SYSTEM OF RICE INTENSIFICATION UNDER DIFFERENT PLANT POPULATION AND LEVELS OF NITROGEN

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The thesis attached hereto, entitled **“SYSTEM OF RICE INTENSIFICATION UNDER DIFFERENT PLANT POPULATION AND LEVELS OF NITROGEN”** prepared and submitted by **Mr. RAJEEV RAJBHANDARI**, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture (Agronomy), is here by accepted.

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ABBREVIATIONS

ANOVA	Analysis of variance
B/C ratio	Benefit: cost ratio
DAT	Day after transplanting
DM	Dry matter
DMRT	Duncan’s multiple range test
FYM	Farm yard manure
GR	Gross return
HI	Harvest index
LAI	Leaf area index
LSD	Least significant difference
NC	Nitrogen content
Rs	Rupees
SEm	Standard errors of means
SRI	System of rice intensification
TGW	Thousands grains weight

ABSTRACT

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Rice, the first among cereal crops in area coverage and production in Nepal has a stagnating productivity throughout the years as compared to the world average productivity. A new technology of rice farming believed to increase the yield, with simple manipulation of cultivation techniques called System of Rice Intensification was evaluated for the variety Rampur Mansuli under different plant population (20 cm × 20 cm, 20 cm × 15 cm and 20 cm × 10 cm.) and levels of nitrogen (0, 40, 80, 120 and 160 kg N/ha) through field experiment conducted in split plot design during rainy season of 2006, at the Institute of Agriculture and Animal Science, Rampur, Chitwan. The grain yield and straw yield of rice increased with increasing levels of nitrogen. The highest average grain yield (5.88 t/ha) was obtained under 120 kg N/ha which might be due to the highest dose of Nitrogen along with drought weather condition prevailing during reproductive growth period. However, highest straw yield (7.03 t/ha) was attained at 160 kg N/ha. The increase in yield due to 120, 80 and 40 kg N/ha was to the extent of 153, 81 and 50% respectively over control. However, at highest level of N 160 kg/ha, the reduction in yield was to the extent of 23% as compared to yield obtained under 120 kg N/ha. Though at par, higher grain yield/ha at wider spacing was recorded. Low plant population under wider spacing showed the best performance due to the greater availability of nutrients owing to more space per plant. The straw yield was significantly high under narrow spacing (20 cm × 20 cm). The economic dose of nitrogen calculated was 115 kg N/ha from response equation which is very close to the treatment 120 kg N/ha. The economic analysis recorded that 120 kg N/ha resulted highest net return Rs. 60200 and B:C ratio 2.6 and among the plant population levels 20 cm × 20 cm produced highest net return Rs. 50620 and B:C ratio 2.27. Yield attributes (effective tiller, panicle length, filled grain, panicle weight and test weight) increased up to 120 kg N/ha, however, it decrease at 160 kg N/ha. They were also higher at wider spacing of 20cm × 20cm as compared to the closer spacing (20cm × 15cm and 20cm × 10cm). Unlike, unfilled grain was higher at closer spacing. Plant height, dry matter (DM) and Leaf area index (LAI) increased with increasing level of N at all growth stages, with the exception of high LAI at lower dose of N at 30 DAT (0.64 at 80 kg N/ha). Highest plant height (102.8cm) was attained at 160 kg N/ha which was at par with 120 kg N/ha, whereas highest DM (110.9 gm) and LAI (3.79) was at 160kg N/ha, at maturity. Spacing did not affect plant height significantly. However LAI was significantly high under higher plant population (20 cm x 10 cm) at all the growth stages. Tillering was high at wider spacing and at higher doses of N; active tillering (55 DAT) onwards, the effect was insignificant. Nitrogen content in the grain increased with decreasing level of plant population while increased with increasing levels of nitrogen.

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1 INTRODUCTION

Rice (*Oryza sativa* L.) is a major staple food crop for many developing countries and not only a main source of calories but also an important source of income and employment for many farmers, particularly poor household. In developing countries as a whole, area of rice accounted to 34% of their arable land, while rice production accounted to 47% of their total grain output in 2000 (Fan *et al.*, 2003).

In Nepal, agriculture holds major share of economy (38% of GDP) and rice is the main crop. It contributes 19.75 % to agricultural GDP. Total area coverage of rice in 2004/2005 was 1.54 million hectares of land, with average productivity of 2785 kg/ha. These data show that the productivity of rice in Nepal is very low as compared to the world average of 4000 kg/ha (MOAC, 2005).

Although Nepal exported substantial quantities of rice in the year 1970s and mid-1980s, the country stopped exporting it from 1987/88 onwards, and in times of drought imports are required. It seems that population growth has outstripped rice production, and rice imports will be necessary unless total production in significantly increased (Pokhrel, 1997).

Rice production increased at a rate of 2.5 to 3.0 percent per year during the 1970s and 1980s. However, during the 1990s, the growth rate was only 1.5 percent. According to United Nations estimates, the world population will grow from 6.3 billion in 2003 to 8 billion in 2025. Most of this increase (93 percent) will occur in developing countries, whose share of population is projected to increase from 78 percent in the 1990s to 83 percent in 2020.

In spite of all the achievements of the green revolution, serious food problems still exist in the world. Every 3.6 seconds somebody dies of hunger. Chronic hunger takes the lives of 2400 people every day. Currently there are more than 800 million undernourished people in the developing world. Three hundred million children under the age of five die of hunger and malnutrition and one out of five babies is born underweight.

It is necessary to produce 40 percent more rice by 2025 to satisfy the growing demand without adversely affecting the resource base. This increased demand will have to be met from less land, using less water, less labor and fewer chemicals. If we are not able to produce more rice from the existing land resources, land-hungry farmers will destroy forest and move into more fragile lands, such as hillsides and wetlands, with disastrous consequences for biodiversity and watersheds. To meet the challenge of producing more rice from suitable lands, it is necessary to use rice varieties with higher yield potential and greater yield stability (Khush, 2004).

It is the principal crop and generate major source of employment and income, especially for the poor. Because of the growing population, farmers will need to produce more rice with improved quality to meet future consumer demand. This additional rice will have to be produced on less land with less water, less labour and fewer chemicals.

Asia's population is projected to increase from 3.7 billion in 2000 to 4.6 billion in 2025. About 530 million tonnes of rough rice were produced from 135 million ha of harvested irrigated rice area (average yield = 3.9 tonnes/ha) in 2002. Further, intensification of irrigated rice farms is necessary to feed the growing population and maintain food security in the near future. Rice farmers, however, face several problems: stagnating yield: declining profit (due to rising input costs and low rice prices); less land, water and labor for rice cultivation. So, there must be integrated use of compatible technologies that meet farmers' needs and improve their productivity and income (Balasubramanian *et al*., 2005). As such, System of Rice Intensification (SRI) as defined by Uphoff *et al.*, (2002) is a technique of agronomic manipulation. The practices are based on a number of sound agronomic principles. They work synergistically with others in order to achieve higher grain yield. It improves physiological activities of the plant and provides better environmental condition.

Father Henri de Laulaine, first reported this system of rice intensification (SRI), in 1983-84. Thousands of farmers in Madagascar have been benefited from SRI technique: with at least double rice yield only by changing certain common practices (Laulanie, 1993).

In Nepal, SRI research is reported to be started in 1999 in Kathmandu valley as cited by (Adhikari, 2000). It is still being evaluated as an approach to raise rice production, requiring only changes in plant, soil, water and nutrient management. Its principles always need to be tested in and adapted to varying environments, as there is no set formula for achieving the higher yields. Tripathi *et al.*, (2004) have concluded from an on farm and on station, trial performance of SRI could vary from location to location. Therefore, it must be verified in local conditions and manipulated accordingly. Instead of making recommendations to the farmers they should be encouraged for experimentation on their own management with different SRI practices.

One of the major factors contributing to high yield of rice is mineral nutrition. Among macronutrients usually applied as commercial fertilizers, nitrogen has the quickest and most pronounced effect on cereal production. It increased size and number of grains per panicle and protein percentage. It also improves the utilization of phosphorus and potassium to an appreciable extent (Brady, 1999). Inadequate nutrition, especially limitation of nitrogen, is one of the major bottlenecks of rice production in the world where about one third of the total N applied to crop is used for rice (Raun and Johnson, 1991) .Rice is very responsive to N fertilization and high yield potential of modern varieties can not be realized without N supply to the plant during the entire growing season. Nitrogen has quickest and remarkable effect on cereals production (Brady, 1999).

Therefore, such technologies are to be developed which are possible to use even by the poor farmers to improve their crops yield. The present investigation is, therefore, undertaken to assess the effect of System of Rice Intensification on different spacing and levels of nitrogen with the following objectives.

- ☞ Determine the optimum spacing and nitrogen levels.
- ☞ Find out the economic dose of nitrogen and response curve.
- ☞ Find out the economics of growing rice under different treatment condition.

2 LITERATURE REVIEW

2.1 System of Rice Intensification

At a time when rice farmers in many countries must begin finding ways to achieve their production goals with less use of water, an innovation in rice-farming methods has become available that can (a) increase yields and production, so that economic and food-security goals are met, (b) reduce costs of production, so that profitability is enhanced, and (c) decrease the amounts of irrigation water required. This innovation is called the System of Rice Intensification (SRI), developed 20 years ago in Madagascar (Stoop *et al.*, 2002 and Uphoff, 2003).

Satyanarayana *et al.* (2004) reported that SRI changes the management of rice plants and of the soil, water and nutrients that support them in simple but specific ways. The aim is to create an optimal growing environment for the rice plant so that its genetic potential is better expressed.

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

Rice has been cultivated under flooded conditions for centuries for various reasons. Reasons among others are the control of weeds and the belief that rice performs better under standing water (Reddy and Reddy, 1999). However, rice is only a flood-tolerant plant, not one that benefits from constantly saturated soil (Vartapetian, 1993).

2.1.1 Principle of SRI

Uphoff (1999) and Association Tefy Saina (1992) have defined following five principles for SRI in contrast to conventional system:

1. Early transplanting of single seedling per clump. This in conjunction allows a greater realization of tillering potential of rice plants. It gives many more rice-forming panicles per plant. Seedlings are transplanted at third or before fourth phyllochron, when the plant has still only two leaves, to avoid reduction in subsequent tillering and root growth (Laulanie, 1993).

2. Wide spaced planting on a square pattern gives the roots more space to grow. The rice plants get more sunlight and air. As a result both root growth and tillering are more vigorous. This also facilitates weeding and saves seeds, up to ten-fold or more in some cases.

3. Mechanical weeding early and frequent, varying from 3 to 4 times throughout the cultivation period. First weeding about 10 days after transplantation and the others in a frequency of 10-20 days.

4. Maintaining moist soil under non-saturated conditions during the vegetative phase with some intermittent drying. As a result there are fewer surficial roots, well developed tap root and more primary roots. This rooting pattern is apparently the result of the soil aeration brought about by the intermittent irrigation and drainage. Once flowering begins, just 3-4cm of water is kept standing on the field until it is drained completely about 25 days before harvesting

5. Compost application to capitalize the biological resources and organic matter improves the soil structure and allows continual release of nutrients.

The success of SRI is based on synergetic development of both tillers and roots. This comes from the combined interaction of all SRI practices (Defeng *et al.*, 2002). As cited In Appropriate technology, Uphoff (2001) has criticized the traditional method of rice cultivation that it does not have the ability to explore natural potential of the rice plant. It is transplanted with old seedlings, closely spaced and continual flooding which held back the plants natural potential.

2.1.2 Nitrogen fertilizer and Water management in SRI against conventional management

In lowland rice farming, water control is the most important management practice that determines the efficacy of other production inputs such as nutrients, herbicides, pesticides, farm machines, microbial activity, mineralization rate, etc. Poor drainage that keeps soil saturated is detrimental to crops and degrades soil quality. In many rice irrigation systems, drainage mechanisms and practices are disfunctional or inadequate because farmers believe that rice grows best when water is supplied in abundance. Rice fields are therefore kept continuously flooded and are drained only at time of harvest. This practice is not only wasteful, but also leads to leaching of soluble nutrients, blocks soil microbial activities, and slows down mineralization and nutrient release from the soil complexes.

