grain yield for a given rice variety (Yoshida, 1972).

From the analysis of the data (Table 10), it was obvious that leaf area index across all treatments increased from 25 to 70 DAT, and thereafter declined at the end of crop growth period (85-100 DAT) due to leaf senescence. This was also supported by Yoshida (1983) that LAI of rice increased as crop growth advanced and reached a maximum at heading or flowering stage. On an average, leaf area index ranged from 1.76 to 2.35 depending on weed control method and variety used, and the increment in the leaf area index was more prominent (14.8%) during the growth period between 40 to 50 DAT.

4.1.6.1 Effect of weed control method on leaf area index

At 25 DAT, three soil-aerating weedings had significantly produced higher leaf area index (2.26) while unweeded check plot produced the lowest leaf area index (1.16). Three soil-aerating weedings provided higher leaf area index followed by chemical weeding supplemented by one hand weeding (2.21), two soil-aerating weedings (2.10) and two hand weedings (1.97). The same trend of leaf area index was also observed during the growth period of crop at 55 and 100 DAT. At 40 DAT, leaf area index was significantly higher at chemical weeding supplemented by one hand weeding (2.51) and the lowest leaf area index was recorded at unweeded check plot (1.29).There was no significant different in leaf area index among three soil-aerating weedings (2.47), two hand weedings (2.35) and two soil-aerating weedings (2.18). At 70 DAT, two hand weedings produced the highest leaf area index (3.02) and the lowest at unweeded check (1.55). At 85 DAT, chemical weeding supplemented by one hand weeding produced the highest leaf area index (3.02) and the lowest at unweeded check plot (1.57).

4.1.6.1.1 Manual weed control

At 25 DAT, two hand weedings (1.97) was significantly different in leaf area index as compared to one hand weeding (1.31). The same trend of LAI was also observed between 40 to 100 DAT. The increments in the leaf area index at two hand weedings over one hand weeding and unweeded check were 50.4% and 69.8%, 61% and 82.2%, 60.7% and 82.4%, 72.6% and 94.8%, 45.9% and 70.1%, and 41.7% and 60.2%, from 25 to 100 DAT, respectively.

4.1.6.1.2 Chemical weed control

There was significant difference in leaf area index at chemical weeding supplemented by one hand weeding over chemical weeding from 25 to 85 DAT while at 100 DAT there was no significant difference between them. The increments in the leaf area index from chemical weeding supplemented by one hand weeding over chemical weeding and unweeded check plot was 32.3% and 90.5%, 35.7% and 94.6%, 58.3% and 92.6%, 27% and 81.9%, and 40.5% and 92.4%, respectively, from 25 to 85 DAT.

4.1.6.1.3 Mechanical weed control

At 25 DAT, three soil-aerating weedings (2.20) and two soil-aerating weedings (2.10) did not differ significantly in the leaf area index, but both of them were significantly differed with one soil-aerating weeding (1.41). Similar trend of leaf area index was also noticed at 40 and 70 DAT. At 55 DAT, there was no significant difference in the leaf area index between three soil-aerating weedings (2.89) and two soil-aerating weedings (2.51), and also between two soil-aerating weedings (2.51) and one soil-aerating weeding (2.11), but three soil-aerating weedings (2.89) was significantly different from one soil-aerating weeding (2.11). The same trend of leaf area index was observed at 100 DAT. At 85 DAT, there was no significant difference among three soil-aerating weedings (2.26), two soil-aerating weedings (2.04) and one soil-aerating weeding (2.03).

4.1.6.2 Effect of variety on leaf area index

There was significant difference in the leaf area index between the variety Ram and Sabitri. The variety Sabitri showed the higher leaf area index as compared to variety Ram from 25 to 100 DAT except at 55 DAT. The increments in the leaf area index due to the variety Sabitri as compared to the variety Ram were 18.6%, 15.4%, 17.4%, 15.6%, 15.8%, respectively at 25, 40, 70, 85 and 100 DAT but at 55 DAT The variety Ram showed the highest leaf area index than Sabitri and the increment was 14.2% over the variety Sabitri.

Thus, form the above results, use of three soil-aerating weedings brought significant increment in leaf area index at 25, 55 and 100 DAT. This treatment was closely followed by chemical weeding supplemented by one hand weeding. There was significant positive correlation (r = 0.817**) between leaf area index at 70 DAT and grain yield (t ha^{-1}) and likewise, positive correlation (r = 0.830** and r = 0.778**) between leaf area index at 70 DAT and total dry matter production at 85 and 100 DAT, respectively (Appendix 16). The variety Sabitri produced higher leaf area index than the variety Ram from 25 to 100 DAT except 55 DAT where the variety Ram produced t higher leaf area index than the variety Sabitri. Mechanical weeding favorably influenced the soil aeration which facilitated more number of tillers and subsequently higher photosynthetic rate for increased leaf area index (Thiyagarajan *et al.*, 2002).

Table 10. Variation in leaf area index (LAI) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Leaf area index (LAI)[a]					
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Weed control method						
Unweeded check	1.16^{d}	1.29^{d}	1.48^{d}	1.55^{d}	1.57^{e}	1.33^{c}
One HW at 21 DAT	1.31^{cd}	1.46^{cd}	1.68^{cd}	1.75^{cd}	1.83^{de}	1.51^{c}
Two HWs at 21 and 42 DAT	1.97^{ab}	2.35^{a}	2.70^{a}	3.02^{a}	2.67^{b}	2.13^{ab}
CW	1.67^{bc}	1.85^{bc}	1.80^{cd}	2.22^{bc}	2.15^{c}	2.05^{b}
CW + one HW at 21 DAT	2.21^{a}	2.51^{a}	2.85^{a}	2.82^{a}	3.02^{a}	2.18^{ab}
One SAW at 14 DAT	1.41^{cd}	1.57^{cd}	2.11^{bc}	1.88^{cd}	2.03^{cd}	1.93^{b}
Two SAWs at 14 & 28 DAT	2.10^{a}	2.18^{ab}	2.51^{ab}	2.62^{ab}	2.04^{cd}	2.26^{ab}
Three SAWs at 14, 28 & 42 DAT	2.26^{a}	2.47^{a}	2.89^{a}	2.96^{a}	2.26c	2.49a
LSD(P-0.05)	0.35	0.39	0.43	0.47	0.27	0.34
SEm (±)	0.12	0.14	0.15	0.16	0.09	0.12
Variety						
Ram	1.61^{b}	1.82^{b}	2.07^{b}	2.18^{b}	2.34^{a}	1.84^{b}
Sabitri	1.91^{a}	2.10^{a}	2.43^{a}	2.52^{a}	2.05^{b}	2.13^{a}
Grand mean	1.76	1.96	2.25	2.35	2.20	1.99
LSD(P-0.05)	0.21	0.24	0.26	0.29	0.17	0.21
CV%	16.76	16.91	16.01	16.91	10.50	14.65
SEm (±)	0.74	0.08	0.09	0.10	0.06	0.73

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.7 Dry matter production

The most important process for rice yield determination is post flowering biomass production (Akita, 1989). The production of total dry matter per unit area is the prerequisites for higher production. The amount of dry matter production depends on the effectiveness of photosynthesis of the crop which in turn depends on large and efficient assimilating area for adequate supply of solar radiation and carbon dioxide and favorable environmental condition (Reddy and Reddi, 2002). The total yield of dry matter accumulation is the total amount of dry matter produced, less than photosynthates used for respiration. Finally, the amount of economic yield depends on the manner in which the net dry matter produced in distributed among the different parts of the plants which will determine the magnitude of economic yield (Aron, 1972). Peng *et al*. (2000) reported that yield improvement of lowland rice cultivars released by International Rice Research Institute (IRRI), Philippines after 1980 was due to increased biomass production.

Initially investment of new biomass partitioning was in the stem followed by root and leaf between 25 to 55 DAT except at 70 DAT where stem followed by leaf and root. At 85 DAT, biomass partitioning was observed on the stem fallowed by root, leaf and grain while at 100 DAT, stem dry matter partitioning was followed by root, grain and leaf. Thus, at 25 DAT, the partitioning of leaf dry matter in the total dry matter accumulation was the highest (30.2%) whereas that of root and stem dry matter accumulation in the total dry matter accumulation showed the highest dry matter partitioning i.e. 41.8% and 50.9%, respectively at 40 and 85 DAT. Fageria *et al*. (1997a) and Fageria, *et al*. (2006) reported more or less similar reduction in shoot dry weight of upland rice from flowering to physiological maturity.

On an average, the total dry matter produced per 0.31 square meter by the plant was increasing from 30 to 100 DAT (Table 12, 13 and 14). The contribution of stem, leaf and root to the total dry matter accumulation was 39.1%, 30.2% and 30.7%, respectively at 25 DAT while they had the contribution to total dry matter accumulation 34.0%, 24.1% and 41.8%, respectively at 40 DAT. But at 55 DAT and 70 DAT, they had contribution o 43.2%, 24.5%, 32.3% and 49.8%, 27.1%, 23.1%, respectively. The contribution of stem, leaf, root and grain to the total were 50.7%, 19.4%, 24.7%, 5% at 85 DAT and 42. %, 13.9%, 22.9%, 21% at 100 DAT.

4.1.7.1 Effect of weed control method and variety of rice on dry matter production at 25 DAT

At 25 DAT, stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter was significantly influenced by weed control method and variety. Stem dry matter accumulated by rice plant was recorded highest (6.04 gm per 0.31 square meter) at three soil-aerating weedings and the lowest stem dry matter accumulation (3.4 gm per 0.31 square meter) at unweeded check. The same trend was observed at root and total dry matter accumulation by rice plant in gm per 0.31 square meter. The highest leaf dry matter accumulation (4.28 gm per 0.31 square meter) accumulated in rice plant at one soil-aerating weeding. One soil-aerating weeding was at par with three soil-aerating weedings (4.18 gm per 0.31 square meter), two soil-aerating weedings (3.90 gm per 0.31 square meter), chemical weeding supplemented by one hand weeding (3.76 gm per 0.31 square meter), and two hand weedings (3.38 gm per 0.31 square meter).

4.1.7.1.1 Manual weed control

There was significant difference in stem, root and total dry matter accumulation between two hand weedings and one hand weeding but there was no significant difference between them at leaf dry matter accumulation in gm per 0.31 square meter. The increment in the dry matter accumulation in rice plant at stem, root and total dry matter accumulation at two hand weedings over one hand weeding and unweeded check plot were 34.3% and 38.2%, 37.3% and 41%, and 29% and 36.9%, respectively.

4.1.7.1.2 Chemical weed control

Stem and total dry matter accumulation by rice plant in gm per 0.31 square meter were significantly different between chemical weeding supplemented by one hand weeding and chemical weeding but leaf and root dry matter accumulation by rice plant in gm per 0.31 square meter did not differ significantly. The increment in the stem and total dry matter accumulation by rice plant in gm per 0.31 square meter at chemical weeding supplemented by one hand weeding over chemical weeding and unweeded check plot were 45.4% and 49.7%, and 29.7% and 51.5%, respectively.

4.1.7.1.3 Mechanical weed control

There was significant difference in the stem dry matter production in gm per 0.31 square meter among three soil-aerating weedings (6.04 gm per 0.31 square meter), two soil-aerating weedings (5.13 gm per 0.31 square meter) and one soil-aerating weeding (4.90 gm per 0.31 square meter) but latter two treatments were at par with each other. The same trend was also seen in the total dry matter accumulation by rice plant in gm per 0.31 square meter. There was no significant difference in the leaf dry matter accumulation by rice plant in gm per 0.31 square meter among three soil-aerating weedings (4.18 gm per 0.31 square meter), two soil-aerating weedings (3.90 gm per 0.31 square meter) and one soil-aerating weeding (4.28 gm per 0.31 square meter). Root dry matter accumulation in gm per 0.31 square meter in rice plan at three soil-aerating weedings (4.61 gm per 0.31 square meter) was at par with two soil-aerating weedings (3.94 gm per 0.31 square meter).

4.1.7.1.4 Variety

Stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter was significantly influenced by varieties and the variety Ram had produced considerably better in term of stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter as compared to the variety Sabitri in under SRI methods of crop management. The increments in the stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter in rice plan at the variety Ram over the variety Sabitri were 20.7%, 35.6%, 25.6% and 26.6%, respectively.

4.1.7.2 Interaction effect of weed control method and variety of rice on dry matter production at 25 DAT

There was significant interaction effect of weed control method and variety in the stem, root and total dry matter partitioning at 25 DAT (Table 11). The variety Ram had produced comparatively higher stem dry matter accumulation than the variety Sabitri with all weed weed control method and the same trend was also noticed at root and total dry matter partitioning

At stem dry matter production, the interaction effect of three soil-aerating weedings with the variety Sabitri had resulted significantly higher stem dry matter accumulation, while the interaction effect of chemical weeding with Sabitri resulted significantly lower stem dry matter accumulation. For root dry matter production, the interaction effect of chemical weeding supplemented by one hand weeding with the variety Ram had resulted significantly higher root dry matter accumulation while the interaction effect of unweeded check with the variety Ram resulted significantly lower root dry matter accumulation. The earlier treatment was statistically at par with three soil-aerating weedings with the variety Ram, two soil-aerating weedings with the variety Ram,

For total dry matter production, the interaction effect of chemical weeding supplemented by one hand weeding with the variety Ram had resulted significantly higher total dry matter accumulation, while the interaction effect of unweeded check plot with the variety Sabitri resulted significantly lower total dry matter accumulation. The earlier treatment was statistically at par with three soil-aerating weedings with the variety Ram.

Table 11. Interaction effect of weed control method and variety of rice on dry matter production (gm/0.31 m^2) under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatments	Dry matter production (gm/0.31 m^2)^{a}					
	25 DAT					
	Stem		Root		Total	
	Variety		**Variety**		**Variety**	
	Ram	Sabitri	Ram	Sabitri	Ram	Sabitri
Weed control method						
Unweeded check	3.57^{ef}	3.29^{ef}	2.25^{g}	2.87^{fg}	8.85^{efg}	8.26^{g}
One HW at 21 DAT	3.58^{ef}	3.37^{ef}	2.86^{fg}	2.40^{g}	9.82^{defg}	8.36^{fg}
Two HWs at 21 and 42 DAT	4.93^{bcd}	4.55^{cde}	3.96^{bcde}	3.25c^{defg}	12.75^{bc}	10.69^{cdefg}
CW	4.49^{cde}	2.49^{f}	3.99^{bcde}	2.98^{efg}	11.73^{cd}	8.27^{g}
CW + one HW at 21 DAT	6.20^{a}	3.99^{de}	5.38^{a}	2.86^{fg}	16.10^{a}	9.85^{defg}
One SAW at 14 DAT	5.46^{abc}	4.35^{cde}	4.16^{bcd}	3.08^{defg}	14.37^{ab}	11.23^{cde}
Two SAWs at 14 & 28 DAT	5.98^{ab}	4.27^{cde}	4.24^{bc}	3.64^{cdef}	15.02^{ab}	10.91^{cdef}
Three SAWs at 14, 28 & 42	5.49^{abc}	6.59^{a}	4.96^{ab}	4.25^{bc}	15.21^{ab}	14.44^{ab}
LSD(P-0.05)	1.13		0.96		2.29	
SEm (±)	0.39		0.33		0.79	

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil-aerating weeding)

4.1.7.3 Effect of weed control method and variety of rice on dry matter production at 40 DAT

At 40 DAT, stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter was significantly influenced by weed control method and variety. Stem dry matter accumulated in rice plant was recorded the highest (13.27 gm per 0.31 square meter) at three soil-aerating weedings and the lowest dry matter accumulation (7.66 gm per 0.31 square meter) at unweeded check. The same trend of three soil-aerating weedings was also observed at leaf, root and total dry matter accumulation in gm per 0.31 square meter in rice plan.

4.1.7.3.1 Manual weed control

Stem, leaf and total dry matter accumulation per 0.31 square meter were significantly influenced by two hand weedings and one hand weeding but root dry matter accumulation in gm per 0.31 square meter in rice plan was not significantly influenced by hand weedings and one hand weeding. The increments in the dry matter accumulation in rice plant at stem, leaf and total dry matter accumulation at two hand weedings over one hand weeding and unweeded check plot were 44.1% and 20.9%, 18.6% and 20.5%, and 22.3% and 30.1%, respectively.

4.1.7.3.2 Chemical weed control

Stem, leaf, root and total dry matter partitioning per 0.31 square meter were significantly influenced by chemical weeding supplemented by one hand weeding and chemical weeding. The increment in total dry matter partitioning at chemical weeding supplemented by one hand weeding as compared to chemical weeding and unweeded check plot was 16% and 42%, 24.6% and 37.8%, 25.2% and 38.6%, and 22% and 38.3%, respectively.

4.1.7.3.3 Mechanical weed control

There was significant difference at stem dry matter production in gm per 0.31 square meter among three soil-aerating weedings (13.27 gm per 0.31 square meter), two soil-aerating weedings (11.37 gm per 0.31 square meter) and one soil-aerating weeding (10.78 gm per 0.31 square meter) but latter two treatments were at par with each other. The same trend was also observed at leaf dry matter accumulation in gm per 0.31 square meter in rice plan. There was no significant difference at root dry matter accumulation in gm per 0.31 square meter in rice plan between three soil-aerating weedings (16.10 gm per 0.31 square meter) and two soil-aerating weedings (15.53 gm per 0.31 square meter) but both of them were significantly different in root dry matter accumulation in rice plant with one soil-aerating weeding (12.19 gm per 0.31 square meter). For total dry matter accumulation in gm per 0.31 square meter in rice plant, there was significant difference among the treatments three soil-aerating weedings (38.22 gm per 0.31 square meter), two soil-aerating weedings (34.62 gm per 0.31 square meter) and one soil-aerating weeding (30.52 gm per 0.31 square meter). The increment in the total dry matter accumulation in gm per 0.31 square meter in rice plan at three soil-aerating weedings over two soil-aerating weedings , one soil-aerating weeding and unweeded check was 10.4%, 25.2% and 56.1%, respectively.

4.1.7.3.4 Variety

Stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter was significantly influenced by varieties and the variety Ram had produced better in term of stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter as compared to the variety Sabitri under SRI methods of crop management. The increments in the stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter in rice plan due to the variety Ram over the variety Sabitri were 10.7%, 11.3%, 11.8% and 11.3%, respectively.

Table 12. Dry matter production (gm/0.31 m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Dry matter production (gm/0.31 m^2)[a]							
	25 DAT				40 DAT			
	Stem	Leaf	Root	Total	Stem	Leaf	Root	Total
Weed control method								
Unweeded check	3.4[c]	2.57[d]	2.56[c]	8.56[c]	7.66[e]	6.24[d]	10.38[b]	24.48[f]
One HW at 21 DAT	3.5[c]	2.99[cd]	2.63[c]	9.09[c]	8.50[de]	6.34[d]	11.20[b]	26.04[ef]
Two HWs at 21 and 42 DAT	4.7[b]	3.38[abcd]	3.61[b]	11.72[b]	12.25[ab]	7.52[bc]	12.07[b]	31.84[cd]
CW	3.5[c]	3.02[bcd]	3.49[b]	10.00[c]	9.38[d]	6.90[cd]	11.49[b]	27.76[e]
CW + one HW at 21 DAT	5.09[b]	3.76[abc]	4.12[ab]	12.97[b]	10.88[c]	8.60[ab]	14.39[a]	33.86[bc]
One SAW at 14 DAT	4.90[b]	4.28[a]	3.62[b]	12.80[b]	10.78[c]	7.55[bc]	12.19[b]	30.52[d]
Two SAWs at 14 & 28 DAT	5.13[b]	3.90[ab]	3.94[ab]	12.97[b]	11.37[bc]	7.71[bc]	15.53[a]	34.62[b]
Three SAWs at 14, 28 & 42 DAT	6.04[a]	4.18[a]	4.61[a]	14.83[a]	13.27[a]	8.84[a]	16.10[a]	38.22[a]
LSD(P-0.05)	0.80	0.82	0.68	1.62	1.17	0.10	1.80	2.46
SEm (±)	0.28	0.28	0.24	0.56	0.40	0.35	0.62	0.85
Variety								
Ram	4.96[a]	4.04[a]	3.98[a]	12.98[a]	11.07[a]	7.86[a]	13.64[a]	32.57[a]
Sabitri	4.11[b]	2.98[b]	3.17[b]	10.25[b]	10.00[b]	7.06[b]	12.20[b]	29.26[b]
Grand mean	4.54	3.51	3.57	11.62	10.54	7.46	12.92	30.92
LSD(P-0.05)	0.49	0.50	0.42	0.10	0.72	0.61	1.10	1.50
CV%	14.87	19.83	16.20	11.81	9.42	11.36	11.78	6.75
SEm (±)	0.17	0.17	0.15	0.34	0.25	0.21	0.38	0.52

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.7.4 Effect of weed control method and variety of rice on dry matter production at 55 DAT

At 55 DAT, stem, leaf, root and total dry matter per 0.31 square meter were significantly influenced by weed control method and variety. Stem dry matter accumulation was significantly higher at three soil-aerating weedings (34.31 gm per 0.31 square meter) and stem dry matter was accumulation non-significant with chemical weeding supplemented by one hand weeding (42.58 gm per 0.31 square meter). But leaf dry matter was significantly higher at chemical weeding supplemented by one hand weeding (23.60 gm per 0.31 square meter) and it was at par with three soil-aerating weedings (23.31 gm per 0.31 square meter). The highest root dry matter accumulation was observed at three soil-aerating weedings (32.85 gm per 0.31 square meter) followed by chemical weeding (29.84 gm per 0.31 square meter) and two soil-aerating weedings (25.15 gm per 0.31 square meter). Total dry matter accumulation was significantly higher with three soil-aerating weedings (100.21 gm per 0.31 square meter), chemical weeding (79.17 gm per 0.31 square meter) and one soil-aerating weeding (67.47 gm per 0.31 square meter) but total dry matter accumulation was at par with chemical weeding supplemented by one hand weeding (96.08 gm per 0.31 square meter).

4.1.7.4.1 Manual weed control

For stem dry matter accumulation, two hand weedings (33.30 gm per 0.31 square meter) was significantly different one hand weeding (28.16 gm per 0.31 square meter) and unweeded check plot (16.86 gm per 0.31 square meter) and the increment in stem dry matter accumulation for two hand weedings (33.30 gm per 0.31 square meter) over one hand weeding (28.16 gm per 0.31 square meter) and unweeded check plot (16.86 gm per 0.31 square meter) was 18.3% and 97.5%. The same trend was also seen in the leaf, root and total dry matter production and the increment in the dry matter production in the rice plant at two hand weedings over one hand weeding and unweeded check plot were 22.2 % and 112.7%-leaf, 15.9 % and 70.2%- root, 18.5 % and 120%- total.

4.1.7.4.2 Chemical weed control

Stem, leaf and total dry matter accumulation per 0.31 square meter were significantly influenced by weed control method and variety but root dry matter accumulation per 0.31 square meter was non- significant with them. The increments in the dry matter accumulation at chemical weeding supplemented by one hand weeding over chemical weeding were 38.1 % and 152.6%, 27.9 % and 150.3%, and 21.4 and 173%, for stem, leaf and total dry matter accumulation, respectively.

4.1.7.4.3 Mechanical weed control

Stem, root and total dry matter accumulation per 0.31 square meter were significantly influenced by weed control method and variety while at leaf dry matter accumulation, three soil-aerating weedings (23.31 gm per 0.31 square meter) was significantly different with two soil-aerating weedings (18.25 gm per 0.31 square meter) and one soil-aerating weeding (17.43 gm per 0.31 square meter) but latter two treatments were non-significant. The increment in the dry matter accumulation at three soil-aerating weedings over two soil-aerating weedings, one soil-aerating weeding and unweeded check plot were 28.4%, 56.3% and 161.3%; 30.6%, 50.7% and 269.1%; 29.3%, 48.7% and 187.8%, for stem, root and total dry matter accumulation per 0.31 square meter, respectively.

4.1.7.4.4 Variety

There was no significant effect in terms of stem and leaf dry matter partitioning between the variety Ram and Sabitri but these varieties was significantly different in terms of root and total dry matter partitioning. The increment in the dry matter accumulation at the variety Ram over the variety Sabitri was 6.9% and 55.4%, respectively.

4.1.7.5 Effect of weed control method and variety of rice on dry matter production at 70 DAT

At 70 DAT, stem, leaf, root and total dry matter accumulation per 0.31 square meter were significantly influenced by weed control method and variety. There was significantly higher stem dry matter accumulation at two hand weedings (91.53 gm per 0.31 square meter) and the lowest at unweeded check plot (45.82 gm per 0.31 square meter). In the similar way, there was significantly higher leaf, root and total dry matter partitioning at three soil-aerating weedings (49.46 gm per 0.31 square meter), three soil-aerating weedings (53.50 gm per 0.31 square meter) and two hand weedings (176.35 gm per 0.31 square meter), respectively and the lowest leaf, root and total dry matter partitioning at unweeded check plot i.e. 45.82, 24.16, 16.97 and 86.95 gm per 0.31 square meter, respectively.

4.1.7.3.1 Manual weed control

Stem, leaf, root and total dry matter accumulation per 0.31 square meter were significantly influenced by two hand weedings and one hand weeding. The increment in dry matter accumulation at two hand weedings over one hand weeding and unweeded check plot at stem, leaf, root and total dry matter partitioning were 77.8 % and 99.8%, 42.5 % and 68.8%, 137.2% and 171.3%, and 79.3% and 105.1%, respectively.

4.1.7.3.2 Chemical weed control

Stem, leaf, root and total dry matter partitioning per 0.31 square meter were significantly influenced by chemical weeding supplemented by one hand weeding and chemical weeding. The increment in the dry matter partitioning at chemical weeding supplemented by one hand weeding as compared to chemical weeding and unweeded check plot was 14.5% and 66.8%, 15.1% and 71.4%, 70.6% and 125.4%, and 23% and 77.5%, respectively.

4.1.7.3.3 Mechanical weed control

There was significant difference in the stem, leaf, root and total dry matter accumulation among three soil-aerating weedings, two soil-aerating weedings, one soil-aerating weeding and unweeded check plot. The increments in the stem, leaf, root and total dry matter accumulation per 0.31 square meter at three soil-aerating weedings over two soil-aerating weedings, one soil-aerating weeding and unweeded check plot were 8.1%, 19% and 51.3%; 39.3%, 5.8% and 104.7%; 97.1%, 97.1% and 215.3%; 35.9%, 59% and 98.1%, respectively.

4.1.7.3.4 Variety

Leaf, root and total dry matter accumulation in gm per 0.31 square meter were significantly influenced by variety while stem dry matter accumulation in gm per 0.31 square meter was not significantly influenced and the variety Ram had produced better in term of stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter as compared to the variety Sabitri under SRI methods of crop management. The increment in leaf, root and total dry matter accumulation by rice plant in gm per 0.31 square meter of the variety Ram over the variety Sabitri were 4.4 %, 6.9% and 3.8%, respectively.