The water management practices proposed for the System of Rice Intensification (SRI), cycles of repeated wetting and drying, were found to be beneficial to rice plant growth through increased nutrient availability leading ultimately to higher grain yields.

The phenomenon of having a large flush of nitrogen mineralization occurring after rewetting of dry soil was first reported by Birch (1958). This intensive pathway of nitrogen mineralization and nitrogen availability has potential to increase lowland rice yields. Worldwide, nitrogen is considered the most limiting nutrient for rice production; therefore, increased nitrogen availability should translate into yield increases.

The main N losses occur from leaching and denitrification as well as volatilization of NH3 from the floodwaters after it diffuses from the soil-water interface. Nitrogen, usually found as ammonium in anaerobic lowland soils, occurs more generally as nitrate (NO3) in aerobic upland soils. Ammonium ought to be more beneficial as a source of N because metabolizing NH4+ requires less energy than does NO3 (Tanaka *et al.,* 1984).

Recent research has found that, actually, N in nitrate form produces 40 to 70% more yield than an equal amount of N as ammonia, with a combination of NH_4^+ and NO_3 leading to better yields than provision of either form of N by itself (Kronzucker *et al.*, 1999). In SRI methods repeatedly wetting and drying the soil, would provide N in both forms.

Birch (1958) reported a flush of N mineralization that occurs after the rewetting of dry soil. This intensive pathway of N mineralization which subsequently increases N availability has become known as 'the Birch effect,' though not much attention has been paid to it for lowland rice. Flooded rice soil is a complex of an aqueous phase, a solid phase, an interchangeable gaseous phase, and various flora and fauna. The main chemical changes brought about by the flooding of soil have an impact on the supply of micronutrients; a decrease in redox potential due to the depletion of molecular oxygen leads to reduced Fe and Mn. Soil submerged for 10 to 12 weeks increases Fe2+ and Mn2+ concentrations, regardless of the soil type. Savithri *et al*., (1999) have mentioned that the concentrations of Zn and Cu decrease in lowland soils, and Zn deficiency is reported to be a widespread nutritional disorder of wetland rice.

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

SRI's benefits lie in important differences from conventional rice growing practice, which, proponents believe, interact synergistically to give high yields. A further advantage of SRI was its ability to break the labor peak during uprooting/ transplanting while the overall labor balance was neutral. SRI increased both the land and labor productivity compared to conventional practices (Anthofer, 2004).

A substantial saving on seeds, up to ten-fold or more in some cases, and tremendous saving on water is particularly important in areas of water scarcity, and avoids the damages of salination that accompanies over-irrigation. Both encourage vigorous root development, which in turn gives more vigorous growth of the rice plants.

Weeding is done manually with no herbicide use, which returns the weeds to the soil as green manure. This financial saving is offset by increased labor, but labor shortage is seldom a problem for farmers in the Third World, and weeding becomes less arduous in successive years. Giving up herbicides is a health bonus for all concerned: the farm worker most of all, and the consumer; and there is no pollution of the environment and ground water. One of the main purposes for flooding rice paddies with some controlled drainage is for weed control (Sahid and Hossain, 1995), so weeding is important in SRI

No mineral fertilizers are used, only liberal application of organic compost. This financial saving is accompanied by an improvement to the quality and fertility of soil, reducing runoff, and improving its water-retaining properties.

2.1.4 Water-saving and increasing yield possibilities associated with SRI

Yuan (2002) reported that the research held on China National Hybrid Rice Research and Development Center, it was found that the water applications could be reduced by as much as 65% on its SRI plots compared with conventional irrigated ones and same time yield was 16 t ha^{-1} in trials with a Super-1 hybrid variety grown with SRI methods in 35.6% higher than the 11.8 t ha^{-1} achieved with the same hybrid in conventional, water-intensive methods.

Sato (2006) stated that on-farm comparison trials had been conducted in Indonesia on 2003 on 1,363 ha, and it was found that an average SRI yield is 7.23 t ha^{-1} compared with 3.92 t ha^{-1} with standard methods, an 84% increase. Water saving with SRI was calculated as 40%, while costs of production were reduced by more than 25% because of reductions in fertilizer application.

Lazaro (2004) reported that an evaluation of SRI done in 2003 on Philippines by farmer field schools supported by the National Irrigation Administration in three communities in Negros Occidental province calculated that the water use was reduced by 67%. The SRI yield of 7.33 t ha^{-1} was more than double the 3.66 t ha^{-1} produced with TQPM, a 'modern' system of rice production that requires the use of fertilizers and more water. It was almost triple the 2.65 t ha^{-1} obtained from standard farmer practice.

Namara *et al.* (2004) reported in Sri Lanka that the average number of paddy irrigations for SRI farmers was 24 in the dry season and 22 in the wet season, compared with 32 and 29 for non-SRI farmers, a 25% reduction there was a 44% increase in yield with SRI.

2.1.5 Lower costs of production and reduced agrochemical use

SRI plants develop larger root systems, so they can utilize better otherwise-unavailable nutrients in the soil, and their functioning appears to confer greater resistance to pests and diseases, so chemical protection becomes unnecessary or uneconomic. While fertilizer can raise yields when used with the other SRI practices, the highest yields have usually come with the application of compost. Farmers can thus avoid or reduce the cost of chemical fertilizers if they have time and opportunity to collect compost and apply organic materials, rice straw, manure or any other biomass that can be gleaned from their surroundings. Almost all farmers who have tried SRI methods report that their rice plants are enough healthier and resistant that they no longer need chemical biocides or can greatly reduce their use, consistent with the theory of trophobiosis (Chaboussou, 2004).

Similarly, in China, sheath blight, the major hazard for rice farmers in the area, was reduced by 70% with SRI methods.

Tech (2004) found that in Cambodia compost use had gone up on average from 942 kg ha^{-1} to 2,100 kg ha^{-1} among SRI users, with a doubling of yield, while applications of chemical fertilizer had fallen from 116 kg ha^{-1} to 67 kg ha^{-1}, and use of chemical pesticides went from 35 kg ha^{-1} to 7 kg ha^{-1}. Farmers' cost of production had declined by more than half.

2.1.6 Reduction in seed requirements

With SRI, seeding rates are drastically reduced, to 5-10 kg ha^{-1}, about 5-10 times less than conventional rates. Especially for poor farmers, this is a real benefit. Farmers in Madagascar have reduced their need for seed by as much as 100 kg/ha. Another important feature of SRI is that farmers do not need to change their variety to get higher yields with less water, since most varieties respond to its practices. To be sure, some respond more than others to the new practices. All SRI yields >15 t ha^{-1} have come from high-yielding varieties (HYVs) or hybrids, so genetic potential is important. Because SRI cuts farmers' seed requirements by 80-90%, those who want to use improved varieties find that the higher cost of seed is no deterrent to planting HYVs or hybrids. While this may not be a huge incentive, if this occurs with fewer requirements for water, it is a boon to farmers. At the same time, however, traditional varieties also respond well to SRI practices, showing previously unrealized potential that is inhibited by modern practices such as heavy application of N fertilizer (Satyanarayana *et al.,* 2004) similarly Uprety, (2005) had also reported that seed requirement is 92,679.6 Mt. (at the rate of 60 kg/ha) in conventional method but by using SRI we can save 77,233 Mt. of seed for consumption. If we introduce this technology on only 10% of land and increase yield by only 1 Mt/ha (SRI potential is 2-3 times more than the present productivity), we can produce 1, 54,466 Mt more rice.

2.1.7 Resistance to abiotic stresses

In addition to reduced losses to pests and diseases, it has been observed that SRI plants, given their larger, healthier roots systems, are better able to resist damage from the effects of hurricane, cyclone, cold snaps and drought. SRI plants can, of course, be damaged by extreme winds, rain, cold or desiccation; but farmers find that these have observably more resilience and capacity to withstand various climate-induced losses (Satyanarayana *et al.,* 2004).

2.1.8 Less economic risk

Farmers using SRI methods are less subject to economic failures, even though SRI practices initially appear to entail greater risk. Two evaluations based on random samples of SRI users and non-users have found SRI methods to be less risky overall. The IWMI evaluation team in Sri Lanka calculated that SRI rice farmers were >7 times less likely than were conventional farmers to experience a net economic loss in any particular season because of SRI's higher yield and lower cost of production (Namara *et al*., 2004).

Anthofer *et al.* (2004) concluded: "SRI is an economically attractive methodology for rice cultivation with a lower economic risk compared to other cultivation practices."

2.1.9 Reduction in crop cycle

In Nepal, farmers using SRI methods have found that their crops mature 10-20 days sooner compared with the same variety grown conventionally. Dates of planting and harvesting are the least disputable agronomic data. In 2004, 22 farmers harvested their SRI rice on average 15.1 days sooner, with 114% higher yield (7.85 vs. 3.37 t ha^{-1}); in 2005, with less favorable conditions, 54 farmers reduced their time to harvest on average by 19.5 days, with 91% higher yield (5.51 vs. 2.88 t ha^{-1}). Harvesting sooner reduces crops' exposure to storm or other damage; it also reduces total amount of irrigation water needed (Satyanarayana *et al.*, 2004).

2.1.10 Possible limitations or disadvantages of SRI

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

SRI has been considered too labor-intensive for many farmers. This was given as a reason for disadoption of SRI by up to 40% of farmers, particularly poor ones, surveyed in one study done in Madagascar (Moser and Barrett, 2003). However, as farmers become more comfortable and skilled with the new methods, SRI is becoming *labor-saving*. In the Chinese study reported above, labor-saving was regarded by farmers as the main attraction of SRI, more than its water saving, and more than its yield and profitability increases (Li *et al.*, 2005) with making agreement Tech (2004) reported that in Cambodia, 55% of 120 farmers who have used SRI for three years evaluated it as 'easier' to practice, whereas only 18% considered it 'more difficult'; 27% said there was 'no difference'. Similar report can be found that an evaluation done of 108 farmers in Madagascar who were using both SRI and conventional methods determined that while first-year users required 20-30% more labor ha^{-1}, by the fourth year, SRI required 4% less labor and by the fifth year, 10% less (Barrett *et al*., 2004).

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

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

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

2.1.11 SRI research and findings

In an experiment conducted in Bangladesh to evaluate the performance of hybrid rice under SRI in 2002 boro (dry season) and T. aman (wet season) at BRRI, transplanting and SRI treatments with 30cm × 30cm spacing produced identical grain yield but the later saved two thirds the amount of seedlings used by farmers (Islam *et al.*, 2005).

In a ISIS press release (2005), it has been reported that for the past three years a dozen farmers in Morang District near the Nepali-Indian border 300 miles south of Kathmandu have been testing SRI, using only a fraction of the normal amount of local *mansuli* variety rice seed and far less water than usual, their yield has more than doubled. Initial trials were not very impressive, largely because of inadequate water management during monsoon season; trials through farmer field schools in 2002 and 2003 at Sunsari-Morang irrigation system established >8 t/ha average for SRI vs. nearly 4 t/ha with farmer methods and nearly 6 t/ha with improved (high input) methods. More than doubling of yields in Morang district in 2004, with reduced time to maturity and lower costs led to national interest in SRI; dissemination now endorsed by Minister of Agriculture and supported by World Bank grant to extension service.

Mae Wan Ho (2005) reported an average SRI yield of 8.07t/ha, 37% higher than the average with improved practices, and 85% higher than the average with farmers' practices in Nepal in 2002. During monsoon season 2004, farmers got more than a doubling of yield (3.37 to 7.85 t/ha) with a 15-day reduction in time to maturity. Being able to harvest sooner reduces farmers' risks of damage from pests or from typhoons, cyclones or other extreme weather that can come at the end of the season. Farmers compared SRI with their own usual practices and "improved" practice.

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

Tripathi *et al.,* (2004) reported that the yields obtained under SRI system from the variety Rampur masuli was higher than the variety Radha-4 and the spacing 20x20 cm^2 produce significantly higher grain yields (8821 kg/ha), 30x30 cm^2 produce (7627 kg/ha) and 40x40 cm^2 produce (5747 kg/ha).

The yield obtained from Sabitri was significantly higher, whereas Radha-4 yielded lower compared with farmers' practice. Excluding weeding cost, there is a 28 percent yield advantage with 20x20 cm^2 spacing and 33 percent with 30x30 cm^2 spacing over farmers' practice with manual weeding treatment hills. Again 20x20 cm^2 spacing out-yielded the rest of the treatments with 49 percent higher (maximum grain yield of 9.6 ton per hectare) grain yields compared to the farmers practice with the chemical fertilizer applied at 100:50:30 kg N, P_2O_5 and K_2O kg/ha. The national average rice yields are 2.7 ton per hectare. There is thus a great potential of SRI to increase rice production in the country. The only problem is the management of weeds on time (Bhatta *et al.*, 2005).

In a review of SRI presentation from 17 countries in Cornell University, Fernandes (2002) concluded:

Three fourth of studies confirms a significant yield advantage in SRI vs conventional rice. For yields below 8 t/ha, yield increases due to SRI were between 10-50%.

SRI results in increased yields for both traditional and improved varieties, several studies reported that some varieties respond better to SRI than others.120-140 day varieties may respond best to SRI. Very short or long duration varieties appear to respond less.

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

Alternate flooding and draining can reduce CH_4 emissions but result in significant increases in NOx emissions. The effect of nitrous oxide is nearly 35 times greater than CH_4. Though SRI requires less water than usually applied when growing rice; it does depend on having good water control.

The potential benefits include production as well as economic and environmental aspects in particular for the situations under which resource poor, small farmers have to operate.

2.1.12 Potential of SRI in Nepal

In the testing carried out by ICIMOD farmer have considered SRI as a potential agronomic option to grow rice especially under control irrigation management. Rice yields, grown under SRI system increased by 10-25%, in case of rain fed plots the yield increase was only 10%. The results of SRI on-farm research plots showed that yields in the SRI plots with different rice var. were 10 to 57% more compared to those recorded in the traditional plots in 2003. The highest yield increase of 57% was recorded for the Naya Parwanipur rice variety, followed by 54% for Panta 10. Farmer perceived that SRI requires only 25% of seeds, 50% less labor for transplanting; and 50-60% less labor for irrigation and less use of pesticide than traditional method. At the same time there is about 40-50% increase in grain and 20-25% increase in biomass production. This was considered as advantageous for a smallholder farmer (ICIMOD, 2006).

According to (Regassa *et al.*, 2003 b) the family size is positively correlated with the rate of adoption of SRI. With each unit increase in family size, the likelihood of being a SRI Farmer increased by 1.45 times. The proportion of children between 7 and 14 increases the likelihood of SRI adoption. He has reported the most appropriate domains (target group) for SRI adoption are those farmers:

1. With limited landholdings
2. Having bigger family size with high proportion of the family members capable of engaging in work.
3. Cash-constrained.

4. For whom rice constitutes the major share of annual income and consumption.
5. With limited alternative employment opportunities.
6. With relative certainty regarding irrigation water supply and
7. Practicing rain-fed paddy cultivation.

Thus SRI can be a potential option for the rice fields of Nepal. This research is undertaken to observe the SRI performance in Chitwan condition under different doses of Nitrogen and under different Spacing.

2.2 Effects of nitrogen

Nitrogen is the integral element of the chlorophyll (Tisdale *et al*., 2002) and is the substrate needed for the synthesis of amino acid and proteins, which are constituents of protoplasm and chloroplast (Singh, 1997). Nitrogen helps to promote plant height, number of tillers, and number of grains and is needed to maximize the panicle number as much as possible at early and mid tillering stage (De Datta, 1986) and these parameter are adversely affected due to deficiency of nitrogen as the formation of enzymes, chlorophyll and proteins necessary for growth and development, gets restricted (Reddy and Reddy, 2000).

Nitrogen is the major nutrient added to increase crop yield (Camara *et al.,* 2003). At a cellular level, N increases the cell number and cell volume; at the leaf level, it increases the photosynthetic rate and efficiency (Lawlor *et al*., 1988). Increases in crop growth rate are largely produced through an increase in leaf area index, and also by an increase in radiation use efficiency (RUE, dry matter produced per unit of either incident radiation or intercepted radiation) (Brown *et al*., 1987; Lawlor, 1995).

Increasing level of nitrogen up to 150 kg/ha increased all the growth and yield attributes in rice. The number of productive tiller/ m2, panicle weight and plant height were increased significantly with increasing levels of N up to 150 kg/ha and beyond which there was marked decrease in yield (Mishra *et al.*, 1972).

Ramaswami *et al*. (1985) also reported increase in dry matter and tiller production of rice due to increase in N levels from 0 to 150 kg/ha similarly a field study initiated at Karnal, India, Kumar *et al.* (1996) states that the significant increment in dry matter yield of rice when N level was increased from 0 to 180 kg N/ha

Ram and Gupta (1973) reported that application of nitrogen remarkably increased the grain yield of rice during both the seasons (1960/1970). Application of 80 kg N/ha produced highest mean grain yield over control and 40 kg N/ha by 71.2 and 6.9 percent respectively in 1969, increasing level so of nitrogen up to 160 kg N/ha increased the grain yield, response was noticed to be linear. But there was no significant difference in yield beyond 80 kg N/ha. In 1970 highest grain yield was obtained with the application of 80 kg N/ha beyond which decreasing trend in yield was noticed as the levels of nitrogen were increased. This was because of lodging of the plots those having variety NP 130 and Jamuna. However, the economic dose of nitrogen was 101 kg/ha taking relation with price of input.

Singh *et al.* (1997) evaluated the response of three modern semi dwarf rice varieties at four level (0, 40, 80 and 120 kg N/ha) of applied N and the result showed that the yield were highest with 120 kg N/ha, however 40 kg N/ha gave the highest return to fertilizer invest.

Sharma and Rajat (1975) conducted experiment at the Indian Agricultural Research Institute New, Delhi and he found that on an average plant height was significantly increased by N application up to a level of 150 kg N/ha. The average percentage increases in grain yield at 50, 100, 150 and 200 kg N/ha over no N were 24.7, 32.9, 40.1 and 36.6

respectively. The percent increases in straw yield at 50, 100, 150 and 200 kg N/ha over no N were 28.4, 41.8, 58.1 and 73.4 respectively.

Subramanian and Rajgopalan (1979) states that nitrogen uptake was proportionate to the level of nitrogen applied. Increased concentration as well as higher dry matter production were the main cause for the enhanced uptake at higher levels by N application. It is generally accepted that nitrogen application increased the N uptake of plants.

Nair (1975) and Yadav *et al*. (1976) recorded significantly higher growth, yield and yield attributing characters of rice with every increase in nitrogen level up to 120 kg/ha similarly up to 150 kg/ha (Panda and Das, 1979)

2.2.1 Effects of nitrogen and spacing on yield attributes and yield of rice

Nitrogen is one of the most important nutrients applied as a fertilizer, responsible to a great extent for the large yields obtained from high input agriculture (Greenwood, 1982).

The supply of nitrogen increases total biomass production and increases yield and yield components (Lawlor *et al.*, 1988). The yield component like number of grains per panicle depends on the amount of nitrogen absorbed by the plant at the later stage of panicle emergence or heading stage. Low availability of N at this stage increase the number of degenerated grains (Wada, 1969) where as, excessive nitrogen or less than optimum rates results in lower grain yield and with reduced quality (Sims and Place, 1968).

A field experiment conducted on clay loam soil with four level of nitrogen (0, 40, 80 and 120 kg N/ha) and 3 varieties (SKAU 23, SKAU 27, SKAU 5) at Khudwani, (India) by Bali *et al.* (1995) showed a significant increase in yield attributes with the increase in N levels. For example, application of 120 kg N/ha produced significantly higher panicles/m^2 (395.8), grains/panicle (89.7), and test weight (24.0) over 0, 40 and 80 kg N/ha (256.3, 65.9, 23.0 gm; 331.1, 72.6, 23.26 and 372.1, 82.5, 23.6 gm, respectively). The increase in the yield attributes was related to better availability of nutrients under higher level of N. The result is in conformity with Ram *et al.*, (1984), states that nitrogen application level significantly affected number of tillers/plant, panicle length, and filled spikelets and application of 80 kg N/ha increased yield significantly over that of other levels (20, 40, 60 kg N/ha).

Maurya and Yadav (1987) studied the effect of N level (0, 50 and 100 kg N/ha) on grain yield and yield parameters using overage seedlings of four transplanted rice varities- Mahsuri, Sarjoo 52, Ratna, and Saket 4 in RCBD with four replication. Experimental plot soil was sandy loam with pH 7.5, EC (1:2) 0.09 mmho/cm, 0.42% organic C, 17.5 kg available P/ha and 135 kg available K/ha. Fifty five day old seedlings were transplanted at 2-3 seedlings/hill at 20 × 10-cm spacing. Each increment of N significantly increased panicle number, panicle weight, test weight, plant height and grain yield but average N use efficiency was low, 17.7 kg grain/kg N with 50 kg N/ha and 14.1 kg grain/kg N with 100 kg N/ha. In general, grain yield and yield parameters were adversely affected by planting overage seedlings, which resulted in low grain yields for all varieties. N application was beneficial to grain yield, even with overage seedlings.

Patel *et al.* (1997) carried out an experiment with 3 level of N (40, 80 and 120 kg N/ha) and rice variety (Swarna) under sandy loam soil at IGKV, Regional Agricultural Research Station, Boirdadar farm, Raigarh (India) and obtained significantly higher yield attributes (9.2 effective tillers/hill, 22.93 cm panicle length and 21.64 gm test weight) with 120 kg N/ha than 40 kg N/ha (7.5, 22.27 cm and 20.75 gm) but was at par with 80 kg N/ha (8.8, 22.63 cm and 21.45 gm, respectively). These responses of rice crop to the application of higher level of N in respect of yield attributes depend on the variety grown.

Similar result were found by Singh *et al.* (1997), conducted the field experiments under rainfed conditions during monsoon seasons (July to October) of 1972 and 1973 with three rice varieties with four levels of nitrogen (0, 40, 80 and 120 Kg N/ha) in a randomized block design at Banaras Hindu university. The result showed a marked and consisting increase in grain yield of rice with increasing levels of nitrogen in all the three varieties during the both years.

Panda and Das, 1997 conducted the trials were conducted at Regional Reserch Station of the Orissa University of Agriculture and Technology located at Chiplima in Sambalpur. The effect of different levels of nitrogen on the yield of grain and straw and grain: straw ratio of the straw ratio of the short duration varieties of rice reveal that the yield of grain and straw and grain: straw ratio increased significantly with increasing levels of nitrogen up to 200 kg N/ha, irrespective of seasons and varieties, while no nitrogen (control) gave the minimum. The reasons for the high yields per hectare with increasing levels of nitrogen may be that the higher dressing of nitrogen causes vigorous shoot growth for manufacturing food materials in large quantities and better development of roots for greater uptake of nutrients. Moreover, the number of productive tillers/m^2, panicle weight and plant height increased significantly with increasing levels of nitrogen application.

Kumar *et al.* (1975) conducted a field experiment during Kharif seasons of 1967 and 1968 at the R.B.S. College Research Farm, Bichpuri, Agra consisting of treatment combinations of three levels of nitrogen (50, 100 and 150 kg N/ha), three spacing (15 × 15, 20 ×15 and 25 × 15 cms) and two varieties (I.R.-8 and T.N.-1).

The application of 150 kg N and 100 kg N per hectare increased significantly 26.30 and 20.17 percent grain yield as compared to 50 kg N/ha, during both the years. The treatments N 100 and N 150 were statistically at par.

Similarly, Singh and Singh (1998) reported that application of 120 kg N/ha in 3 split doses improved significantly increased the yield and yield attributes as compared to lower N level. The magnitude of increase in yield at 120 kg N/ha was 55 and 26.3% over

80 and 40 kg N/ha respectively. Crop receiving 120 kg N/ha resulted significantly more protein (404.8 kg/ha) content in grains which was 35.93 and 8.14% higher than 80 and 40 kg N/ha respectively.