Table 13. Dry matter production (gm/0.31 m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Dry matter production (gm/0.31 m^2)[a]							
	55 DAT				70 DAT			
	Stem	Leaf	Root	Total	Stem	Leaf	Root	Total
Weed control method								
Unweeded check	16.86[e]	9.43[e]	8.90[f]	35.19[d]	45.82[h]	24.16[e]	16.97[g]	86.95[g]
One HW at 21 DAT	28.16[d]	16.41[d]	20.75[e]	65.31[c]	51.47[g]	28.62[d]	19.41[fg]	99.50[f]
Two HWs at 21 and 42 DAT	33.30[bc]	20.06[b]	24.05[cd]	77.40[b]	91.53[a]	40.78[b]	46.04[b]	178.35[a]
CW	30.84[cd]	18.45[bc]	29.87[b]	79.17[b]	66.75[d]	35.98[c]	22.75[e]	125.47[d]
CW + one HW at 21 DAT	42.58[a]	23.60[a]	29.89[b]	96.08[a]	76.41[b]	41.41[b]	36.56[c]	154.37[c]
One SAW at 14 DAT	28.18[d]	17.43[cd]	21.80[de]	67.41[c]	58.10[f]	29.31[d]	20.94[ef]	108.35[e]
Two SAWs at 14 & 28 DAT	34.31[b]	18.05[cd]	25.15[c]	77.50[b]	64.09[e]	35.51[c]	27.15[d]	126.75[d]
Three SAWs at 14, 28 & 42 DAT	44.05[a]	23.31[a]	32.85[a]	100.21[a]	69.31[c]	49.46[a]	53.50[a]	172.26b[b]
LSD(P-0.05)	3.21	1.87	2.29	4.45	2.39	2.37	2.97	4.05
SEm (±)	1.11	0.65	0.79	1.54	0.83	0.82	1.03	1.40
Variety								
Ram	32.95[a]	18.89[a]	24.96[a]	76.80[a]	66.14[a]	36.42[a]	31.42[a]	133.98[a]
Sabitri	31.62[a]	17.79[a]	23.36[b]	72.77[b]	64.73[a]	34.89[b]	29.40[b]	129.02[b]
Grand mean	32.28	18.34	24.16	74.78	65.43	35.65	30.41	131.50
LSD(P-0.05)	1.97	1.14	1.40	2.72	1.46	1.45	1.82	2.48
CV%	7.91	8.27	8.02	5.05	3.10	5.64	8.29	2.61
SEm (±)	0.68	0.40	0.48	0.94	0.51	0.50	0.63	0.86

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.1.7.6 Effect of weed control method and variety of rice on dry matter production at 85 DAT

At 85 DAT, stem, leaf, root and total dry matter accumulation per 0.31 square meter were significantly influenced by weed control method and variety. Stem dry matter accumulation was significantly higher (125.24 gm per 0.31 square meter) at three soil-aerating weedings and this treatment was non-significant with chemical weeding supplemented by one hand weeding (136.68 gm per 0.31 square meter).The same trend was also observed at root dry matter production in gm per 0.31 square meter. But leaf dry matter accumulation was significantly higher (53.39 gm per 0.31 square meter) at chemical weeding supplemented by one hand weeding and it was at par with three soil-aerating weedings (52.74 gm per 0.31 square meter). The same trend was also noticed at grain and total dry matter accumulation in gm per 0.31 square meter.

4.1.7.6.1 Manual weed control

Stem, leaf, root and total dry matter accumulation per 0.31 square meter were significantly influenced by two hand weedings and one hand weeding but grain dry matter accumulation per 0.31 square meter did not differ significantly between these two treatments. The increment in stem, leaf, root and total dry matter partitioning at two hand weedings over one hand weeding and unweeded check plot were 22.8% and 86.1%, 24.7% and 74.9%, 39.9% and 58.1%, and 27.2% and 75.6%, respectively.

4.1.7.6.2 Chemical weed control

Stem, leaf, root, grain and total dry matter partitioning per 0.31 square meter were significantly influenced by chemical weeding supplemented by one hand weeding and chemical weeding. The increments in the stem, leaf, root, grain and total dry matter partitioning per 0.31 square meter at chemical weeding supplemented by one hand weeding as compared to chemical weeding and unweeded check plot were 26.3% and

99.4%, 25.5% and 95.6%, 27.5% and 67.3%, 164.6% and 819%, and 34.8% and 102.8%, respectively.

4.1.7.6.3 Mechanical weed control

There was significant difference in stem, leaf, root, grain and total dry matter accumulation among three soil-aerating weedings, two soil-aerating weedings, one soil-aerating weeding and unweeded check plot. The increment in stem, leaf, root, grain and total dry matter accumulation per 0.31 square meter at three soil-aerating weedings over two soil-aerating weedings, one soil-aerating weeding and unweeded check plot were 9.7%, 25.9% and 97.3%; 21.4%, 25.2% and 93.3%; 25.4%, 42.9% and 70.8%; 75.6%, 116% and 725.9%; 19.1%, 34.1% and 100.8%, respectively.

4.1.7.6.4 Variety

Stem, leaf, root, grain and total dry matter accumulation in gm per 0.31 square meter was significantly influenced by variety and the variety Ram had produced better in terms of stem, leaf, root, grain and total dry matter accumulation in gm per 0.31 square meter as compared to the variety Sabitri under SRI method of crop management. The increments in the stem, leaf, root, grain and total dry matter accumulation in gm per 0.31 square meter in rice plan at the variety Ram over the variety Sabitri were 1.4%, 6%, 3.8%, 29.6%, and 4.2%, respectively.

4.1.7.7 Effect of weed control method and variety of rice on dry matter production at 100 DAT

At 100 DAT, stem, leaf, root, grain and total dry matter accumulation in gm per 0.31 square meter were significantly influenced by weed control method and variety. Stem dry matter accumulation in rice plant was recorded the highest (149.80 gm per 0.31 square meter) at three soil-aerating weedings and the lowest dry matter accumulation (94.77gm per 0.31 square meter) at unweeded check plot. The same trend was also observed at leaf and root matter accumulation in gm per 0.31 square meter in rice plan. Again, grain dry matter accumulation in rice plant was recorded the highest (77.84 gm per 0.31 square meter) at chemical weeding supplemented by one hand weeding, and the lowest dry matter accumulation (48.78 gm per 0.31 square meter) in unweeded check plot. The same trend was also observed at total dry matter accumulation in gm per 0.31 square meter in rice plan.

4.1.7.7.1 Manual weed control

Stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter were significantly influenced by doing two hand weedings as compared to one hand weeding but there was no significant difference in grain dry matter accumulation in grams per 0.31 square meter in rice plants between two hand weedings and one hand weeding. The increment in the dry matter accumulation in the rice plants by stem, leaf, root and total dry matter accumulation from two hand weedings vs. one hand weeding and unweeded check plots were 25.3% and 40.1%, 40.8% and 47.5%, 21.9% and 28.6%, and 24.5% and 34%, respectively.

4.1.7.7.2 Chemical weed control

Stem, leaf, root and total dry matter partitioning per 0.31 square meter were significantly influenced by chemical weeding supplemented by one hand weeding compared with chemical weeding at 100 DAT only, but grain dry matter accumulation in rice plant in grams per 0.31 square meter was not significantly different between chemical weeding supplemented by one hand weeding and chemical weeding. The increments in the stem, leaf and root and total dry matter partitioning resulting from chemical weeding supplemented by one hand weeding as compared to chemical weeding and unweeded check were 37.2% and 55.4%, 15% and 53.8%, 8.1% and 48.7%, and 17.6% and 54.7%, respectively.

4.1.7.7.3 Mechanical weed control

There was significant difference in stem dry matter production in gm per 0.31 square meter among three soil-aerating weedings (149.80 gm per 0.31 square meter), two soil-aerating weedings (131.70 gm per 0.31 square meter) and one soil-aerating weeding (130.91 gm per 0.31 square meter) and the same trend was also observed at total dry matter accumulation in gm per 0.31 square meter. The increment in the stem and total dry matter accumulation in gm per 0.31 square meter in rice plan from three soil-aerating weedings over two soil-aerating weedings, one soil-aerating weeding and unweeded check plots were 13.7%, 14.4% and 58.1%; 12.2%, 21% and 53.9%, respectively.

There was no significant difference at leaf dry matter accumulation in gm per 0.31 square meter in rice plant by using three soil-aerating weedings (47.98 gm per 0.31 square meter) and two soil-aerating weedings (44.22 gm per 0.31 square meter) and also between two soil-aerating weedings (44.22 gm per 0.31 square meter) and one soil-aerating weeding (40.68 gm per 0.31 square meter) but three soil-aerating weedings (47.98 gm per 0.31 square meter) had significant difference in leaf dry matter accumulation with one soil-aerating weeding (40.68 gm per 0.31 square meter).

There was no significant effect in the root dry matter accumulation in gm per 0.31 square meter in rice plan at three soil-aerating weedings (79.92 gm per 0.31 square meter) and two soil-aerating weedings (76.75 gm per 0.31 square meter) but three soil-aerating weedings (79.92 gm per 0.31 square meter) had significant difference with one soil-aerating weeding (59.47 gm per 0.31 square meter). Grain dry matter accumulation in gm per 0.31 square meter in rice plan was significantly different among three soil-aerating weedings (71.75 gm per 0.31 square meter), two soil-aerating weedings (58.78 gm per 0.31 square meter) and one soil-aerating weeding (57.80 gm per 0.31 square meter) but latter two treatments were at par with each other.

4.1.7.7.4 Variety

Stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter were significantly co-influenced by varieties under SRI methods of crop management while grain dry matter accumulation in gm per 0.31 square meter was not significantly influenced. The variety Ram produced better in terms of stem, leaf, root and total dry matter accumulation in gm per 0.31 square meter as compared to the variety Sabitri under SRI method of crop management. The increments in the stem, leaf, root, and total dry matter accumulation in gm per 0.31 square meter in rice plant at the variety Ram over Sabitri were 2 %, 8.3%, 3.3% and 4.2%, respectively.

Thus, on the basis of above results, it can be described that initial investment of biomass partitioning was in the leaf at 25 DAT and root at 40 DAT, later in the stem up to 85 DAT and ultimately in the storage organ i.e. panicle at 100 DAT. Use of three soil-aerating weedings brought significant increment in total dry matter accumulation in rice plant under SRI method of crop management. This might be due to the fact that mechanical weeding increased the soil aeration by dissolved oxygen in irrigation water rather than from the deeper part of the soil thereafter increasing shoot: root ratio and leaf area index which subsequently increased total dry matter accumulation (Uphoff, 2002). Hasegawa (2003) reported that higher yields of rice cultivars were associated with higher dry matter accumulation. Three soil-aerating weedings was closely followed by chemical weeding supplemented by one hand weeding. There was significant positive correlation (r = 0.986 ** and r = 0.974**) between total dry matter accumulation (gm per 0.31 square meter) at 85 and 100 DAT and yield (t ha^{-1}), respectively (Appendix 16). The contribution from total dry matter accumulation at 85 and 100 DAT (gm per 0.31 square meter) to yield (t ha^{-1}) was 97.2% and 94.8%, respectively; while from other parameter was 2.8% and 5.2%, respectively(Figure 3).

Table 14. Dry matter production (gm/0.31 m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Dry matter production (gm/0.31 m^2)[a]									
	85 DAT					100 DAT				
	Stem	Leaf	Root	Grain	Total	Stem	Leaf	Root	Grain	Total
Weed control method										
Unweeded check	68.54[f]	27.29[e]	40.78[f]	2.66[f]	139.27[f]	94.77[h]	30.80[c]	52.79[e]	48.78[b]	227.13[f]
One HW at 21 DAT	103.88[e]	38.26[d]	46.10[e]	4.06[ef]	192.30[e]	105.90[g]	32.25[c]	55.70[e]	50.59[b]	244.44[e]
Two HWs at 21 and 42 DAT	127.55[b]	47.72[b]	64.49[b]	4.86[e]	244.61[b]	132.74[c]	45.42[ab]	67.91[c]	58.22[b]	304.28[bc]
CW	108.20[d]	42.53[c]	49.60[d]	9.14[d]	209.48[d]	107.70[f]	41.19[b]	72.64[b]	77.41[a]	298.94[cd]
CW + one HW at 21 DAT	136.68[a]	53.39[a]	68.22[a]	24.18[a]	282.47[a]	147.75[b]	47.38[a]	78.49[a]	77.84[a]	351.45[a]
One SAW at 14 DAT	107.41[d]	42.14[cd]	48.77[d]	10.17[d]	208.48[d]	130.91[e]	40.68[b]	59.47[d]	57.80[b]	288.86[d]
Two SAWs at 14 & 28 DAT	123.33[c]	43.46[c]	55.57[c]	12.51[c]	234.86[c]	131.70[d]	44.22[ab]	76.75[a]	58.78[b]	311.45[b]
Three SAWs at 14, 28 & 42 DAT	135.24[a]	52.74[a]	69.67[a]	21.97[b]	279.62[a]	149.80[a]	47.98[a]	79.92[a]	71.75[a]	349.45[a]
LSD(P-0.05)	2.69	3.91	2.55	1.93	5.78	0.72	4.56	3.60	9.66	11.59
SEm (±)	0.93	1.35	0.88	0.67	2.00	0.25	1.58	1.25	3.35	4.01
Variety										
Ram	114.70[a]	44.70[a]	56.45[a]	12.64[a]	228.48[a]	126.41[a]	42.89[a]	69.06[a]	65.49[a]	303.86[a]
Sabitri	113.07[b]	42.19[b]	54.36[b]	9.75[b]	219.29[b]	123.90[b]	39.59[b]	66.85[b]	59.80[a]	290.14[b]
Grand mean	113.85	43.44	55.40	11.19	223.89	125.16	41.24	67.96	62.65	297.00
LSD(P-0.05)	1.65	2.40	1.56	1.18	3.54	0.44	2.79	2.20	5.92	7.10
CV%	2.00	7.64	3.91	14.65	2.19	3.20	9.38	4.49	13.08	3.31
SEm (±)	0.57	0.83	0.54	0.41	1.23	0.15	0.97	0.76	2.05	2.46