Verma (1972) conducted experiment for two years (1967 and 1968) during Kharif season at research farm, faculty of agriculture, Banaras Hindu University. The treatment included the comparisons of three fertility levels (low= 60 kg N + 30 kg P_2O_5 + 30 K_2O/ha., medium= 120 kg N + 60 kg P_2O_5 + 60 kg. K_2O/ha and high= 180 kg. N + 90 kg P_2O_5 + 90 kg. K_2O/ha), three spacing (15 cm × 15 cm, 15 cm × 20 cm and 15 cm × 30 cm) and two varieties (N.S.J. 98 and Taichung Native-1). All the yield attributes increased progressively due to increase in fertility level. However, the weight of 1000 grains did not differ significantly due to fertility levels in the second year. The greater availability of all the major nutrients to growing plants might have resulted into increased yield attributes.

Chauhan *et al.* (1974) reported that the rice yield response to nitrogen level up to 150 kg/ha and further increase in nitrogen level fails to increase the crop yield.

Sadaphal *et al*. 1981 conducted experiment at the Indian agricultural research institute, New Delhi during the kharif seasons of 1978 and 1979. The soil was sandy clay loam having a pH of 7.9. The total N and available P of the soil were 0.11% and 18 kg/ha, respectively. They reported that the differences amongst the three rates of nitrogen application viz., 40, 80 and 120 kg/ha as regards height of plant, number of tillers per hill, number of productive tillers per hill, length of panicle and grain weight per panicle were significant. Grain weight per panicle at 120 kg N/ha was significantly greater than those fertilized at 80 kg N/ha which was in turn greater over 40 kg N/ha. Number of tillers per hill, number of productive tillers per hill and length of panicle under 80 and 120 kg N/ha were at par and were significantly superior to the attributes recorded at 40 kg N/ha. Height of plants at 120 kg N/ha was significantly superior to those recorded at 40 and 80 kg N/ha. The yield of grain increased with increase in the rates of nitrogen applied to the soil.

Sharma and Rajat (1975) conducted experiment at the Indian Agricultural Reserch Institute New, Delhi and he found that on an average plant height was significantly increased by N application up to a level of 150 kg N/ha. The average percentage increases in grain yield at 50, 100, 150 and 200 kg N/ha over no N were 24.7, 32.9, 40.1 and 36.6 respectively. The percent increases in straw yield at 50, 100, 150 and 200 kg N/ha over no N were 28.4, 41.8, 58.1 and 73.4 respectively.

2.2.2 Time of nitrogenous fertilizer application

The timing of N application is an important aspect of overall N management in rice for efficient utilization of this nutrient. Proper time of N application minimizes its loss in rice fields, which depends on the amount of nutrient supply and also environmental conditions under which the crop is grown (Thakur, 1992).

Surekha *et al.* (1999) reported that the hybrid rice grain yield (6.20 t/ha) was obtained significantly higher with when 120 kg N/ha applied in 4 equal splits i.e. basal, tillering, panicle initiation and flowering stages than same dose of N applied in three equal quantities: at basal, tillering and panicle initiation (5.87 t/ha). There was no significant different in straw yield.

Paraye *et al.* (1996) states that the split application of 100 kg N/ha significantly influenced all the yield attributes along with grain yield except effective tillers/m2 in pooled analysis. Split application of nitrogen as 30% basal + 40% at tillering and 30% at panicle initiation gave significantly higher grain yield than the other treatments. The combination recorded significantly higher plant height, tillers/m2, panicle length and weight, test weight, grains/panicle and grain yield/panicle than other treatments. Similarly, this result is in agreement with Gupta and Sharma (1991).

The rice plant absorbed 50% nitrogen by the early panicle initiation stage and about 80% of applied nitrogen by the heading stage (Biswas *et al.*, 1996).

Prasad (1999) stated that split application of the nitrogen was useful to increase nitrogen use efficiency and recommended two-split application of nitrogen for short and medium varieties; three splits for long and more splits those for sandy soils.

De Datta (1978) reported that the nitrogen absorbed by the plant from tillering to panicle initiation increased the number of tillers and panicles, that absorbed during panicle to flowering increased the number of filled spikelets per panicle and that absorbed after the flowering tends to increase the test weight similarly the N fertilizer applied at latter stages is better utilized by the rice plant than basal application of N, particularly for grain production (Mishra, 1993).

Zhiming *et al.* (1996) stated that increasing the number of N application induced higher grain yield but the higher N application (180 kg N/ha) had significantly favorable effect on dry matter production and N uptake during the vegetative stage of the crop but these were not reflected in the final yield.

Bhujel and Nepal (1996) reported that the nitrogen supplied at basal dose with top dressing produces more grain yield that only top dressing.

Much of the nitrogenous fertilizer supplied as basal dose is not utilized by the crop and lost from the root zone. Therefore, to realize high efficiency of fertilizer nitrogen, the major part of its total amount needs to be applied at the stage of 3-6 weeks after germination or sowing of sprouted seeds and the rest at the panicle initiation stage (Krishnaiah, 1998).

2.2.3 Method of nitrogenous fertilizer application.

De Datta (1984) reported that deep placement of fertilizer in reduced zone had been considered to be the most efficient method to increase N efficiency in low land rice similarly deep placement of urea super granule was found to be superior to urea alone (Maskey *et al.*, 1992)

Nitrogen use efficiency (NUE) by surface broadcast application is usually low but may be improved through deep incorporation of fertilizer or through deep placement in mud balls (IRRI, 1993).

Das and Singh (1994) also reported that the grain yield and nitrogen use efficiency of rice was more when urea super granules was deep place as compared with urea super granules broadcasted and incorporated and prilled urea applied in three splits.

Craswell and De Dattta (1980) reported that the deep placement of fertilizer is generally more efficient than the traditional split application of urea, likewise deep placement of nitrogeneous fertilizers is becoming increasingly relevant since the introduction of modified urea materials such as urea briquettes, urea super granules (USG) and urea marbles for testing in lowland rice (De Datta, 1986).

3 MATERIALS AND METHODS

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

3.1 Description of the experimental site

3.1.1 Geographical location

The field experiment entitled "System of Rice Intensification under different plant population and levels of nitrogen" was carried out at the research farm of the Institute of Agriculture and Animal Science (IAAS) Rampur, Chitwan; during the rainy season of 2006. Rampur is located at 256m above mean sea level. Geographically, it is located at 27^0 37' North latitude and 84^0 25' East longitude (Sharma *et al*., 1984).

3.1.2 Climate and weather

The site is situated in subtropical type of climate. The maximum temperature rises up to 420 C during the hottest months of April, May and June. The minimum temperature (6^0C-10^0C) never goes to freezing point even during the coldest month of December and January. Rainy season starts from June and lasts up to September. June and July receives the highest amount of rainfall. Relative humidity starts to rise from May (average 50%) and reaches to its extreme (100%) in December and January (Thapa and Dangol, 1988).

3.1.3 Meteorological data during the crop season

The meteorological data for the cropping season recorded at meteorological observatory lab of the National Maize Research Program, Rampur, are appended in (Appedix 1) and depicted in (Figure 1). The rainfall received during the growth period of the crop (June to October) totaled 1567.4 mm. The mean maximum and minimum temperatures were 34.17 ^{0}C and 24.03 ^{0}C respectively for the cropping season. During the crop season, the maximum temperature ranged from 32.93 ^{0}C (October'06) to 35.08 ^{0}C

(May' 06). Similarly, the minimum temperature ranged from 19.92 ^{0}C (October'06) to 26.56 ^{0}C (July '06). The relative humidity ranged between 76.35% in the month of May and 85.53% in the month of September.

Climate is most dominating factor influencing the sustainability of crop in a particular region. The yield potential of the crop depends on the climate. The most important factor influencing growth, development and yields of crop are solar radiation, temperature and rainfall (Upadhaya, 2005).

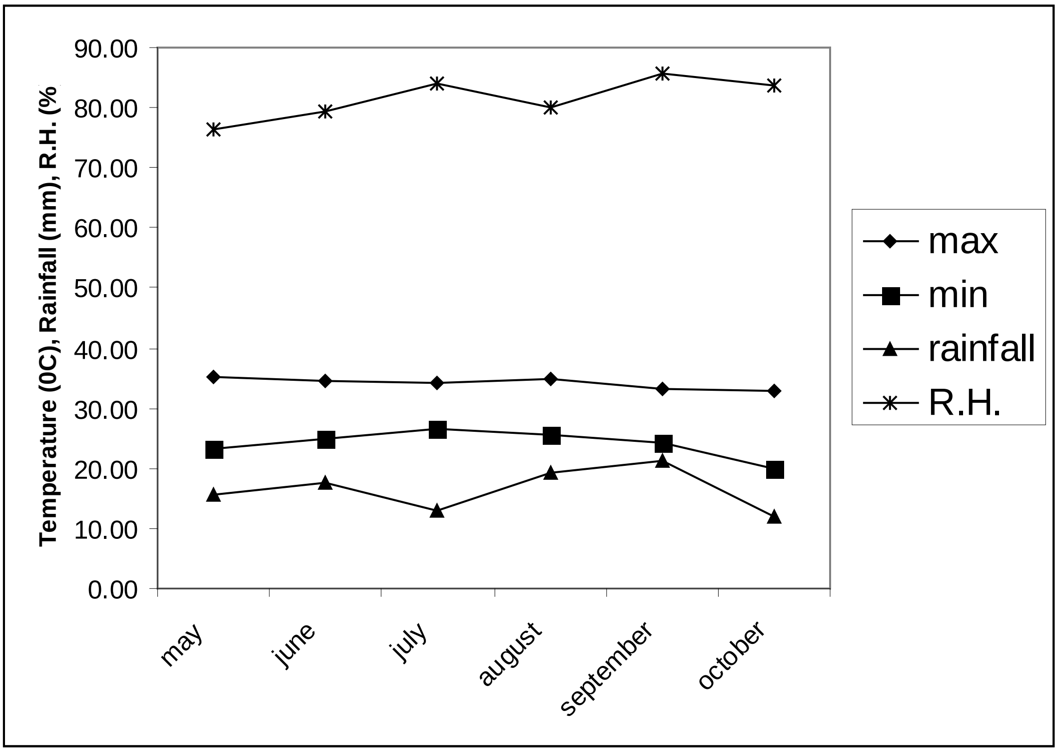

Figure 1 Weather conditions during the experimentation.

3.1.4 Cropping history

The cropping history of the experimental field included growing of rice and then after buckwheat for the research purpose.

3.1.5 Soil properties of the site.

Soil samples were taken from the experimental site and analyzed at the Directorate of soil management of MOAC/HMG, Hariharbhawan, lalitpur, Nepal to know the initial fertility status. Experimental site was divided into three blocks four spots in each block were marked for taking soil sample. Samples were taken from each spots in each block using tube auger from 0-15cm of the soil layer one day before the field preparation. The samples of each plot of each block were mixed together and composite sample was made. These samples were dried, grounded and passed through 0.2 mm sieve for chemical analysis.

Total nitrogen was determined by Macro-Kjeldahl Method (Jackson, 1967), available phosphorous by Olsen’s Method (Olsen et al., 1954) and available potassium by Neutral ammonium acetate method (Jackson, 1967). Organic matter was determined by Walky and Black method, pH (1:1 soil: water) by Beckman Glass Electrode pH meter and soil texture by USDA Triangular system-hydrometer method. Physico-chemical properties of the soil experimental site are presented in (Table 1).

Table 1 Physico-chemical composition of the soil of the experimental site.

Constitutes	Value
1. Physical Properties	
Sand (%)	64.1%
Silt (%)	6.5%
Clay (%)	29.4%
2. Textural Class	Sandy loam
3. Chemical Properties	
a. Soil pH	5.6
b. Soil Organic Matter	3.26%
c. Available Nitrogen	0.15%
d. Available Phosphorus	20.53 kg/ha
e. Available Potassium	114 kg/ha

3.2 Details of the experiments

3.2.1 Field layout

The experimental field was laid out in split plot design with 15 treatments and three replications (45 plots) with gross plot size of 4.8 x 2.4 m^2. Total of 15 treatments consist of three spacing as main plot and five level of nitrogen (0, 40, 80, 120 and 160 kg N/ha) as subplot. The plots were separated by a bond of 0.75 m for main plot, 0.5m for sub-plot and 1m for replication. Plant geometry was maintained with 3 spacing; 20 cm × 20 cm, 20 cm × 15 cm and 20 cm × 10 cm. There were 12 rows of 4.8 m length in each plot. The 6 row of net plot were used for harvesting and 3 rows of sampling row were used for all biometrical and phonological observations at different stages of crop growth. The layout plan of an individual plot and the experiment is shown in figure 2 and figure 3 respectively.

Individual gross plot size = 11.52 m^2 (4.8m x 2.4m)

Individual net plot size = 5.76 m^2 (4.8m x 1.2m)

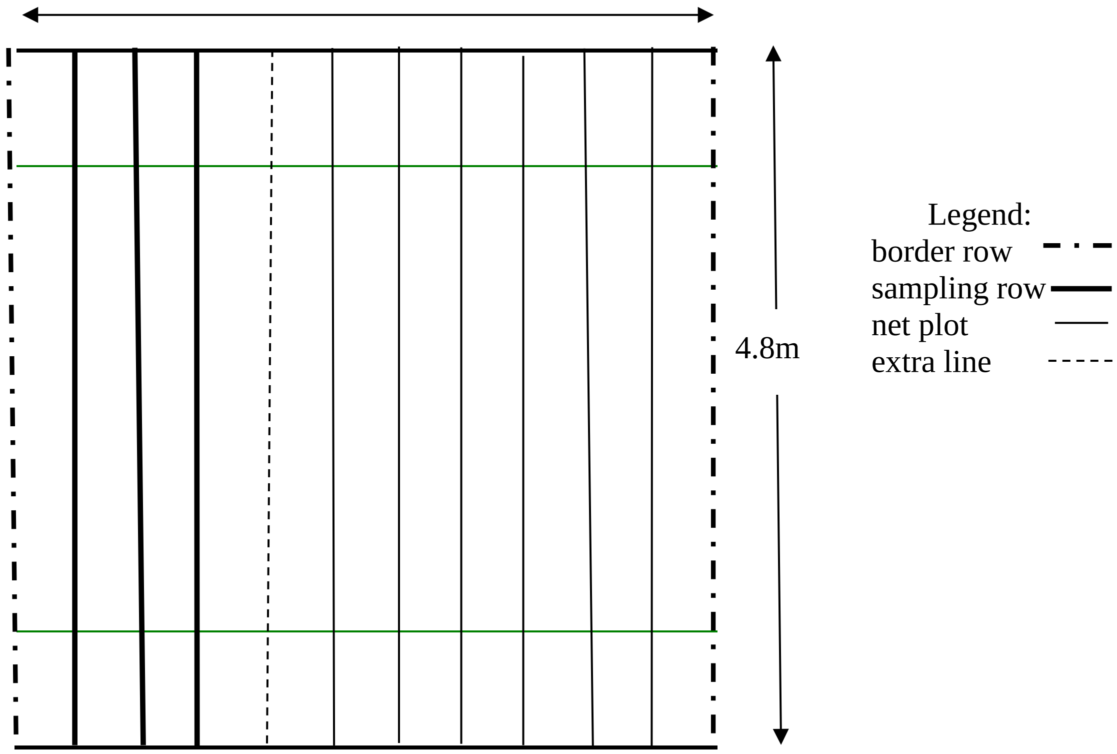

Figure 2 Layout of an individual plot.

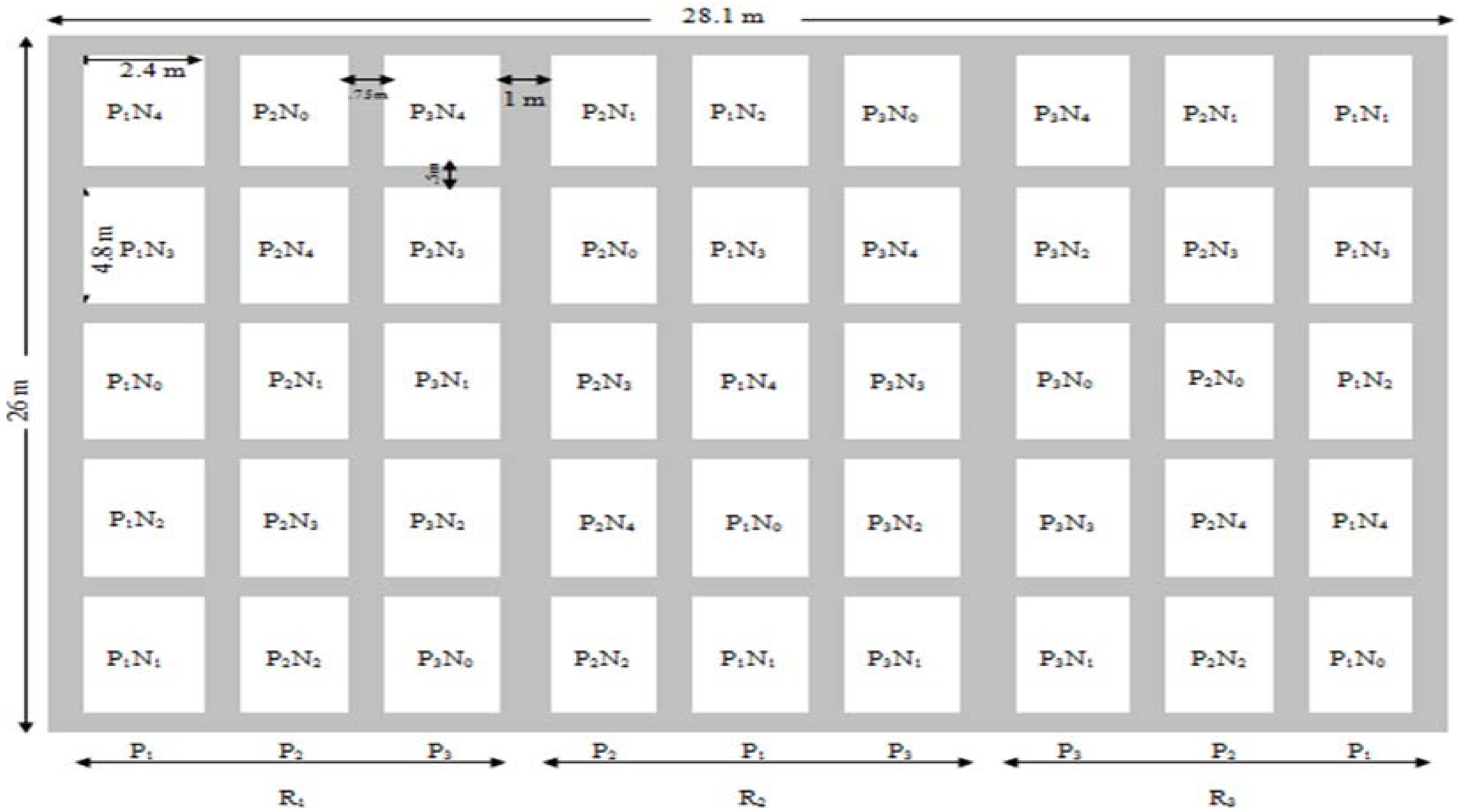

Figure 3 Layout of experimental field

3.2.2 Treatment details and their symbols

There were 15 treatment combinations comprising of 3 plant population (spacing) and 5 levels of nitrogen. The plant population (spacing) is represented by a symbol P while Nitrogen level is represented by a symbol N.

Table 2 Details of treatments those were used in experiment

S. N.	**Treatment combination**	**Symbol**
T_1	Spacing (20 cm × 20 cm) + nitrogen @ 0 kg N/ha	P_1N_0
T_2	Spacing (20 cm × 20 cm) + nitrogen @ 40 kg N/ha	P_1N_1
T_3	Spacing (20 cm × 20 cm) + nitrogen @ 80 kg N/ha	P_1N_2
T_4	Spacing (20 cm × 20 cm) + nitrogen @ 120 kg N/ha	P_1N_3
T_5	Spacing (20 cm × 20 cm) + nitrogen @ 160 kg N/ha	P_1 N_4
T_6	Spacing (20 cm × 15 cm) + nitrogen @ 0 kg N/ha	P_2 N_0
T_7	Spacing (20 cm × 15 cm) + nitrogen @ 40 kg N/ha	P_2 N_1
T_8	Spacing (20 cm × 15 cm) + nitrogen @ 80 kg N/ha	P_2 N_2
T_9	Spacing (20 cm × 15 cm) + nitrogen @ 120 kg N/ha	P_2 N_3
T_{10}	Spacing (20 cm × 15 cm) + nitrogen @ 160 kg N/ha	P_2 N_4
T_{11}	Spacing (20 cm × 10 cm) + nitrogen @ 0 kg N/ha	P_3 N_0
T_{12}	Spacing (20 cm × 10 cm) + nitrogen @ 40 kg N/ha	P_3 N_1
T_{13}	Spacing (20 cm × 10 cm) + nitrogen @ 80 kg N/ha	P_3 N_2
T_{14}	Spacing (20 cm × 10 cm) + nitrogen @ 120 kg N/ha	P_3 N_3
T_{15}	Spacing (20 cm × 10 cm) + nitrogen @ 160 kg N/ha	P_3 N_4

3.3 Characteristics of rice variety

Rampur masuli, a fine grained and a long duration variety (Tripathi *et al.*, 2004) was taken in this experiment. This variety is cultivated widely in Chitwan as rainy season rice.

3.4 Cultural practices of rice

The experimental field was harrowed and planted three times. The stubbles and dried weeds were removed manually from the field. The field was laid out as shown in Figure 2 and replicated three times.

The seedling was raised in nursery bed and transplanted after 15 days after sowing. The nursery bed was solarized for about 15 days before sowing. Transparent plastic sheets used for solarization allows short wave lengths into the soil. These wave lengths convert to long wave lengths which do not pass through the plastic sheets. These wave lengths then raise the temperature of the soil to 50^0C. At this temperature weed seeds and harmful microorganisms get destroyed (Adhikari, 2001).

Only one seedling per hill was transplanted. The crop was transplanted on 24th May 2006 in agronomy farm of IAAS, Rampur. A seed rate 8 kg/ha was used for sowing and 20 cm row to row distance with 10 cm, 15 cm and 20 cm plant to plant distance was maintained. Nitrogen was applied as per treatment and was applied in 4 split (basal, 20 days after transplanting, panicle initiation and at flowering) where phosphorus and potash was applied as basal, at the dose of 50 kg P_2O_5/ha and 30 kg K_2O/ha. FYM was applied 1 kg/ sq m (10 ton/ha). The source of chemical fertilizer was urea, triple super phosphate, and murate of potash. Zinc (commercial product) was applied @ 16 kg/ha. Irrigation was provided only to make field moist but not in flooded condition. All the required cultivation practices were rendered uniformly as per necessity.

3.5 Observation taken

Different biometrical and phonological observations taken at different growth stages of crop were as follows.

3.5.1 Biometrical Observation

3.5.1.1 Plant height

Randomly selected and tagged 10 plants were used for the measurement of plant height at an interval of 15 days from 15^{th} day after transplanting and ending with just flowering. It will be measured from base to tip of the upper leaves of the main stem.

3.5.1.2 No. of tiller

Number of tiller per plant were counted from one meter row length.

3.5.1.3 Leaf Area Index (LAI)

Leaf area (cm^2) of the functional leaves obtained from samples drawn for dry matter accumulation study were measured by automated leaf area meter. Then leaf area of the plants/unit is will be worked out by following formula:

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

3.5.2 Nitrogen content

Nitrogen content in the grain of rice crop was analyzed in the laboratory.

3.6 Yield attributing characters of rice

3.6.1 Effective panicle per meter row length

Observation regarding the effective tillers per row length was recorded just before harvesting the crop and the average values was used to obtain the effective panicles per meter row length.

3.6.2 Length of panicle

The length of panicle was taken from the 10 panicles from each plot which were randomly selected just before harvesting and mean were calculated.

3.6.3 Number of grains per panicle

Number of filled and unfilled grains were counted to determine the number grains per panicle.

3.6.4 Thousand Grain weight (TGW)

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

3.6.5 Biomass yield and grain yield

Biomass yield and grain yield was be taken at harvesting from net plot. Dicky Johns Multi-grain moisture meter was used to record the moisture percentage of the grain. Finally grain yield was adjusted at 12% moisture using the formula as suggested by Paudel (1995).

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

Where,

MC is the moisture content in percentage of the grains.