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

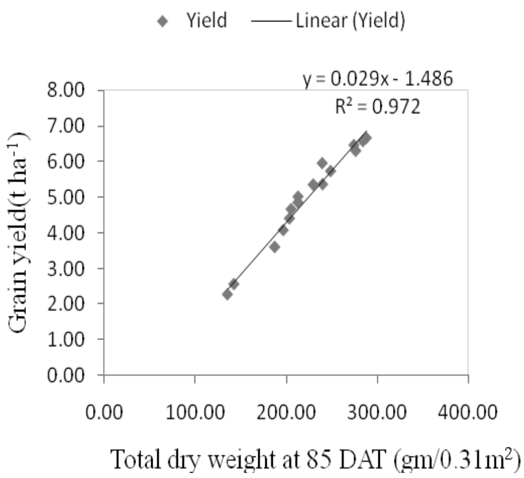

Figure (a)

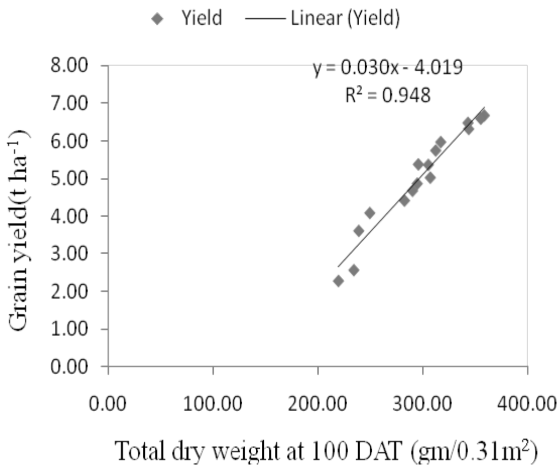

Figure (b)

Figure 3. Relationship between total dry weight production (gm per 0.31 square meter) at 85 DAT to grain yield (t ha^{-1}) in fig. (a) and total dry weight production (gm per 0.31 square meter) at 100 DAT to grain yield (t ha^{-1}) in fig. (b) of rice at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

4.2 Effect of weed control method and variety of rice on weed flora, weed density, weed dry weight and weed control efficiency under SRI practices

4.2.1 Weed flora

The dominant grass species were *Cynodon dactylon* (L.) Pers., *Echinochloa colonum* (L.) Link., *Commelina diffusa* Burm f., *Digitaria ciliaris* (Retz.) Koel., *Eleusine indica* (L.) Gaertn and sedges were *Cyperus rotundus* L., *Cyperus esculentus* L., *Fimbristylis miliaceae* (L.) Vahl. while broad leaves species were Ageratum connyzoids L. Similar weed species were also reported in rice field by Acharya *et al*. (2007). Monocot weed species appeared along the early stage while dicot weed species were most dominant at later stages.

At 21 DAT, *Cyperus esculentus* L. was found dominant weed species (40.53%) but at 42 DAT, *Commelina diffusa* Burm f. was found dominant weed species (42.19%). At 63, *Cyperus esculentus* L. (38.92%) was found dominant weed species followed by

Ageratum connyzoids (35.18%) while at harvest *Commelina diffusa* Burm f. (52.99%) and *Fimbristylis miliaceae* (L.) Vahl. (34.76%) were dominant weed species.

4.2.2 Weed density

On an average, the weed density varied from 109.42 to 565.42 per square meter (Table 15) depending on weed control method and variety used in all trials. The weed density was significantly influenced by weed control method while it did not differ significantly by variety.

4.2.2.1 Effect of weed control method on weed density

At 21 DAT, significantly higher weed density (1062.00 per square meter) recorded at unweeded check plot and lower weed density (242.67 per square meter) from chemical weeding supplemented by one hand weeding. Similar results were observed by Singh and Bhandari (1986), Singh (1996), Thapa and Jha (2002) who reported that the highest weed density and dry weight of weed was recorded in weedy plots. Chemical weeding supplemented by one hand weeding produced less weed density (242.67) which was followed by chemical weeding (304.00 per square meter), two soil-aerating weedings (350.67 per square meter), three soil-aerating weedings (436.67 per square meter) and one soil-aerating weeding (446.67 per square meter).

At 42 DAT, the highest weed density was recorded at unweeded check treatment (736.00 per square meter) while it was the lowest at chemical weeding supplemented by one hand weeding (338.67 per square meter). The latter treatment was at par with three soil-aerating weedings (375.33 per square meter), two soil-aerating weedings (397.33 per square meter), chemical weeding (426.67 per square meter), one soil-aerating weeding (434.67 per square meter) and two hand weedings (536.00 per square meter).

At 63 DAT, unweeded check plot (800.67 per square meter) recorded the highest weed density and the lowest weed density was recorded at three soil-aerating weedings

(225.33 per square meter), which was at par with two hand weedings (255.33 per square meter), two soil-aerating weedings (296.67 per square meter), chemical weeding supplemented by one hand weeding (365.33 per square meter) and chemical weeding (375.33 per square meter).

At harvesting stage, unweeded check plot (214.67 per square meter) recorded the highest weed density and the lowest weed density was recorded at three soil-aerating weedings (46.67 per square meter). There was no significant difference in weed density between two soil-aerating weedings (67.33 per square meter) and one soil-aerating weeding (76.00 per square meter).

Thus, on the basis of above results, it can be decided that the trend of weed density was in descending order from 21 DAT to harvesting stage. Use of chemical weeding supplemented by one hand weeding drastically reduced weed density at the early stage of crop growth while three soil-aerating weedings drastically reduced weed density at the later stage of crop growth.

Table 15. Variation in weed density (No. /m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Weed density (No./m^2)			
	21 DAT	42 DAT	63 DAT	Harvest
Weed control method				
Unweeded check	32.23(1062.00)[a]	26.32(736.00)[a]	27.99(800.67)[a]	14.59(214.67)[a]
One HW at 21 DAT	27.87(834.00)[a]	26.64(727.33)[a]	26.00(696.67)[a]	11.57(137.33)[b]
Two HWs at 21 and 42 DAT	28.94(846.67)[a]	22.00(536.00)[ab]	15.62(255.33)[bc]	11.03(124.67)[bc]
CW	16.39(304.00)[b]	20.31(426.67)[b]	18.31(375.33)[bc]	10.02(110.00)[bcd]
CW + one HW at 21 DAT	15.24(242.67)[b]	17.77(338.67)[b]	18.85(365.33)[bc]	9.51(98.67)[bcd]
One SAW at 14 DAT	20.21(446.67)[b]	20.78(434.67)[b]	20.02(403.33)[b]	8.55(76.00)[cde]
Two SAWs at 14 & 28 DAT	18.65(350.67)[b]	19.21(397.33)[b]	16.99(296.67)[bc]	8.10(67.33)[de]
Three SAWs at 14, 28 & 42 DAT	19.93(436.67)[b]	19.12(375.33)[b]	14.43(225.33)c	6.74(46.67)[e]
LSD(P-0.05)	6.40	4.65	4.92	2.53
SEm (±)	2.21	1.61	1.70	0.88
Variety				
Ram	22.37(552.33)	21.11(477.50)	19.33(409.50)	10.14(112.33)
Sabitri	22.49(578.50)	21.93(515.50)	20.23(445.17)	9.88(106.50)
Grand mean	22.43(565.42)	21.52(496.50)	19.78(427.33)	10.01(109.42)
LSD(P-0.05)	NS	NS	NS	NS
CV%	24.17	18.33	21.09	18.33
SEm (±)	1.36	0.99	1.04	0.54

Data subjected to square-root ($\sqrt{X+0.5}$) transformation; figures in parentheses are original values; Mean separated by DMRT and columns represented with same letters are non significant at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.2.3 Weed dry weight

On an average, the dry weight of weed ranged from 41.56 to 146.70 gm per square meter (Table 16) depending on weed control method and variety used in all treatments. The dry weight of weed was significantly influenced by weed control methods while dry weight of weed was not significantly influenced by varieties except at 21 DAT.

4.2.3.1 Effect of weed control method on weed dry weight

At 21 DAT, the maximum dry weight of weed was noticed at unweeded check plot (47.33 gm per square meter) while the minimum at one soil-aerating weeding (39.59 gm per square meter). There was no significant difference among two soil-aerating weedings (40.23 gm per square meter), chemical weeding supplemented by one hand weeding (40.35 gm per square meter), three soil-aerating weedings (40.43 gm per square meter), chemical weeding (40.75 gm per square meter) and one hand weeding (41.40 gm per square meter) in terms of dry weight of weed.

At 42 DAT, the maximum dry weight of weed was recorded at unweeded check plot (142.19 gm per square meter) while the minimum at three soil-aerating weedings (15.05 gm per square meter), which was at par with chemical weeding supplemented by one hand weeding (18.35 gm per square meter).

At 63 DAT, unweeded check plot (346.25 gm per square meter) recorded the maximum weed density and the minimum weed density was recorded at three soil-aerating weedings (12.29 gm per square meter). The latter treatment was at par with chemical weeding supplemented by one hand weeding (73.49 gm per square meter), two hand weedings (73.46 gm per square meter) and two soil-aerating weedings (76.93 gm per square meter).

At harvesting, unweeded check treatment (270.37 gm per square meter) recorded the maximum weed density and the minimum weed density was recorded at three soil-aerating weedings (67.23 gm per square meter). Three soil-aerating weedings did not differ significantly with two hand weedings (54.73 gm per square meter), chemical weeding supplemented by one hand weeding (96.65 gm per square meter), two soil-aerating weedings (105.35 gm per square meter) and one soil-aerating weeding (139.41 gm per square meter).

4.2.3.2 Effect of variety on weed dry weight

The dry weight of weed was significantly influenced by varieties at 21 DAT only and was not significantly influenced at later growth stages of rice crop i.e. between 42 DAT to harvest. The variety Ram recorded significantly the maximum dry weight of weed (42.73 gm per square meter) as compared to the variety Sabitri (40.40 gm per square meter).

Thus, on the basis of above results, it can be stated that weed dry weight was drastically reduced by using one soil-aerating weeding at the early stage i.e. at 21 DAT and thereafter it gradually decreased by using three soil-aerating weedings at the later crop growth stages.

4.2.4 Weed control efficiency

At 21 DAT, the highest weed control efficiency (17.05%) was recorded at one soil-aerating weeding and the lowest at unweeded check plot (0.00 %) (Table 16). One soil-aerating weeding did not differ significantly with two soil-aerating weedings (15.71%), chemical weeding supplemented by one hand weeding (15.46%) and three soil-aerating weedings (15.29%). The highest weed control efficiency (15.36%) was recorded with the variety Sabitri and the lowest with the variety Ram (10.48%).

At 42 DAT, three soil-aerating weedings recorded the highest weed control efficiency (89.42%) and unweeded check treatment recorded the lowest weed control efficiency (0.00%). Three soil-aerating weedings did not differ significantly with chemical weeding supplemented by one hand weeding (87.09%), two soil-aerating weedings (61.38%) and chemical weeding (55.69%). The highest weed control efficiency (58.88%) was recorded with variety Ram and the lowest with the variety Sabitri (42.99%).

At 63 DAT, three soil-aerating weedings recorded the highest weed control efficiency (96.45%) and unweeded check plot recorded the lowest weed control efficiency (0.00%). Three soil-aerating weedings did not differ significantly with chemical weeding supplemented by one hand weeding (78.78%), two hand weedings (78.78%) and two soil-aerating weedings (77.78%). The highest weed control efficiency (58.33%) was recorded with the variety Sabitri and the lowest with the variety Ram (56.73%).

At harvesting stage, the highest weed control efficiency (79.76%) was recorded at two hand weedings and lowest at unweeded check (0.00%). Two hand weedings was at par with two soil-aerating weedings (61.03%), chemical weeding supplemented by one hand weeding (64.25%) and two soil-aerating weedings (61.03%). The highest weed control efficiency (52.71%) was recorded with the variety Ram and the lowest with the variety Sabitri (44.91%).

Thus, on the basis of above results, it can be stated that weed control efficiency was found to be highest in one soil-aerating weeding at 21 DAT, and thereafter it was highest at three soil-aerating weedings during 42 to 63 DAT, but two hand weedings was found to be highest at harvesting stage.