3.6.6 Biomass

All the plants from 1m row length were uprooted and weighed to determine the total biomass yield.

3.6.7 Harvest index

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

H.I. % = (grain yield × 100)/ (grain yield + straw yield)

3.7 Economic analysis

3.7.1 Cost of cultivation

Cost of cultivation of rice crop was calculated on the basis of local charges for different agro-inputs viz., labor, fertilizer, machines and other necessary materials used for conducting the experiment (appendix 2).

3.7.2 Gross return

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

3.7.3 Net return

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

3.7.4 B:C ratio

It was calculated by following formula:

Benefit: cost ratio= Net return / cost of cultivation

3.8 Statistical analysis

All the recorded data were compiled and analyzed through MSTAT-C package. Means were separated by least significant difference (LSD) and Duncan's Multiple Range Test (DMRT). Microsoft Excel was used for tabulation and simple calculation, presentation of graph for different comparisons. Pearson's correlation coefficient and regression equation were run between selected parameters wherever necessary.

4 RESULTS AND DISCUSSION

The results obtained from rice research trial "System of Rice Intensification under different spacing and levels of nitrogen" are presented in this chapter. The results are summarized in tables and illustrated through figures wherever appropriate and essential. The findings are discussed with possible reasons and correlated with other findings.

4.1 Growth and development

4.1.1 Plant height

The effect of spacing and levels of nitrogen on plant height (cm) at different growth period of rice are presented in Table 3. The plant height increased as the age of crop advanced and maximum plant height was observed at 85 DAT in all spacing and nitrogen treatments.

At 25 DAT the rice plant was in tillering stage but had not yet reached the maximum tillering stage. During this stage spacing and nitrogen had significant effect on plant height. Maximum plant height (36.39 cm) was recorded at 20 cm × 10 cm spacing followed by (36.27 cm) at 20 cm × 20 cm which were statistically at par. However, 20 cm × 20 cm spacing resulted lowest plant height. The lowest plant height under wider spacing at the initial period of rapid growth could be attributed to the rapid tillering (Table 5) of the rice plant under wider spacing and less competition for light.

Similarly, different dose of Nitrogen had also influenced crop growth. Highest plant height (37.23 cm) was attained at 120 kg N/ha, but it was at par with other doses of Nitrogen except control. The lowest plant height (33.51 cm) was under control. Thus it revealed that plant height responded to doses of nitrogen as compared to control from the initial growth stages.

After the initial phase the rice plants enters the active tillering stage followed by reproductive phase. Observations revealed that nitrogen doses exerted significant effect on plant height but spacing had no significant effect on plant height after initial stages. The plant heights at three spacing were at par during 40, 55, 70 and 85 DAT. The plant height observations did not reveal an increasing trend with wider spacing. At 40 and 85 DAT the highest plant height was at wider spacing whereas at 55 and 70 DAT highest plant height was at closer spacing. Thus plant height was not seen to be affected by spacing.

Unlike spacing different levels of nitrogen affected plant height significantly at different growth stages. Plant height was highest at 160 kg N/ha at all the growth stages except at 25 DAT. A similar result where spacing had no effect on plant height but increase in plant height with increase in dose of Nitrogen was observed by Shivay and Singh (2003); Chopra and Chopra (2000). Rajput and Warshi (1992) also reported that plant height increased significantly as the level of nitrogen increased.

At 25 DAT and 40 DAT the highest plant height (37.2 cm and 50.51 cm respectively) was observed at 120 kg N/ha and 160 kg N/ha followed by (37.09 cm, 48.71 cm) 160 kg N/ha and 120 kg N/ha respectively, but they were at par with each other. Thus at 25 and 40 DAT plant height was at par, at 120 and 160 kg N/ha.

At 55, 70 and 85 DAT the highest plant heights of 67.83 cm, 85.16 cm and102.8 cm were observed at 160 kg N/ha followed by (63.94 cm, 79.18 cm and 101.3 cm) at 120 kg N/ha respectively. At 85 DAT plant height at 120 and 160 kg N/ha was 101.3 cm and 102.8 cm and they were at par. This revealed the fact that plant height responded to high dose of nitrogen fertilizer during the vegetative growth stages i.e. before 85 DAT. Datta (1986) also reported that nitrogen helps to promote plant height, number of tillers, and number of grains and was needed to maximize the panicle number as much as possible at early and mid-tillering stage.

The lowest plant height in all the observations was observed in control. At 25 and 40 DAT it was 33.51 cm and 42.27 cm and statistically different from nitrogen applied observations. After active tillering phase i.e. 55 DAT onwards the lowest plant height was under control but it was statistically at par: with 40 kg N/ha at 55 DAT, with 40 kg N/ha and 80 kg N/ha at 70 and 85 DAT. The effects of nitrogen thus observed were significant under early stages of rapid growth. The effect nullifies as the rice plants attains maturity.

Table 3 Effect of spacing and levels of nitrogen on plant height (cm) at different growth period of rice during 2006 at Rampur, Chitwan.

Treatment	Plant height				
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT
A. Spacing (cm^2)					
20x20	34.94[b]	47.99[a]	61.34[a]	74.69[a]	98.84[a]
20x15	36.27[a]	46.00[a]	61.10[a]	76.20[a]	98.60[a]
20x10	36.39[a]	46.25[a]	61.53[a]	76.80[a]	94.60[a]
S. Em.	0.4356	1.231	1.213	1.328	2.000
LSD (0.05)	1.271	3.593	3.539	3.877	5.836
B. Nitrogen level (kg/ha)					
0	33.51[b]	42.27[d]	56.28[d]	70.29[c]	93.36[b]
40	35.57[a]	45.16[c]	57.83[d]	70.51[c]	94.56[b]
80	35.92[a]	47.09[bc]	60.72[c]	74.36[bc]	94.73[b]
120	37.23[a]	48.71[ab]	63.94[b]	79.18[b]	101.3[a]
160	37.09[a]	50.51[a]	67.83[a]	85.16[a]	102.8[a]
S. Em.	0.3373	0.9637	0.9081	1.728	1.572
LSD (0.05)	0.9845	2.813	2.651	5.045	4.588

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

Moreover the interaction effect of spacing and different levels of nitrogen was seen significant at 25 and 85 DAT (Appendix 7). The appraised data in Table 4 showed that at 25 DAT maximum height (39.3 cm) was attained at 120 kg N/ha with 20 cm ×15 cm spacing. But, this was at par with plant heights under different spacing and with same level of Nitrogen. Thus at this stage of plant growth spacing effects were not seen though effects of different level of nitrogen could be observed. This could be due to the fact that the root canopy had not yet overlapped and did not compete for space and nutrients as a result effect of spacing was not observed.

The interaction effect at 85 DAT showed that highest plant height (107.4 cm) was observed at 160 kg N/ha under 20 cm × 20 cm spacing. It was significantly higher then the lowest plant height (90.53 cm) at 160 kg N/ha at 20 cm ×10 cm spacing. Nayak *et al.* (2003) also supported that maximum plant height at harvest was attained in wider spacing and minimum in closer spacing under same rates of fertilizer. This shows that wider spacing supports plant growth when there is adequate nutrient supply.

Also, the highest plant height was at par with plant height under 20 cm × 20 cm spacing at 120 kg N/ha which revealed the fact that 120 and 160 kg N/ha does not affect plant growth significantly. Additionally, plant height responds according to spacing only at higher doses of Nitrogen fertilizer. From the interaction effect it could be seen that the plant heights were at par among all the spacing at all nitrogen doses below 120 kg N/ha. Also in an experiment done by Chopra and Chopra (2000), the plant height could not reach the level of significance due to different spacing in response to different doses of N fertilizer up to 120 kg N/ha.

However, the plant height increases with increasing level of Nitrogen fertilizer in all the spacing. This was supported by Gangaiah and Prasad (1999), where significant increase in plant height was observed with successive increment of N from 0 to 180 kg N/ha. Also Siddiqui *et al.* (1999) reported that fertilizer level had significant influence on plant height, it increased with higher fertilizer levels (0 to 120 kg N/ha). The lowest plant height was observed in control nitrogen under 20 cm × 20 cm spacing. Thus when nitrogen was not applied the plant performance was not enhanced only by wider spacing.

Singh *et al.* (1996) observed significantly higher plant height (97.7 cm) in 90 kg N/ha than control (90.0 cm) but was at par with 60 kg N/ha (94.8 cm). On the other hand, Thakur (1993) found significantly higher plant height (81.77 cm) at 120 kg N/ha than at 0, 40 and 80 kg N/ha (64.70, 69.82 and 75.50 cm respectively). These differences in crop response to the level of nitrogen applied were due to differences in type of soil and the varieties used in the research.

Table 4 Interaction effect of spacing and levels of nitrogen on plant height (cm) at different growth period of rice during 2006 at Rampur, Chitwan.

Treatments	Plant height	
	25 DAT	85 DAT
P_1N_0	31.72^{d}	96.80^{cde}
P_1N_1	32.98^{cd}	96.13^{cde}
P_1N_2	36.73^{abc}	91.67^{de}
P_1N_3	36.00^{abc}	102.2^{abc}
P_1 N_4	37.27^{ab}	107.4^{ab}
P_2 N_0	34.47^{bcd}	91.40^{de}
P_2 N_1	36.47^{abc}	94.93^{cde}
P_2 N_2	36.30^{abc}	96.40^{cde}
P_2 N_3	39.30^{a}	99.93^{bcd}
P_2 N_4	34.80^{bcd}	110.3^{a}
P_3 N_0	34.33^{bcd}	91.87^{de}
P_3 N_1	37.27^{ab}	92.60^{de}
P_3 N_2	34.73^{bcd}	96.13^{cde}
P_3 N_3	36.40^{abc}	101.9^{abc}
P_3 N_4	39.20^{a}	90.53^{e}
S. Em.	1.177	2.722
LSD (0.05)	3.436	7.946

Means in the column followed by same letters don't differ significantly with each other by DMRT at P = 0.05

4.1.2 Number of tillers

The analysis of variance of data on number of tillers per plant (appendix 10) shows significant effect of spacing at 25, 40 and 55 DAT whereas the effect of levels of nitrogen was significant at 25 and 40 DAT only. Also, the tiller count was seen increasing up to 55 DAT after which it was almost constant. Up to 55 DAT the plant was at maximum vegetative growth and active tillering stage, this justifies the significant effect of the treatment only during these stages.

At 25 DAT, maximum tillering 8.23 tillers/hill was observed in 20 cm × 10 cm spacing followed by 8tillers/hill in 20 cm × 20 cm spacing which are at par. The lowest tiller count during this observation was 7.53 tillers/hill in 20 cm ×15 cm spacing (Figure 4).

Unlike to the observation above, at 40 DAT and 55 DAT maximum number of tillers 17.96 and 20.03tillers/hill, respectively was observed in 20 cm × 20 cm spacing.

At 40 DAT lowest tillering 15.68tillers/hill was observed in 20 cm ×15 cm followed by 16.31tillers/hill in 20 cm × 10 cm which were at par.

At 55 DAT significantly lowest number of tiller 16.51tillers/hill was observed at 20 cm ×10 cm spacing followed by 18.46tillers/hill under 20 cm ×15 cm spacing. This tillering at 20 cm x15 cm spacing was at par with the tiller count of 20 cm × 20 cm spacing. This suggests that during active tillering stage tillering was profuse in wider spacing (20×20 and 20×15 as compared to 20×10).

As mentioned above significant effects of level of Nitrogen was observed only at 25 and 40 DAT. At 25 DAT highest tillers 8.53 tillers/hill was observed at 80 kg N/ha followed by 8.44 and 8.09 tillers/hill in 160 and 120 kg N/ha respectively. However these observations were at par. The lowest number of tillers/hill was 6.9 in control.

At 40 DAT highest tiller count was 18.69tillers/hill at 160 kg N/ha followed by 17.84tillers/hill at 120 kg N/ha and were at par. However it significantly differed with the tiller count at lower doses of nitrogen, the lowest 14.58 tillers/hill being at control. The effects of levels of nitrogen were not seen significant after 40 DAT.

It reveals that the tiller count was significantly low in control as compared with the tiller count at adequate dose of nitrogen. All the observations are at par after 40 DAT which means that nitrogen did not significantly affect tillering after the plant crosses the active tillering stage.

Similar tillering pattern have been observed by Nayak *et al.* (2003) in an experiment done during the wet season of 1999 and 2000 where highest tillering was attained at 20x15 when compared to 20 cm × 10 cm and 15 cm × 15 cm.

Thus, tillering is furnished under wider spacing as compared to closer spacing. It also attributed to the fact that transplanting of single young seedlings (10 days old) under wider spacing exerts less competitive pressure within plants in one hill and among plants in the field as a result tillering was higher under wider spacing.

The interaction effect of levels of nitrogen and spacing was also seen significant at 25 and 40 DAT (Appendix 10). The perusal of data in table 6 reveal that the lowest tiller count (5.4 tillers/hill) was observed at control.

Significant high tiller count (10.07 tillers/hill) was observed at 80 kg N/ha under 20 cm × 15 cm spacing. At 20 cm × 20 cm spacing the highest tiller count 9.4 tillers/hill was observed at 160 kg N/ha followed by 8.2 tillers/hill at 120 kg N/ha which were at par. This was the highest tiller count at 25 DAT among all the treatment combinations.

At 40 DAT significantly high tiller count (23.27 tillers/hill) at 160 kg N/ha under 20 cm × 20 cm followed by 18.6 tillers/hill at 120 kg N/ha under 20 cm × 20 cm. Tillers count per hill were at par with other remaining treatment combinations.

Table 5 Effect of spacing and levels of nitrogen on tiller number at different growth period of rice during 2006 at Rampur, Chitwan.

Treatment	Tiller number				
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT
A. Spacing (cm^2)					
20x20	8.00[a]	17.96[a]	20.03[a]	18.93[a]	18.56[a]
20x15	7.53[b]	15.68[b]	18.46[a]	18.51[a]	17.93[a]
20x10	8.23[a]	16.31[b]	16.51[b]	16.09[a]	16.16[a]
S. Em.	0.1	0.48	0.58	1	1.42
LSD (0.05)	0.31	1.39	1.7	2.91	4.16
B. Nitrogen level (kg/ha)					
0	6.93[b]	14.58[b]	16.70[a]	15.73[a]	15.40[a]
40	7.60[ab]	14.84[b]	17.27[a]	16.98[a]	16.42[a]
80	8.53[a]	17.29[ab]	19.02[a]	18.80[a]	18.98[a]
120	8.09[a]	17.84[a]	19.78[a]	19.24[a]	19.00[a]
160	8.44[a]	18.69[a]	18.89[a]	18.47[a]	17.96[a]
S. Em.	0.34	0.95	1.21	1.34	1.37
LSD (0.05)	0.98	2.78	3.53	3.9	3.99

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

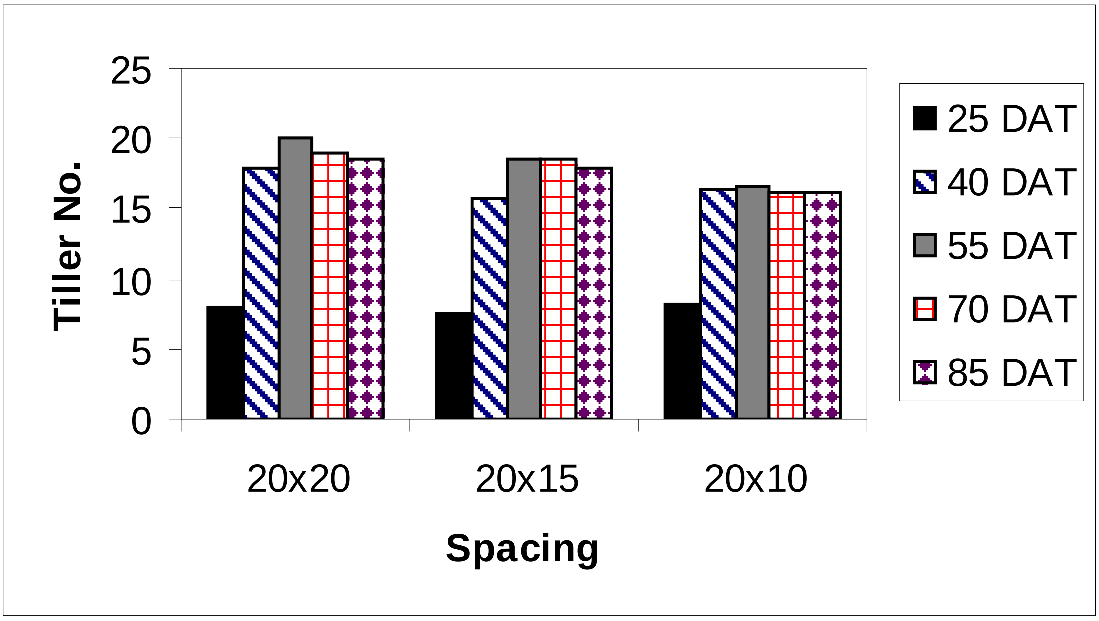

Figure 4 Effect of spacing on tiller number on different days after transplanting

Table 6 Interaction effect of spacing and levels of nitrogen on tiller number at different growth period of rice during 2006 at Rampur, Chitwan.

Treatments	Tiller number	
	25 DAT	40 DAT
P_1N_0	7.87^{bcd}	16.40^{bc}
P_1N_1	7.40^{cd}	15.07^{bc}
P_1N_2	7.13^{cde}	16.47^{bc}
P_1N_3	8.20^{abcd}	18.60^{ab}
P_1 N_4	9.40^{ab}	23.27^{a}
P_2 N_0	5.40^{e}	12.40^{c}
P_2 N_1	6.67^{de}	14.40^{bc}
P_2 N_2	10.07^{a}	17.73^{bc}
P_2 N_3	7.93^{bcd}	17.53^{bc}
P_2 N_4	7.60^{bcd}	16.33^{bc}
P_3 N_0	7.53^{bcd}	14.93^{bc}
P_3 N_1	8.73^{abc}	15.07^{bc}
P_3 N_2	8.40^{abcd}	17.67^{bc}
P_3 N_3	8.13^{abcd}	17.40^{bc}
P_3 N_4	8.33^{abcd}	16.47^{bc}
S. Em.	0.58	1.65
LSD (0.05)	1.71	4.81

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

4.1.3 Dry matter accumulation

Crop yields depend upon the dry matter production per unit area therefore high production of total dry matter was first pre requisite for high yield. The effects of different treatments on dry matter accumulation are shown on Table 7. It showed the progressive increase in total dry matter accumulation as crop attained maturity. Both spacing and nitrogen exert significant effect on dry matter accumulation (Appendix 8).

Regarding the effect of spacing, at 30 DAT dry weight was significantly highest (6.38 g) under 20 cm ×15 cm and significantly lowest (5.32 g) under 20 cm ×10 cm. But at 60 DAT it was significantly high (29.91g) under 20 cm ×10 cm. This rapid gain in dry matter of plants under closer spacing could be due to vertical growth of rice plants at closer spacing as compared to horizontal tillering in wider spacing. DM had strong positive correlation with straw yield (r = 0.469) (Appendix 6).

However, at 90 DAT dry matter observations were high and at par in two wider spacing (20 cm × 20 cm and 20 cm × 15 cm) as the plant switches from vegetative phase to reproductive phase.

Unlike, above observations, it was significantly high (200.4 g) under wider spacing of 20 cm × 20 cm at harvest. This indicated that wider spacing influenced profuse growth of yield attributing characters as compared to vegetative growth. This could be the cause of higher dry matter observations during the later phase of plant development. Higher dry matter accumulation during harvest at wider spacing had also been observed by Nayak *et al.* (2003) in an experiment done during the wet season of 1999 and 2000 where highest DM was attained at 20 cm ×15 cm when compared to 20 cm ×10 cm and 15 cm ×15 cm.

Regarding the effect of different levels of Nitrogen, at 30 and 60 DAT the DM accumulation was high (6.33 g and 34.17 g respectively) at 120 kg N/ha. At 30 DAT the

DM accumulation of 80 and 120 kg N/ha were at par. At 90 DAT and at harvest DM accumulation was significantly high (110.9 g and 233.1 g respectively) in 160 kg N/ha, followed by 95.91 g and 202.7 g respectively in 120 kg N/ha.

After 30 DAT the effect of Nitrogen was significantly different. Thus it could be concluded that different levels of nitrogen show have shown their effect in rice crop performance as the plant matures.

It revealed that increase in dry matter followed the same pattern under all the spacing treatment. However, dry matter at 90 DAT under 20 cm ×10 cm was lowest and dry matter under 20 cm × 20 cm increases rapidly from 90 DAT to harvest and it was maximum at harvest (Figure 5).

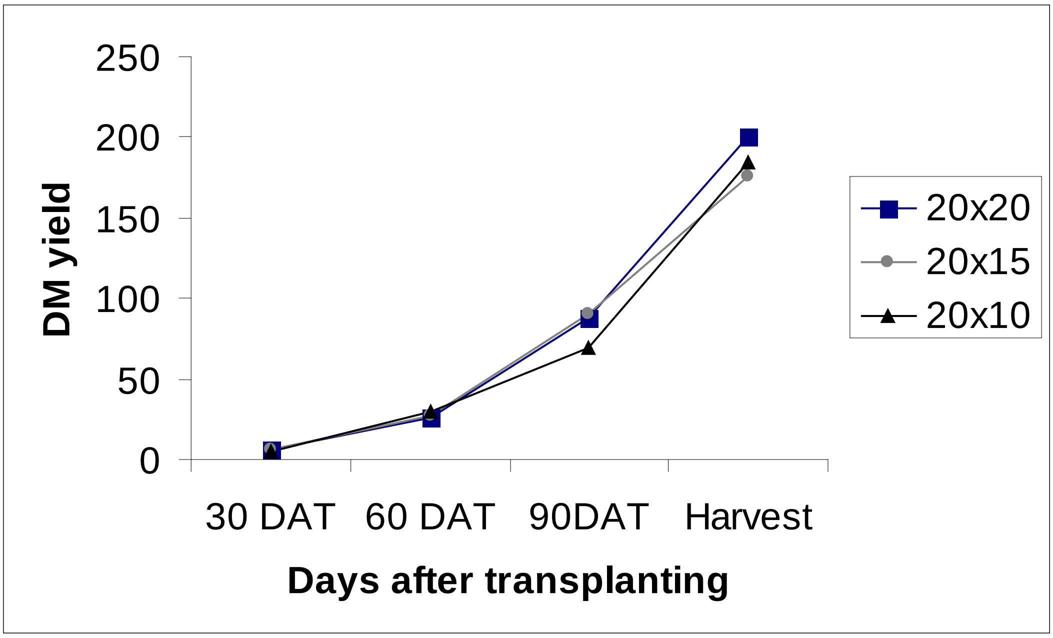

Figure 5 Effect of spacing on dry matter on different days after transplanting

Table 7 Effect of spacing and levels of nitrogen on dry matter (g) at different growth period of rice during 2006 at Rampur, Chitwan.

Treatment	Dry matter			
	30 DAT	60 DAT	90 DAT	At harvest
A. Spacing (cm^2)				
20x20	5.64^{b}	26.37^{c}	88.02^{a}	200.40^{a}
20x15	6.38^{a}	27.69^{b}	90.61^{a}	175.60^{c}
20x10	5.32^{c}	29.91^{a}	69.43^{b}	184.60^{b}
S. Em.	0.04	0.12	0.97	0.29
LSD (0.05)	0.11	0.34	2.84	0.86
B. Level of nitrogen (kg/ha)				
0	5.43^{b}	27.25^{c}	67.53^{d}	166.80^{c}
40	5.75^{b}	21.41^{e}	65.66^{d}	165.00^{d}
80	5.88^{ab}	24.33^{d}	73.41^{c}	166.80^{c}
120	6.33^{a}	34.17^{a}	95.91^{b}	202.70^{b}
160	5.52^{b}	32.78^{b}	110.90^{a}	233.10^{a}
S. Em.	0.17	0.13	1.02	0.32
LSD (0.05)	0.5	0.37	2.98	0.93

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

The interaction effect of different spacing and levels of Nitrogen was also found significant in case of dry matter, shown in (Appendix 8). The observations of dry matter are presented in (Table 8).