Table 16. Variation in weed dry weight (gm/m^2) and weed control efficiency (%) as influenced by weed control method and variety of rice under SRI practices at Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Weed dry weight (gm/m^2)				Weed control efficiency (%)			
	21 DAT	42 DAT	63 DAT	Harvest	3	6	9	Harvest
Weed control method								
Unweeded check	6.94(47.73)^{a}	11.29(142.19)^{a}	17.92(346.25)^{a}	16.08(270.37)^{a}	0.00	0.00	0.00	0.00
One HW at 21 DAT	6.47(41.40)^{b}	11.12(125.81)^{a}	15.00(237.79)^{ab}	13.57(187.15)^{ab}	13.26	11.52	31.32	30.78
Two HWs at 21 and 42 DAT	6.52(42.01)^{b}	7.87(68.97)^{b}	8.46(73.46)^{c}	7.31(54.73)^{c}	11.98	51.49	78.78	79.76
CW	6.42(40.75)^{b}	7.37(63.01)^{bc}	11.12(127.34)^{bc}	12.62(186.35)^{ab}	14.62	55.69	63.22	31.08
CW + one HW at 21 DAT	6.39(40.35)^{b}	4.23(18.35)^{cd}	8.27(73.49)^{c}	9.70(96.65)^{bc}	15.46	87.09	78.78	64.25
One SAW at 14 DAT	6.33(39.59)^{b}	7.97(69.83)^{b}	14.63(226.07)^{ab}	11.05(139.41)^{bc}	17.05	50.89	34.71	48.44
Two SAWs at 14 & 28 DAT	6.38(40.23)^{b}	6.99(54.91)^{bc}	8.47(76.93)^{c}	10.04(105.35)^{bc}	15.71	61.38	77.78	61.03
Three SAWs at 14, 28 & 42	6.39(40.43)^{b}	3.82(15.05)d	3.35(12.29)^{d}	8.09(67.23)c	15.29	89.42	96.45	75.13
LSD(P-0.05)	0.24	3.00	4.05	3.80				
SEm (±)	0.08	1.04	1.40	1.32				
Variety								
Ram	6.57(42.73)^{a}	6.87(58.47)	11.05(149.82)	10.75(127.86)	10.48	58.88	56.73	52.71
Sabitri	6.39(40.40)^{b}	8.29(81.06)	10.75(143.59)	11.37(148.96)	15.36	42.99	58.53	44.91
Grand mean	6.48(41.56)	7.58(69.77)	10.90(146.70)	11.06(138.41)				
LSD(P-0.05)	0.14	NS	NS	NS				
CV%	3.08	33.50	31.53	29.15				
SEm (±)	0.05	0.64	2.48	0.81				

Data subjected to square-root ($\sqrt{X+0.5}$) transformation; figures in parentheses are original values; Mean separated by DMRT and columns represented with same letters are non significant at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.3 Effect of weed control method and variety on yield-contributing characteristics of rice under SRI practices

4.3.1 Number of effective tillers per square meter

Grain yield of cereals is highly dependent upon the number of effective tillers per produced by each plant (Power and Alessi, 1978; Nerson, 1980). According to the data presented in Table 17, the average number of effective tillers per square meter across all treatments was 248.44, ranging from 194.67 to 297.33 depending on weed control method and variety used. In general, the number of effective tillers per square meter was significantly influenced by both weed management and variety, but the interaction effect of weed control method and variety was non-significant.

4.3.1.1 Effect of weed control method on number of effective tillers per square meter

Three soil-aerating weedings produced significantly higher number of effective tillers per square meter (282.67), two hand weedings (254.17), chemical weeding (249.67), one soil-aerating weeding (235.00), and unweeded check (198.00). However, number of effective tillers per square meter did not differ significantly between chemical weeding supplemented by one hand weeding (280.50), and two soil-aerating weedings (261.33).

Three soil-aerating weedings (282.67) had increased the number of effective tillers per square meter over two hand-weedings (254.17), one soil-aerating weeding (235.00), and unweeded check (198.00), by 8.2%, 20.3% and 42.8%, respectively. The increase in the number of effective tillers per square meter due to chemical weeding supplemented with one hand-weeding (280.50) over chemical weeding (249.67) and unweeded check (198.00) were 17.4% and 41.7%, respectively. The increment in the number of effective tillers per square from two hand weedings (254.17) were 12.4% and 28.4%, respectively, over one hand weeding (280.50) and unweeded check (198.00).

4.3.1.2 Effect of variety on number of effective tillers per square meter

There was significant difference in the number of effective tillers per square between the two varieties, when grown with the same methods or set of practices, the variety Ram (265.25) and Sabitri (231.63).

Thus, on the basis of above results, it can be mentioned that the rice yield (t ha^{-1}) was significantly positively correlated with the number of effective tillers per square meter (r=0.878**) (Appendix 17). Three soil-aerating weedings produced significantly higher number of effective tillers per square meter which was at par with chemical weeding supplemented by one hand weeding and two soil-aerating weedings. The variety Ram comparatively produced higher number of effective tillers per square meter than the variety Sabitri.

4.3.2 Panicle length

The average panicle length in the experiment for all trials, and all combinations of practices was 25.85 cm (Table 17), ranging from 24.37 to 26.62 cm depending upon the particular combination of weed control method and variety involved. Statistical analysis of the data indicated that the panicle length differed significantly with weed control method only but there was non-significant effect in terms of panicle length with variety and the interaction effect of weed control method and variety.

4.3.2.1 Effect of weed control method on panicle length

Higher panicle length was produced by two hand weedings (26.43 cm), which was only significant over unweeded check plot (24.66 cm). However, no significant differences were observed among the remaining weed control method.

4.3.2.2 Effect of variety on panicle length

The higher panicle length was produced by the variety Sabitri (26.09 cm) which was not significantly different with the variety Ram (25.60 cm), but produced 1.9% more than the variety Ram.

Thus, from the above analysis, it can be described that higher panicle length was produced by two hand weedings, which was only significant over unweeded check plot. There was no significant difference were observed among remaining weed control methods. The higher panicle length was produced by the variety Sabitri which was not much different with the variety Ram. There was significant positive correlation (r=0.537*) between panicle length (cm) and grain yield (t ha^{-1}) (Appendix 17).

4.3.3 Panicle weight

The analysis of data from the experiment (Table 17) showed that the average panicle weight for all of the trials was 3.56 gm, ranging from 2. 63 to 4.25 gm. There was significant effect in terms of panicle weight for different combinations of weed control method and variety, but the interaction effect of weed control method and variety on panicle weight was not significant.

4.3.3.1 Effect of weed control method on panicle weight

Statistical analysis of the data showed that only three soil-aerating weedings had only a significant higher panicle weight (3.92 gm) as compared to the unweeded check (2.98 gm). There was no significant difference in panicle weight among remaining weed control method.

4.3.3.2 Effect of variety on panicle weight

The variety Sabitri had significantly higher panicle weight (3.85 gm) as compared to the variety Ram (3.28 gm), and the increment was 17.4% over the variety Ram.

Thus, it can be mentioned that, three soil-aerating weedings had only a significantly higher panicle weight as compared to unweeded check plot. There was no significant difference in panicle weight among remaining weed control methods. The variety Sabitri rice had significantly higher panicle weight (3.85 gm) as compared to the variety Ram.

4.3.4 Number of grains per panicle

The average number of grains per panicle from all trials was 161.01 (Table 17), with a range of 125.26 to 196.58, depending upon the treatment combinations of weed control method and variety. Number of grains per panicle was significantly influenced by weed control method and the variety, but the interaction effect of weed control method and variety on number of grains per panicle was non-significant.

4.3.4.1 Effect of weed control method on number of grains per panicle

The number of grains per panicle was significantly higher with three soil-aerating weedings (184.54) as compared to chemical weeding supplemented by one hand weeding (158.98), one soil-aerating weeding (157.05), chemical weeding (141.48), and unweeded check (132.28), but it was at par with two soil-aerating weedings (175.92), two hand weedings (172.88), and one hand weeding (164.92).

Three soil-aerating weedings (184.54) was significantly different for the number of grains per panicle at one hand weeding (164.92), but was non-significant with two soil-aerating weeding (175.92). There was no significant difference between chemical weeding and one hand weeding (158.98) or chemical weeding (141.48) and one soil aerating weeding (157.03) for the number of grains per panicle.

4.3.4.2 Effect of variety on number of grains per panicle

There was no significant difference between the variety Ram and Sabitri for number of grains per panicle, but comparatively higher numbers of grains per panicle was found in the variety Ram (167.68) than the variety Sabitri (154.33), which was an 8.7% more number of grains per panicle than the variety Sabitri.

Thus, on the basis of above results, it can be mentioned that the number of grains per panicle was significantly higher at three soil-aerating weedings which was at par with two soil-aerating weedings, two hand weedings and one hand weeding. While in case of varieties, there was no significant difference between Ram and Sabitri for number of grains per panicle. These results are in accordance with the findings of Vijayakumar *et al*. (2006) who reported that use of mechanical weeding resulted in higher nutrient availability subsequently resulting in better source to sink conversion which enhanced higher number of grains per panicle.

4.3.5 Test weight

The test weight is a stable varietal character because the grain size is rigidly controlled by the size of the hull (Yoshida, 1981). The average test weight (thousand-grain weight) was 22.14 gm in the experiment as a whole, ranging between 20.89 to 23.75 gm (Table 19) depending upon the combination of weed control method and variety. Test weight was significantly influenced by weed control method and variety along with the interaction effect of weed control method and variety.

4.3.5.1 Effect of weed control method on test weight

Test weight was found to be significantly higher with chemical weeding supplemented with one hand weeding (23.28 gm) as compared to chemical weeding (22.42 gm), two soil-aerating weedings at 14 and 28 DAT (21.84 gm), one soil-aerating weeding (21.52 gm), one hand weeding (21.40 gm), and unweeded check (21.33 gm). There was no significant difference in test weight between three soil-aerating weedings (22.70 gm) and two hand weedings (22.64 gm).

Three soil-aerating weedings (22.70 gm) was significantly more than two soil-aerating weedings (21.84 gm), and one soil-aerating weeding (21.52 gm), while there was no significant difference between two soil-aerating weedings (21.84 gm) and one soil-aerating weeding (21.52 gm). Two hand weedings produced significantly higher test weight (22.64 gm) as compared to one hand weeding (21.40 gm), being 5.8% more.

4.3.5.2 Effect of variety on test weight

Test weight was significantly influenced by variety where Sabitri (22.61 gm) produced significantly higher test weight than Ram (21.67 gm) and it was more by 4.3%.

4.3.5.3 Interaction effect of weed control method and variety of rice on test weight

There was significant interaction effect between weed control method and variety on test weight (Table 17). Chemical weeding supplemented by one hand weeding produced no significant effect in test weight for both Ram and Sabitri varieties. The same pattern was seen at chemical weeding, two hand weedings, one hand weeding, one soil-aerating weeding and unweeded check. There was significant difference at three soil-aerating weedings and two soil-aerating weedings for the variety Ram and Sabitri.

In general, the variety Sabitri had more test weight with all weed control method except for chemical weeding supplemented with one hand weeding**.** The analysis of data (Table17) showed that test weight was found to be significantly higher with chemical weeding supplemented by one hand weeding as compared to rest of the treatments. For variety, Sabitri produced comparatively higher test weight than Ram.

Table 17. Interaction effect of weed control method and variety of rice on test weight (gm) under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatments	Test weight(gm)	
	Variety	
	Ram	Sabitri
Weed control method		
Unweeded check	20.90[f]	21.75[def]
One HW at 21 DAT	21.05[ef]	21.75[def]
Two HWs at 21 and 42 DAT	22.13[cde]	23.14[abc]
CW	22.27[cd]	22.58[bcd]
CW + one HW at 21 DAT	23.44[ab]	23.12[abc]
One SAW at 14 DAT	21.02[ef]	22.01[cdef]
Two SAWs at 14 & 28 DAT	20.89[f]	22.79[abcd]
Three SAWs at 14, 28 & 42 DAT	21.65[def]	23.75[a]
LSD(P-0.05)	1.03	
SEm (±)	0.36	

Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil-aerating weeding)

4.3.6 Sterility percentage

The average sterility percentage observed in the experiment as a whole was 9%, and ranged from 6.7 to 14.1% (Table 19) depending upon the treatment combination. Statistical analysis of the data indicated that the sterility percentage was significantly influenced by weed control method and variety.

4.3.6.1 Effect of weed control method on sterility percentage

Significantly, higher sterility percentage was recorded with unweeded check (13.73%), and this was lowest at three soil-aerating weedings (7.16%). Three soil-aerating weedings, two hand weedings (7.26%), chemical weeding followed by one hand weeding (7.52%) and two soil-aerating weedings (7.64%) did not differ significantly in terms of sterility percentage

4.3.6.2 Effect of variety on sterility percentage

Sterility percentage was statistically higher with variety Sabitri (9.78%) than the variety Ram (8.33%), 17.4% more than the variety Ram (8.33%).

4.3.6.3 Interaction effect of weed control method and variety of rice on sterility percentage

Interaction effect was observed on sterility percentage between the combinations of weed control method and variety (Table 18). The highest sterility percentage was produced by unweeded check treatment for both variety Ram and Sabitri, The lowest sterility percentage was recorded at three soil-aerating weedings with the variety Ram.

In general, the variety Sabitri had produced higher sterility percentage with all weed control method as compared to the variety Ram. The variety Sabitri produced the highest sterility percentage (14.12%) with unweeded check which was significantly different from all other interaction effect of weed control method and variety, but was at par with the variety Ram for unweeded check (13.33%).

Thus, on the basis of above results, it can be mentioned that the highest sterility percentage was recorded at unweeded check plot and this was lowest with three soil-aerating weedings. The latter treatment was at par with two hand weedings, chemical weeding followed by one hand weeding and two soil-aerating weedings. There was significant negative correlation (r= -0.885**) between sterility percentage and grain yield (t ha^{-1}).

Table 18. Interaction effect of weed control method and variety of rice on sterility percentage under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatments	Sterility percentage	
	Variety	
	Ram	Sabitri
Weed control method		
Unweeded check	13.33[a]	14.12[a]
One HW at 21 DAT	7.30[e]	12.78[a]
Two HWs at 21 and 42 DAT	6.90[e]	7.61[de]
CW	9.39[bcd]	10.13[bc]
CW + one HW at 21 DAT	7.33[e]	7.72[de]
One SAW at 14 DAT	8.37[cde]	10.33[b]
Two SAWs at 14 & 28 DAT	7.67[e]	7.91[de]
Three SAWs at 14, 28 & 42 DAT	6.67[e]	7.65[de]
LSD(P-0.05)	1.77	
SEm (±)	0.61	

Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: WAT (weeks after transplanting), DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil-aerating weeding)

Table 19. Yield-contributing characteristics as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Yield contributing characteristics[a]					
	Effective tillers	Panicle length	Panicle weight	No. of grains	1000 grain	Sterility
Weed control method						
Unweeded check	198.00^{e}	24.66^{b}	2.98^{b}	132.28^{d}	21.33^{d}	13.73^{a}
One HW at 21 DAT	226.17^{d}	25.81^{a}	3.46^{a}	164.92^{abc}	21.40^{d}	10.04^{b}
Two HWs at 21 and 42 DAT	254.17^{bc}	26.43^{a}	3.82^{a}	172.88^{ab}	22.64^{ab}	7.26^{c}
CW	249.67^{cd}	26.01^{a}	3.51^{a}	141.48^{cd}	22.42^{bc}	9.76^{b}
CW + one HW at 21 DAT	280.50^{ab}	26.28^{a}	3.74^{a}	158.98^{bc}	23.28^{a}	7.52^{c}
One SAW at 14 DAT	235.00^{cd}	25.86^{a}	3.48^{a}	157.05^{bc}	21.52^{d}	9.35^{b}
Two SAWs at 14 & 28 DAT	261.33^{abc}	26.13^{a}	3.61^{a}	175.92^{ab}	21.84^{cd}	7.64^{c}
Three SAWs at 14, 28 & 42 DAT	282.67^{a}	25.59^{a}	3.92^{a}	184.54^{a}	22.70^{ab}	7.16^{c}
LSD(P-0.05)	25.21	0.84	0.41	22.33	0.72	1.25
SEm (±)	8.73	0.29	0.14	7.73	0.25	0.43
Variety						
Ram	265.25^{a}	25.60^{a}	3.28^{b}	167.68^{a}	21.67^{b}	8.33^{b}
Sabitri	231.63^{b}	26.09^{a}	3.85^{a}	154.33^{a}	22.61^{a}	9.78^{a}
Grand mean	248.44	25.85	3.56	161.01	22.14	9.06
LSD(P-0.05)	15.44	0.51	0.25	13.68	0.45	0.77
CV%	8.61	2.75	9.71	11.76	2.79	11.71
SEm (±)	5.35	0.178	0.09	4.73	0.15	0.27

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

4.4 Effect of weed control method and variety on grain yield of rice under SRI practices

4.4.1 Grain yield

Grain production, which is the final product of growth and development, is controlled by dry matter accumulation during the ripening phase (De Datta, 1981). The rice grain yield was found to range from 2.29 to 6.67 t ha^{-1}, depending upon the combination of different weed control method and variety, with an average yield in the experiment being 5 t ha^{-1} (Table 20). Statistically both weed control method and variety significantly influenced the grain yield, but the interactions between them did not influence the grain yield.

4.4.1.1 Effect of weed control method on grain yield of rice

Three soil-aerating weedings produced significantly higher grain yield (6.53 t ha^{-1}) as compared to two soil-aerating weedings (5.66 t ha^{-1}), two hand weedings (5.56 t ha^{-1}), chemical weeding (4.86 t ha^{-1}), one soil-aerating weeding (4.64 t ha^{-1}), one hand weeding (3.85 t ha^{-1}) and unweeded check (2.43 t ha^{-1}). The lowest grain yield was produced by unweeded check plot which was due to increased crop-weed competition higher weed dry matter, lowest number of effective tillers per square meters and test weight and this was somewhat similar with the observation of Tomer (1987) and Phogat *et al*. (1998).

Two soil-aerating weedings (6.53 t ha^{-1}) was found to be significantly higher in grain yield than one soil-aerating weeding (4.64 t ha^{-1}), chemical weeding (4.85 ha^{-1}) and one hand-weeding (3.85 t ha^{-1}). One soil-aerating weeding (4.64 t ha^{-1}) was at par with chemical weeding (4.85 ha^{-1}) in terms of grain yield. Two hand weedings (5.56 t ha^{-1}) increased the grain yield by 44.2% and 128.44% over one hand weeding (3.85 t ha^{-1}) and unweeded check (2.43 t ha^{-1}), respectively. Chemical weeding supplemented by one hand weeding (6.49 t ha^{-1}) increased grain yield by 33.9% and 167.8% over chemical weeding

(4.85 ha^{-1}) and unweeded check (2.43 t ha^{-1}), respectively. The increment in grain yield by chemical weeding supplemented by one hand weeding (6.49 t ha^{-1}) over two hand weedings (5.56 t ha^{-1}) was by 16.8%. Three soil-aerating weedings (6.53 t ha^{-1}) increased grain yield by 15.2%, 40.7% and 168.2% over two soil-aerating weedings (5.66 t ha^{-1}), one soil-aerating weeding (4.64 t ha^{-1}) and unweeded check (2.43 t ha^{-1}), respectively.

4.4.1.2 Effect of variety on grain yield of rice

The variety Ram produced significantly higher grain yield (5.19 t ha^{-1}) as compared to the variety Sabitri (4.81 t ha^{-1}). This might be due to significantly higher number of effective tillers per square meters (265.25), comparatively moderate number of grains per panicle (167.68) and significantly lower sterility percentage (8.33 %). The pattern of grain yield production was similar to the number of effective tillers per square meter indicating significant correlation (r= 0.878**) (Appendix 17 and Figure 4). The contribution from the number of effective tillers per square meter and grain yield was 77 %, while from other parameter was 33%.

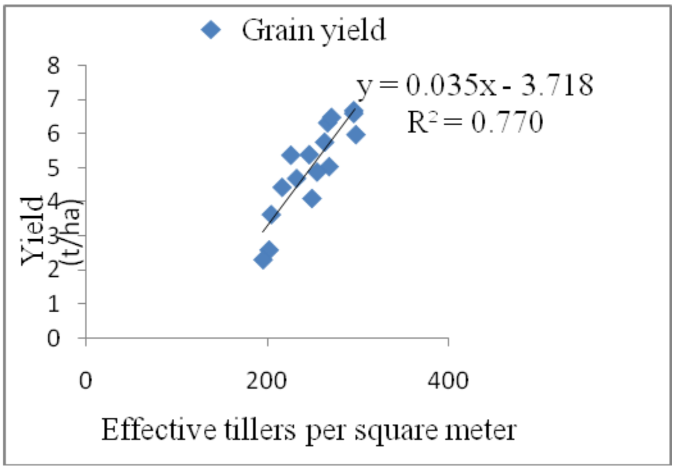

Figure 4. Relationship between the number of effective tillers per square meter and grain yield (t ha^{-1}) of rice at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Thus, as per findings, it can be described that three soil-aerating weedings produced significantly higher grain yield while it was at par with chemical weeding supplemented by one hand weeding. The variety Ram had produced significantly higher grain yield as compared to the variety Sabitri, with the variety Ram producing 79% more than the variety Sabitri. Similar trend was also obtained in number of effective tillers per square meter with these treatments i.e. three soil-aerating weedings and the variety Ram. Higher grain yield from three soil-aerating weedings might be due to less weeds competition, lower weed density (no. /m^2), lower dry weight of weeds (g/m^2) and higher weed control efficiency (%) resulted by better weed control under this treatment. Shad (1986) also reported that the combination of limited irrigation and mechanical weeding increased the yield which might be due to the reason that this minimizes weeds besides improving soil aeration and root pruning. Vijayakumar *et al*. (2006) also reported that incorporation of weeds through by mechanical weeder recorded the highest grain yield.

4.4.2 Straw yield

Analysis of the data (Table 20) showed an average straw yield of 7.93 t ha^{-1} across the experimental trials, ranging from 4.99 to 10.55 t ha^{-1}. The straw yield was significantly influenced by weed control method and variety, but their interaction of weed control method and variety on grain yield did not influence the straw yield.

4.4.2.1 Effect of weed control method on straw yield of rice

Three soil-aerating weedings (10.37 t ha^{-1}) produced the highest straw yield and it was significantly superior to two soil-aerating weedings (8.53 t ha^{-1}), one soil-aerating weeding (7.49 t ha^{-1}), chemical weeding (7.51 t ha^{-1}), two hand weedings (8.09 t ha^{-1}), one hand weeding (6.75 t ha^{-1}), and unweeded check (5.01 t ha^{-1}).

Two soil-aerating weedings (8.53 t ha^{-1}) gave significantly higher straw yield than chemical weeding (7.51 t ha^{-1}), one hand weeding (9.72 t ha^{-1}) and unweeded check (2.43 t ha^{-1}).

Two hand weedings (8.09 t ha^{-1}) produced significantly higher straw yield than one hand weeding (6.75 t ha^{-1}) and increased straw yield by 19.9% and 61.5% over one hand weeding (6.75 t ha^{-1}) and unweeded check (5.01 t ha^{-1}), respectively. Chemical weeding supplemented with one hand weeding (9.72 t ha^{-1}) produced 29.5% and 93.6% more straw yield, respectively, than chemical weeding (7.51 t ha^{-1}) and unweeded check (5.01 t ha^{-1}).

4.4.2.2 Effect of variety on straw yield of rice

There was no significant difference between the variety Ram (8.12 t ha^{-1}) and Sabitri (7.75 t ha^{-1}) for producing straw yield but the variety Ram (8.12 t ha^{-1}) produced 5% higher straw yield than Sabitri (7.75 t ha^{-1}).

Thus, as per findings, it can be described that three soil-aerating weedings produced the highest straw yield and was statistically at par with chemical weeding supplemented by one hand weeding. There was no significant difference between the variety Ram and Sabitri for producing straw yield. There was significant positive correlation (r= 0.977**) between straw yield (t ha^{-1}) and grain yield (t ha^{-1}) of rice.

4.4.3 Harvest index

Grain yield in cereals is related to biological yield and grain harvest index (Donald and Hamblin, 1976). The values of rice harvest index varied greatly among cultivars, locations, seasons, and ecosystems, and ranged from 0.35 to 0.62, indicating the importance of this variable for yield simulation (Kiniry *et al.*, 2001). The average value (Table 20) of harvest index in the experiment for all of the trials was 38.19%, ranging from 31.3 to 41.22%. Snyder and Carlson (1984) reviewed harvest index for selected annual crops and noted variations 23 to 50% for rice. Harvest Index was significantly different among weed control method but there was no significant difference between two varieties.

4.4.3.1 Effect of weed control method on harvest index of rice

Two hand weedings (40.74%) produced the highest harvest index which was significantly different from one hand weeding (36.36%) and unweeded check (32.43%). Two hand weedings (40.74%) produced more harvest index by12.1% and 25.6% than one hand weeding (36.36%) and unweeded check (32.43%), respectively. Chemical weeding supplemented by one hand weeding (39.95 %) produced higher harvest index by 1.7% and 23.2% over chemical weeding (39.3%) and unweeded check (32.4%), respectively. Three soil-aerating weedings (38.6%) decreased harvest index by 3.2% over two soil-aerating weedings (39.89 %) and increased harvest index by 1.1% and 19.1% over one soil-aerating weeding (38.23 %) and unweeded check (32.43 %), respectively.

4.4.3.2 Effect of variety on harvest index of rice

There was no significant difference in harvest index produced by the variety Ram (38.6%) and Sabitri (37.8%).

Table 20. Grain yield, straw yield, and harvest index as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
Weed control method			
Unweeded check	2.43^{e}	5.01^{e}	32.43^{c}
One HW at 21 DAT	3.85^{d}	6.75^{d}	36.36^{b}
Two HWs at 21 and 42 DAT	5.56^{b}	8.09^{bc}	40.74^{a}
CW	4.85^{c}	7.51^{cd}	39.30^{ab}
CW + one HW at 21 DAT	6.49^{a}	9.72^{a}	39.95^{a}
One SAW at 14 DAT	4.64^{c}	7.49^{cd}	38.23^{ab}
Two SAWs at 14 & 28 DAT	5.66^{b}	8.53^{b}	39.89^{a}
Three SAWs at 14, 28 & 42 DAT	6.53^{a}	10.37^{a}	38.63^{ab}
LSD(P-0.05)	0.59	0.73	3.00
SEm (±)	0.20	0.25	1.04
Variety			
Ram	5.19^{a}	8.12^{a}	38.57
Sabitri	4.81^{b}	7.75^{a}	37.82
Grand mean	5.00	7.93	38.19
LSD(P-0.05)	0.36	0.45	NS
CV%	10.03	7.80	6.67
SEm (±)	0.13	0.15	0.64

Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil-aerating weeding)

4.5 Effect of weed control method and variety of rice on economical analysis under SRI practices

Farmers' resources such as land, labor, and capital are important considerations in making the final choice of weeding method (De Datta and Barker 1977). The economical analysis of various treatments under study was worked out in the Table 21 to evaluate the most beneficial and economical treatment for rice cultivation with SRI practices. The details of cost of various weed control method and variety are given in Appendix 4.

4.5.1 Cost of cultivation

The data (Table 21) showed that, in general, two hand weedings (Rs 56.22 thousand/ha) required higher cost of cultivation per hectare while unweeded check plot (Rs 47.22 thousand/ha) required the lower cost of cultivation. While in case of variety, higher cost of cultivation per hectare was comparatively required for the variety Ram (Rs. 50.58 thousand/ha) than the variety Sabitri (Rs. 50.57 thousand/ha)

4.5.2 Gross return

The data in the Table 21 showed that average gross return was Rs. 130.55 thousand/ha and it ranging from Rs. 60.90 to 181.52 thousand/ha for all treatments depending up on weed control method and variety. The gross return was significantly influenced by weed control method and variety.

There was significantly higher gross return (Rs. 170.18 thousand/ha) at three soil-aerating weedings and lowest (Rs. 67.69 thousand/ha) at unweeded check plot. Three soil-aerating weedings was not significantly different with chemical weeding supplemented by one hand weeding (Rs. 167.30 thousand/ha). For variety, Ram recorded comparatively higher gross return (Rs. 142.54 thousand/ha) than Sabitri (Rs. 118.55 thousand/ha).

Thus, the higher gross return was obtained from three soil-aerating weedings on one hand, while on the other hand, the higher gross return was obtained from the variety Ram. This weed control method can be used for better economic return in rice production.

4.5.3 Net profit

The analyzed data (Table 21) indicated that the average net profit was Rs. 79.97 thousand/ha and it ranged from Rs. 13.69 to 130.30 thousand/ha for all trials depending upon the weed control method and variety. The higher net profit (Rs. 119.81 thousand/ha) obtained with three soil-aerating weedings which was at par with chemical weeding supplemented by one hand weeding (Rs. 114.75 thousand/ha). The second highest net profit (Rs. 96.75 thousand/ha) was recorded from two soil-aerating weedings which was not significantly different with two hand weedings (Rs. 86.27 thousand/ha). Unweeded check plot recorded the lower net profit of Rs. 20.37 thousand/ha.

The variety Ram recorded comparatively higher net return (Rs. 91.95 thousand/ha) than the variety Sabitri (Rs. 67.99 thousand/ha). Thus, it can be mentioned that three soil-aerating weedings and the variety Ram can be used for better net return for rice cultivation with SRI practices.

4.5.4 Benefit cost ratio

Benefit cost ratio is the ratio of gross return to cost of cultivation which can also be expressed as returns per rupee invested. Any value greater than 2 is considered safe as the farmer get Rs. 2.00 for every rupee invested (Reddy and Reddi, 2002). On the other hand, minimum benefit cost ratio of 1.5 has been fixed for an enterprise in the agricultural sector to be economically viable. Therefore, any agricultural enterprise must maintain a 1.5 benefit cost ratio to be economically sustainable (Bhandari, 1993).

Thus, the analyzed data (Table 21) revealed that the average benefit cost ratio was above 2 (2.57) and it ranged from 1.29 to 3.59. Three soil-aerating weedings recorded the higher benefit cost (3.38) while unweeded check recorded the lower benefit cost ratio (1.43). Three soil-aerating weedings was at par with chemical weeding supplemented by one hand weeding (3.19). The second higher benefit cost ratio (2.95) was recorded at two soil-aerating weedings but was also at par with chemical weeding supplemented by one hand weeding (3.19). There was non-significant difference between chemical weeding (2.62) and two hand weedings (2.53).

While for varieties, Ram recorded comparatively higher benefit cost ratio (2.81) than Sabitri (2.34).

Table 21. Economic analysis of weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Treatment	Economic analysis			
	Cost of cultivation Rs./ha('000)	Gross return Rs./ha ('000)	Net profit Rs./ha('000)	B C ratio
Weed control method				
Unweeded check	47.22	67.59^{e}	20.37^{e}	1.43^{e}
One HW at 21 DAT	51.72	102.89^{d}	51.17^{d}	1.99^{d}
Two HWs at 21 and 42 DAT	56.22	142.48^{b}	86.27^{bc}	2.53^{c}
CW	48.04	125.93^{c}	77.88^{c}	2.62^{c}
CW + one HW at 21 DAT	52.54	167.30^{a}	114.75^{a}	3.19^{ab}
One SAW at 14 DAT	48.87	121.62^{c}	72.75^{c}	2.49^{c}
Two SAWs at 14 & 28 DAT	49.62	146.37^{b}	96.75^{b}	2.95^{b}
Three SAWs at 14, 28 & 42 DAT	50.37	170.18^{a}	119.81^{a}	3.38^{a}
LSD(P-0.05)		13.39	13.39	0.26
SEm (±)		4.64	4.64	0.09
Variety				
Ram	50.58	142.54^{a}	91.95^{a}	2.81^{a}
Sabitri	50.57	118.55^{b}	67.99^{b}	2.34^{b}
Grand mean		130.55	79.97	2.57
LSD(P-0.05)		8.20	8.20	0.16
CV%		8.70	14.20	8.72
SEm±		2.84	2.83	0.06

[a]Average of three replications. Mean separated by DMRT and columns represented with same letters are not significantly different at 5% level of significance. Note: DAT (days after transplanting), HW (hand weeding), CW (chemical weeding), SAW (soil aerating weeding)

5 SUMMARY AND CONCLUSION

A field experiment entitled “Effect of weed control methods on rice cultivars under the system of rice intensification (SRI)” was conducted at a farmer’s field at Shivanagar-3, Chitwan during the rainy season of 2008. The experiment was laid out in two factorial randomized complete block designs (RCBD) with three replications, having sixteen treatment combinations. First factor had eight weed-control method i.e., 1) unweeded check plot, 2) one hand weeding at 21 days after transplanting, 3) two hand weedings at 21 and 42 days after transplanting, 4) chemical weeding (Pyrazosulfuron ethyl @ 0.015 a.i. kg/ha), 5) chemical weeding supplemented with one hand weeding at 21 days after transplanting, 6) one soil-aerating weeding at 14 days after transplanting, 7) two soil-aerating weedings at 14 and 28 days after transplanting, and 8) three soil-aerating weedings at 14, 28 and 42 days after transplanting; and second factor had 2 rice variety, i.e., 1) Ram (OR-367), and 2) Sabitri.

The soil of the experimental site was sandy loam in texture, having 61%, 30%, 9% of sand, silt and clay, respectively, with pH of 6.1. The soil was low in organic matter content (2.1%), low in total nitrogen (0.09%), low in available phosphorus (26 kg/ha), and medium in available potassium (119 kg/ha). The results of the trial are summed up as follows:

As compared to unweeded control, root length for all weed control methods generally increased up to 85 DAT, and thereafter declined; while root volume increased most between 25 to 40 DAT, and thereafter gradually decreased. Use of three soil-aerating weedings brought significantly greater growth in root length between 25 to 100 DAT except at 70 and 85 DAT, and also significant increase in root volume between 25 to 100

DAT except at 70 and 85 DAT. The variety Ram produced significantly higher root length and root volume.

Plant height increased up to 100 DAT, and the increment was higher (31.8%) between 40 and 55 DAT. Use of three soil-aerating weedings brought significantly taller plants between 25 to 100 DAT except at 40 and 70 DAT. The variety Ram produced significantly taller plants as compared to the variety Sabitri at 25, 40, 70 and 85 DAT, but it did not differ significantly at 55 and 100 DAT.

The number of tillers per plant increased up to 70 DAT, and thereafter gradually declined, while the number of leaves per plant increased during 25 to 70 DAT and thereafter gradually decreased. Use of two hand weedings brought significant increase in the number of tillers per plant and also brought a significant increase in the number of leaves per plant at the early stage of crop growth; but three soil-aerating weedings brought significant increment in both parameters at the later stage. The variety Ram produced significantly higher number of tillers per plant as compared to the variety Sabitri during 25 to 100 DAT, and also produced significantly higher numbers of leaves per plant from 25 to 55 DAT and from 70 to 100 DAT.

LAI increased during 25 to 70 DAT and thereafter declined at the end of crop growth period (85 to100 DAT). Use of three soil-aerating weedings brought significantly greater increments in LAI at 25, 55 and 100 DAT. The variety Sabitri produced comparatively higher leaf area index than the variety Ram from 25 to 100 DAT except 55 DAT.

The initial investment in biomass partitioning was found in the leaves at 25 DAT and in the roots at 40 DAT, and later in the stem up to 85 DAT, and ultimately in the storage organ, i.e., panicle at 100 DAT. Use of three soil-aerating weedings brought significant increment in total dry matter accumulation during 25 to 55 DAT, while chemical weeding supplemented by one hand weeding brought significant increment in total dry matter accumulation during 85 to 100 DAT. The variety Ram produced significant increment in total dry matter accumulation during 25 to 100 DAT as compared to the variety Sabitri.

Use of chemical weeding supplemented with one hand weeding reduced drastically weed density at the early stage of growth, while three soil-aerating weedings drastically reduced them at the later stage of plant growth. There was no significant difference between the two rice varieties for weed density at all crop growth stages.

Weed dry weight was drastically reduced by one soil-aerating weeding at early crop growth stage, i.e., 21 DAT, and thereafter it gradually decreased by three soil-aerating weedings at the later crop growth stages. There was no significant difference between the two varieties for weed dry weight at the different crop growth stages, except at 21 DAT. Weed control efficiency was found to be highest with one soil-aerating weeding at 21 DAT, and thereafter it was highest with three soil-aerating weedings, at 42 to 63 DAT, but two hand weedings was found to have highest efficiency at harvesting stage.

Three soil-aerating weedings produced significantly higher number of effective tillers per square meter. The variety Ram produced significantly higher numbers of effective tillers per square meters than the variety Sabitri. Greater panicle length was obtained with two hand weedings, which was only significantly different treatment as compared to unweeded check plot. There was no significant difference in terms of panicle length between two varieties.

Three soil-aerating weedings produced significantly higher panicle weight as compared to unweeded check plot. The variety Sabitri had significantly higher panicle weight as compared to the variety Ram. The number of grains per panicle was significantly higher at three soil-aerating weedings. In the case of variety, there was no significant difference between Ram and Sabitri in terms of number of grains per panicle.

Test grain weight was found to be significantly higher with chemical weeding supplemented with one hand weeding, but it was at par with three soil-aerating weedings. For the variety, Sabitri produced significantly higher test weight than Ram. There was significantly higher sterility percentage at unweeded check plot, and it was lower with three soil-aerating weedings. Sterility percentage was statistically higher with the variety Sabitri compared to the variety Ram.

Three soil-aerating weedings produced significantly higher grain and straw yield, while it was at par with chemical weeding supplemented with one hand weeding. The variety Ram produced significantly higher grain yield as compared to the variety Sabitri, while there was no significant difference between the variety Ram and Sabitri for straw yield. Two hand weedings produced the highest harvest index, which was significantly different compared to unweeded check plot while it was statistically at par with chemical weeding supplemented with one hand weeding. There was significantly higher gross return, higher net profit and higher benefit cost ratio with three soil-aerating weedings as compared to all the other treatment combinations.

So, it would be better to use the variety Ram and follow three soil-aerating weedings as weed control practice for rice cultivation along with the other elements for crop management under the system of rice intensification (SRI) where there are assured facilities for irrigation and drainage. These findings need to be tested across the wide range of climatic and soil conditions of all major agro-ecological regions of Nepal, i.e., Terai and Inner Terai, Hills and Mountains for further verification and wider adaptability among farmers, researchers, policy makers, development workers.

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APPENDICES

Appendix 1. Details of cultural operations of rice under SRI practices at the experimental site during May to November 2008 at farmer's field, Shivanagar-3, Chitwan, Nepal

S.N.	Particular operations	Date (D-M-Y)
1.	Nursery bed preparation	29-05-2008
2.	Solarization of nursery bed	30-05-2008
3.	Removal of plastic cover	19-06-2008
4.	Soaking of seed	18-06-2008
5.	Seed sowing	20-06-2008
6.	Main field preparation	28-06-2008
7.	Fertilizer application	20-06-2008
8.	Transplanting	29-06-2008
9.	Gap filling after 5 days after transplanting	04-07-2008
10.	Weeding	
	One hand weeding at 21 days after transplanting	20-07-2008
	Two hand-weedings at 21 and 42 days after transplanting	20-07-2008 & 10-08-2008
	Chemical weeding	01-07-2008
	Chemical weeding + one hand weeding at 21 days after transplanting	01-07-2008 & 20-07-2008
	One soil-aerating weeding at 14 days after transplanting	13-07-2008
	Two soil-aerating weedings at 14 and 28 days after transplanting	13-07-2008 & 27-07-2008

	Three soil-aerating weedings at 14, 28 and 42 days after transplanting	13-07-2008, 27-07-2008 & 11-08-2008
11.	Irrigation	
	First irrigation	13-07-2008
	Second irrigation	20-07-2008
	Third irrigation	27-07-2008
	Fourth irrigation	03-08-2008
	Fifth irrigation	11-08-2008
	Sixth irrigation	18-08-2008
12.	Nitrogen top-dressing	
	First top-dressing	30-07-2009
	Second top-dressing	10-08-2009
13.	Cypermathin spraying 25%	25-09-2008
14.	Harvesting	
	First harvesting (Ram)	03-11-2009
	Second harvesting (Sabitri)	10-11-2009
15.	Threshing, cleaning and weighing	15-11-2009

Appendix 2. Monthly meteorological data of cropping season (June to November 2008) of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal

Months	Standard	Temperature ^{0}C		Relative	Total	Sunshine
		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
November	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 3. General cost of rice production (Rs. /ha) under SRI practices at irrigated land during May to November 2008 at farmer's field, Shivanagar-3, Chitwan, Nepal

S.No	**Particulars**	**Unit**	**Qu**	**Rate**	**Total**
I.	**Variable cost**				
A.	**Nursery raising (100 m^2)**				
1.	Land preparation through disc harrow	Min.	5	17	85.00
2.	Nursery bed preparation	Labour	1	150	150.00
4.	Solarization with 300 guage plastic sheet	Sq. m	100	40/m^2	4000.0
5.	Vermi-compost	Kg	5	25	125.00
6.	Sanjeewani	Kg	0.2	90/kg	18.00
7.	Bavistin	gm	20	65	65.00
8.	Cost of uprooting of seedlings	Labour	1	150	150.00
B.	**Transplanting field (1 ha)**				
1.	3 Ploughing (planking and puddling)	Hours	3	1020	3060.0
2.	Bund making and digging	Labour	6	200	1200.0
3.	Well decomposed FYM	tonnes	10	1000	10000.
4.	Fertilizer @ 100:45:45 NPK kg/ha				
	Urea	Kg	179	23	4119.7
	DAP	Kg	97.	42	4108.8
	MOP	Kg	75.	24	1800.0
5.	Sanjeewani	Kg	20	85	1700.0
6.	Application of fertilizer	Labour	1	150	150.00
7	Transplanting of seedling	Labour	30	150	4500.0
8.	Irrigation				
	Irrigation channel	Month	3.5	1050/ha/	308.25
	Pump-set	Hours	6	150	900.00
9.	Labor for irrigation	Labour	2	150	300.00
10.3.	Cypermethrin	ml	100	100	100.00
11.	Spraying of Cypermethrin	Labour	1	150	150.00
12.	Harvesting	Labour	30	150	4500.0
13.	Threshing	Labour	10	150	1500.0
14.	Cleaning, drying and storage	Labour	8	150	1200.0
	Sub-total				**44189.**
15.	**Interest on variable cost**	Month	6	**12 % /**	2651.3
	Total variable cost				**46841.**
II.	**Fixed cost: Govt. land tax**	Month	6	500/ha/yr	250.00
III.	**Total cost**				47091.

Appendix 4. Variable cost of rice production (Rs. /ha^{-1}) under SRI practices of different treatment combinations during May to November 2008 at farmer's field, Shivanagar-3, Chitwan, Nepal

Treatment	Particulars	Unit	Qua	Rate (Rs.)	Total (Rs.)
T_1	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	Total				**47226.26**
T_2	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	One hand weeding	Labour	30	150	4500
	Total				**51726.26**
T_3	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	Two hand weedings	Labour	60	150	9000
	Total				**56226.26**
T_4	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	Cost of Pyrazosulfuron ethyl	gm	150	Rs.90/20gm	675
	Application of herbicide	Labour	1	150	150
	Total				**48051.26**
T_5	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	Cost of Pyrazosulfuron ethyl	gm	150	Rs.90/20gm	675
	Application of herbicide	Labour	1	150	150
	One hand weeding	Labour	30	150	4500
	Total				**52551.26**
T_6	General cost of cultivation				47091.26
	Cost of seed	Kg	5	27	135
	Cost of rotatory weeder	Rs.	1	900	900
	One soil-aerating weeding	Labour	5	150	750
	Total				**48876.26**

T_7	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	Cost of rotatory weeder	Rs.	1	900	900
	Two soil-aerating weedings	Labour	10	150	1500
	Total				**49626.26**
T_8	General cost of cultivation				47091.26
	Cost of seed	kg	5	27	135
	Cost of rotatory weeder	Rs.	1	900	900
	Three soil-aerating weedings	Labour	15	150	2250
	Total				**50376.26**
T_9	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Total				**47211.26**
T_{10}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	One hand weeding	Labour	30	150	4500
	Total				**51711.26**
T_{11}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Two hand weedings	Labour	60	150	9000
	Total				**56211.26**
T_{12}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Cost of Pyrazosulfuron ethyl	gm	150	Rs.90/20	675
	Application of herbicide	Labour	1	150	150
	Total				**48036.26**
T_{13}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Cost of Pyrazosulfuron ethyl	gm	150	Rs.90/20gm	675
	Application of herbicide	Labour	1	150	150
	One hand weeding	Labour	30	150	4500

	Total				**52536.26**
T_{14}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Cost of rotatory weeder	Rs.	1	900	900
	One soil-aerating weeding	Labor	5	150	750
	Total				**48861.26**
T_{15}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Cost of rotatory weeder	Rs.	1	900	900
	Two soil-aerating weedings	Labor	10	150	1500
	Total				**49611.26**
T_{16}	General cost of cultivation				47091.26
	Cost of seed	kg	5	24	120
	Cost of rotatory weeder	Rs.	1	900	900
	Three soil-aerating weedings	Labor	15	150	2250
	Total				**50361.26**

Appendix 5. Price of different product and by-products of rice at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

S. N.	Products and by-products	Price rate(Rs./kg)
1	Rice grain	
	Ram	22
	Sabitri	19
3	Rice straw	3.5

Appendix 6. Rating chart of soil values to determine the fertility status of experimental soil

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

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

Appendix 7. Mean squares from ANOVA associated to root length (cm) and root volume ($cm^3/0.31\ m^2$) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Root length						Root volume					
		25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Replication	2	14.441	0.947	4.990	2.559	1.971	2.268	116.311	430.020	834.509	1724.737	357.530**	809.344*
Factor A	1	5.387**	11.388**	9.983**	17.352**	19.0**	12.000**	431.520**	327.869**	272.510**	315.444*	400.959**	432.000**
Factor B	7	1.774*	4.519**	6.951**	3.189**	6.979**	2.551**	55.664**	394.349**	3065.974**	4463.585**	3672.490	1071.024
AB	7	0.203	0.449	0.428	2.112	0.985	0.150	39.243*	3.264	5.250	9.492	3.429	3.981
Error	30	0.638	0.728	0.826	0.939	1.568	0.694	16.033	20.313	2.864	72.059	40.699	94.353

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 8. Mean squares from ANOVA associated to plant length (cm) and number of tillers per plant as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Plant height						Number of tillers per plant					
		25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Replication	2	16.776	5.353	21.813	15.651	21.291	5.150	1.116	6.967	30.939	7.057	1.509	0.457
Factor A	1	116.096**	38.718**	22.564*	37.383**	35.673*	10.688*	5.293**	21.924*	44.622**	48.965**	70.543**	77.145**
Factor B	7	7.796**	17.878**	23.012**	39.512**	38.835**	55.870**	4.329**	15.759**	78.980**	133.288**	40.994**	27.161**
AB	7	6.104*	4.299	3.127	1.991	1.336	5.950*	0.425	1.086	2.279	0.948	2.619	1.032
Error	30	2.107	2.846	5.399	1.886	4.860	2.180	0.661	3.393	5.478	2.516	4.771	6.759

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 9. Mean squares from ANOVA associated to number of leaves per plant and leaf area index as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Number of leaves per plant						Leaf area index					
		25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	100 DAT
Replication	2	106.350	66.605	21.111	30.644	4.136	2.777	0.702	0.787	1.199	1.349	1.821	2.648
Factor A	1	26.985*	39.931**	25.317**	35.415*	42.000*	70.543*	1.082**	0.967**	1.558**	1.364**	1.036**	1.035**
Factor B	7	100.091**	140.013**	1161.946**	1280.597**	1093.826**	527.840**	1.120**	1.402**	1.858**	2.019**	1.267**	0.906**
AB	7	1.706	0.594	0.433	1.566	1.795	0.431	0.029	0.007	0.014	0.009	0.049	0.035
Error	30	4.271	3.123	2.059	7.406	7.123	16.399	0.087	0.110	0.130	0.158	0.053	0.085

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 10. Mean squares from ANOVA associated to dry matter production (gm/0.31 m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Dry matter production at 25 DAT				Dry matter production at 40 DAT				Dry matter production at 55 DAT			
		Stem	Leaf	Root	total	Stem	Leaf	Root	total	Stem	Leaf	Root	total
Replication	2	1.336	2.557	0.815	12.977	18.679	4.253	0.908	53.253	39.956	44.368	9.307	221.415
Factor A	1	8.704**	13.717**	7.881**	89.517**	13.750**	7.608**	25.071**	131.639**	21.347	14.575*	30.800**	195.657**
Factor B	7	5.614**	2.285**	2.933**	28.905**	20.530**	5.436**	27.262**	130.131**	448.702**	119.497**	335.848**	2438.179**
AB	7	1.864**	0.269	1.129**	5.458*	1.209	0.287	0.563	2.133	1.515	1.924	0.502	6.334
Error	30	0.455	0.484	0.334	1.881	0.984	0.719	2.317	4.360	6.513	2.301	3.756	14.254

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 11. Mean squares from ANOVA associated to dry matter production (gm/0.31 m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Dry matter production at 70 DAT				Dry matter production at 85 DAT				
		Stem	Leaf	Root	total	Stem	Leaf	Root	Grain	total
Replication	2	2.497	39.003	9.336	89.591	206.733	31.980	11.332	9.871	663.945
Factor A	1	24.168*	27.984*	49.005**	296.070**	34.425*	75.777*	52.334**	100.572**	1013.703**
Factor B	7	1245.892**	404.524**	1093.588**	6843.072**	2984.209**	423.424**	710.230**	390.469**	13448.961**
AB	7	0.768	0.439	0.890	1.237	2.170	0.954	0.609	1.902	3.015
Error	30	4.107	4.043	6.353	11.759	5.196	11.001	4.682	2.689	24.028

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 12. Mean squares from ANOVA associated to dry matter production (gm/0.31 m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Dry matter production at 100 DAT				
		Stem	Leaf	Root	Grain	total
Replication	2	302.493	8.691	11.807	61.414	233.924
Factor A	1	76.129*	131.043**	58.477*	387.717*	2257.843**
Factor B	7	2442.687**	256.680**	690.514**	795.216**	11735.317**
AB	7	2.164	2.775	1.145	6.759	8.299
Error	30	16.075	14.954	9.295	67.180	96.595

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 13. Mean squares from ANOVA associated to yield contributing characteristics of rice as influenced by weed control method and variety under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Effective tillers	Panicle length	Panicle weight	Number of grains	1000 grain weight	Sterility percentage
Replication	1	6285.250	3.273	0.582	291.362	8.043	0.258
Factor A	1	13567.688**	2.848*	3.851**	2139.949*	10.691**	25.197**
Factor B	7	4817.807**	1.808**	0.501**	1850.514**	3.101**	29.618**
AB	7	586.688	0.357	0.069	462.773	0.923*	4.323**
Error	30	457.206	0.504	0.120	358.738	0.381	1.124

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety

Appendix 14. Mean squares from ANOVA associated to gain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index of rice as influenced by weed control method and variety under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Replication	1	0.307	1.357	0.126
Factor A	1	1.687*	1.643*	6.810
Factor B	7	11.464**	16.988**	43.214**
AB	7	0.031	0.220	1.186
Error	30	0.251	0.382	6.497

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety

Appendix 15. Mean squares from ANOVA associated to weed density (No. /m^2) and weed dry weight (gm/m^2) as influenced by weed control method and variety of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Sources	df	Weed density (No./m^2)				Dry weight of weeds (g/m^2)			
		21 DAT	42 DAT	63 DAT	Harvest	21 DAT	42 DAT	63 DAT	Harvest
Replication	1	124.923	286.497	64.411	11.895	0.202	27.591	3.666	38.796
Factor A	1	0.170	8.204	9.672	0.825	0.376**	24.069	1.064	4.622
Factor B	7	241.534**	65.728**	139.555**	35.342**	0.226**	44.784**	133.640**	51.123**
AB	7	26.249	17.189	18.027	7.663	0.016	3.871	8.932	6.648
Error	30	29.403	15.559	17.395	4.617	0.040	6.452	11.819	10.387

*significant at the 0.01 level of significance; ** significant at the 0.05 level of significance; df, degree of freedom; Factor A, weed control method; Factor B, variety; DAT, days after transplanting

Appendix 16. Correlation coefficient among growth contributing characteristics and yield of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Parameters	RV 85	PL 100	NT 70	NL 70	LAI 55	LAI 70	LAI 85	LAI 100	TDN 85	TDN 100	YLD
RL 85	0.808**	0.593*	0.726**	0.711**	0.497	0.499*	0.799**	0.403	0.754**	0.713**	0.763**
RV 85		0.842**	0.759**	0.805**	0.811**	0.836**	0.770**	0.795**	0.954**	0.915**	0.975**
PL 100			0.572*	0.623**	0.640**	0.641**	0.535*	0.708**	0.847**	0.832**	0.874**
NT 70				0.952**	0.641**	0.754**	0.787**	0.520*	0.708**	0.667**	0.708**
NL 70					0.726**	0.834**	0.678**	0.630**	0.729**	0.642**	0.726**
LAI 55						0.942**	0.594*	0.879**	0.851**	0.792**	0.822**
LAI 70							0.615*	0.881**	0.830**	0.778**	0.817**
LAI 85								0.439	0.805**	0.779**	0.787**
LAI 100									0.782**	0.786**	0.805**
TDN 85										0.960**	0.986**
TDN 100											0.974**

**, correlation is significant at the 0.01 level (2-tailed);*, correlation is significant at the 0.05 level (2-tailed); RL 80, root length (cm) at 80 days after transplanting; RV 80, root volume ($cm^3/0.31m^2$) at 80 days after transplanting; PL 100, plant height (cm) at 100 days after transplanting; NT 70, number of tillers per plant at 70 days after transplanting; NL 70, number of leaves per plant at 70 days after transplanting; LAI 55, leaf area index at 55 days after transplanting; LAI 70, leaf area index at 70 days after transplanting; LAI 85, leaf area index at 85 days after transplanting; LAI 100, leaf area index at 100 days after transplanting; TDN 85, total dry matter($gm/0.31m^2$) at 85 days after transplanting; TDN 100, total dry matter($gm/0.31m^2$) at 100 days after transplanting; Yield, yield (t/ha)

Appendix 17. Correlation coefficient among yield contributing characteristics and yield of rice under SRI practices at farmer's field, Shivanagar-3, Chitwan, Nepal, 2008

Parameters	Panicle length	Panicle weight	No of grains per panicle	1000 grain weight	Sterility percentage	Grain yield
Effective tillers per m^2	0.231	0.146	0.720**	0.212	-0.838**	0.878**
Panicle length		0.764**	0.162	0.631**	-0.446	0.537*
Panicle weight			0.225	0.762**	-0.370	0.524*
No of grains per panicle				-0.012	-0.833**	0.657**
1000 grain weight					-0.307	0.536*
Sterility percentage						-0.885**

**, Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)

BIOGRAPHICAL SKETCH

The author, Sharad Pandey, was born on 12th November 1982 at Sidharthanagar-8, Rupandehi as eldest son of Mr. Chandrakant Pandey and Mrs. Kumari Pandey. His school education was completed in 1999 from Sunshine English Boarding High School Siddharthanagar, Bhairahawa, Rupandehi. He joined at Tilottama Higher Secondary School, Butwal, Rupandehi and completed 10+2 in Science in 2001. Then he joined Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan in 2002 and completed Bachelor of Science in Agriculture with elective Agronomy in 2006. After his graduation he went for on the job training on Postgraduate Diploma in Advance Agriculture at Arava International Center for Agriculture Trainees (AICAT), Arava, Israel from October 2006 to May 2007. Then he enrolled at the same institute for Master of Science in Agriculture (Agronomy) in 2007.