At 30 DAT highest dry matter 7.29 g was observed at 120 kg N/ha as against the lowest of 4.62 g at 80 kg N/ha under 20 cm ×20 cm. But in closer spacing (20 cm ×15 cm and 20 cm ×10 cm) significantly higher dry matter (7.72 g and 5.84 g) was observed at lower doses of N (80 and 40 kg N/ha) as against the lowest of 5.81 g and 5.06 g in control.

Among the three spacing higher dry matter was observed under wider spacing (20 cm × 20 cm and 20 cm × 10 cm) at all the four different levels of nitrogen. However, it was significantly high (7.29 g) at 120 kg N/ha in 20 cm × 20 cm followed by 6.39 g in 20 cm × 10 cm. This trend suggested that dry matter accumulation was positively related with increasing dose of nitrogen and wider spacing. Also, dry matter was significantly higher in 20 cm ×20 cm at 120 kg N/ha then at 160 kg N/ha but dry matters at closer spacing was at par among 120 and 160 kg N/ha. Which indicated that wider spacing furnished higher DM accumulation at optimum doses of fertilizer. This might be due to the higher plant canopy under wider spacing that favors photosynthetic activity such that plants responds to optimum doses of fertilizer unlike in closer spacing where it did not happen.

Unlike at 30 DAT, at 60 DAT highest DM of 44.37 g was observed at 120 kg N/ha followed by 36.77 g at 160 kg N/ha under 20 cm ×10 cm, and were statistically significant. Lowest DM was observed at wider spacing.

Also, at 90 DAT highest DM of 138.9 g was observed at 160 kg N/ha under 20 cm ×15 cm followed by 131.1 g at 160 kg N/ha under 20 cm × 20 cm. Thus as crop advanced from vegetative phase to maturity the dry matter was significantly higher at two wider spacing as compared to closer spacing and higher doses of N. This observation was in line with the observation at harvest. At harvest highest 332.2 g dry matter was observed under 20 cm × 20 cm followed by 242.8 g under 20 cm × 15 cm at 160 kg N/ha.

Thus DM was higher under closer spacing during initial stages but later it was higher under wider spacing. This also suggests that wider spacing exerts its effect during maturity and significantly affects yield attributing characters. Regardless of spacing DM tends to be higher at higher doses of nitrogen. Significant increase in DM was also reported by Gangaiah and Prasad (1999) that with each successive increment of N from 0 to 180 kg N/ha in a two year field study conducted at IARI during 1992-94.

Table 8 Interaction effect of spacing and levels of nitrogen on dry matter (g) at different growth period of rice during 2006 at Rampur, Chitwan.

Treatments	Dry matter			
	30 DAT	60 DAT	90 DAT	At harvest
P_1N_0	5.42[bcde]	28.08[e]	53.50[j]	152.30[k]
P_1N_1	5.31[cde]	26.87[f]	75.36[fg]	164.70[i]
P_1N_2	4.62[e]	20.81[i]	79.66[f]	168.40_h
P_1N_3	7.29[a]	28.03[e]	100.50[d]	184.50[f]
P_1 N_4	5.56[bcde]	28.05[e]	131.10[b]	332.20[a]
P_2 N_0	5.81[bcd]	25.54[g]	60.26[i]	155.40[j]
P_2 N_1	6.10[bc]	22.7[h]	66.99[h]	132.60[l]
P_2 N_2	7.72[a]	26.58[f]	73.51[g]	154.70[j]
P_2 N_3	6.39[b]	30.1[d]	113.40[c]	192.70[e]
P_2 N_4	5.90[bcd]	33.52[c]	138.90[a]	242.80[b]
P_3 N_0	5.06[de]	28.13[e]	88.83[e]	192.80[e]
P_3 N_1	5.84[bcd]	14.68[j]	54.62[j]	197.50[d]
P_3 N_2	5.30[cde]	25.59[g]	67.06[h]	177.40[g]
P_3 N_3	5.32[cde]	44.37[a]	73.80[g]	230.80[c]
P_3 N_4	5.08[cde]	36.77[b]	62.85[hi]	124.50[m]
S. Em.	0.30	0.2183	1.77	0.55
LSD (0.05)	0.87	0.6373	5.16	1.60

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

4.1.4 Leaf Area Index

Leaves are the main photosynthetic organs and area of the leaf surface per unit area is the leaf area index (LAI) (Gomez, 1972), which is an important yield determining growth parameter of plants (Watson, 1947). The analysis of data shown on Table 9 reveals that leaf area index increased continuously with the age of rice plant.

Leaf area index was highest 0.72, 3.21 and 3.58 at 30, 60 and 90 DAT respectively under higher plant population i.e. 20 cm x 10 cm spacing, whereas it was significantly lowest under wider spacing (lower plant population). Similar result was reported by Nayak *et al.* (2003) in a field experiment conducted in Bhuvaneshwor during wet season of 1999 and 2000 where LAI was lower in wider spacing of 20 cm × 15 cm compared to 15 cm ×15 cm.

At 30 and 60 DAT LAI was significantly high (0.64, 2.63) at 80 and 120 kg N/ha respectively, followed by 0.57 and 2.49 at 120 and 160 kg N/ha. The LAI (0.57) observed at 120 kg N/ha was at par with LAI at control and 40 kg N/ha. Thus, LAI was neither seen to be positively correlated with increasing levels of Nitrogen at early stages nor did it respond to higher level of nitrogen. It had strong positive correlation with dry matter production (r = 0.599) (Appendix 6).

Unlike, at 90 DAT LAI was seen to increase with the increasing level of nitrogen fertilizer. The highest LAI was 3.79 at 160 kg N/ha followed by 3.53 and 3.05 kg N/ha at 120 and 80 kg N/ha respectively. Thus at the reproductive stage LAI increased successively with successive increment in the level of Nitrogen. Similar increase in LAI with increasing level of Nitrogen from control to 120 kg N/ha was observed by Bali *et al.* (1995) in a field experiment conducted during the rainy season of 1987 and 1988 in Kashmir Valley.

The interaction effect of different spacing and nitrogen levels was significant at all the stages of plant growth. The analysis of variation is shown in (Appendix 9).

At 30 DAT significantly high LAI 0.82 was observed at 80 kg N/ha under 20 cm × 20 cm spacing, followed by 0.78 under 20 cm × 15 cm and same dose of N, which are at par. The lowest LAI was observed under 20 cm × 20 cm spacing at 80 kg N/ha.

At 60 DAT maximum LAI was recorded under 20 cm × 10 cm spacing at 120 kg N/ha whereas the lowest LAI 1.16 was recorded under 20 cm × 20 cm spacing at 80 kg N/ha. At 90 DAT, unlike at 30 and 60 DAT highest LAI 4.51 was seen on 20 cm × 15 cm followed by 4.45 at 120 kg N/ha and 160 kg N/ha. The lowest LAI 1.64 was recorded under wider spacing of 20 cm × 20 cm at 40 kg N/ha (Figure 6).

Thus LAI was found to be drastically low at wider spacing as compared to closer spacing in all the stages of plant growth. Whereas, LAI was higher in lower doses of N at the early stages but conversely higher LAI were recorded at higher doses of N at later stages. However, LAI was maximum at medium spacing of 20 cm × 15 cm and at 120 kg N/ha.

Table 9 Effect of spacing and levels of nitrogen on leaf area index at different growth period of rice during 2006 at Rampur, Chitwan.

Treatment	Leaf area index		
	30 DAT	60 DAT	90 DAT
A. Spacing (cm^2)			
20x20	0.39^{c}	1.40^{c}	2.31^{c}
20x15	0.58^{b}	1.93^{b}	3.18^{b}
20x10	0.72^{a}	3.21^{a}	3.58^{a}
S. Em.	0.01	0.01	0.01
LSD (0.05)	0.02	0.02	0.02
B. Level of nitrogen (kg/ha)			
0	0.55^{b}	2.15^{c}	2.65^{d}
40	0.57^{b}	1.82^{d}	2.11^{e}
80	0.64^{a}	1.81^{d}	3.05^{c}
120	0.57^{b}	2.63^{a}	3.53^{b}
160	0.49^{c}	2.49^{b}	3.79^{a}
S. Em.	0.01	0.01	0.01
LSD (0.05)	0.03	0.03	0.03

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

Table 10 Interaction effect of spacing and levels of nitrogen on leaf area index at different growth period of rice during 2006 at Rampur, Chitwan.

Treatments	Leaf area index		
	30 DAT	60 DAT	90 DAT
P_1N_0	0.36^{gh}	1.51^{jk}	1.37^{o}
P_1N_1	0.37^{g}	1.55^{j}	1.64^{n}
P_1N_2	0.31^{h}	1.16^{m}	2.33^{k}
P_1N_3	0.51^{f}	1.32^{l}	2.58^{h}
P_1 N_4	0.38^{g}	1.46^{k}	3.65^{e}
P_2 N_0	0.53^{ef}	1.65^{i}	2.20^{m}
P_2 N_1	0.58^{de}	1.56^{j}	2.25^{l}
P_2 N_2	0.78^{ab}	1.82^{h}	2.50^{i}
P_2 N_3	0.51^{f}	2.04^{g}	4.51^{a}
P_2 N_4	0.50^{f}	2.58^{d}	4.45^{b}
P_3 N_0	0.76^{b}	3.30^{c}	4.38^{c}
P_3 N_1	0.76^{b}	2.34^{f}	2.43^{j}
P_3 N_2	0.82^{a}	2.45^{e}	4.33^{d}
P_3 N_3	0.68^{c}	4.52^{a}	3.50^{f}
P_3 N_4	0.59^{d}	3.44^{b}	3.27^{g}
S. Em.	0.02	0.02	0.02
LSD (0.05)	0.05	0.05	0.05

Means in the column followed by same letters don't differ significantly with each other by DMRT at P = 0.05

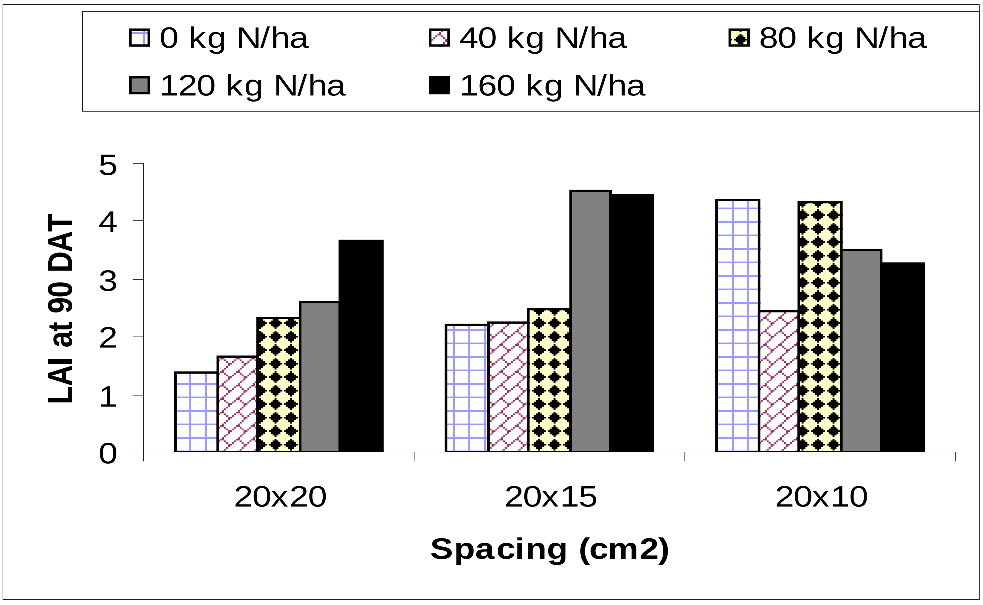

Figure 6 Interaction effect on leaf area index (LAI) at 90 DAT

4.2 Nitrogen Content of grain

Analysis of nitrogen content data of the grain shows significant effect of different treatments on the nitrogen content of the grain (Appendix 11).

A significant increase in total nitrogen content was obtained with increasing level of nitrogen over control (Figure 7). The nitrogen content data tabulated in Table 12 revealed that the nitrogen content was lowest in the plots receiving no nitrogen. It was observed to be significantly high (1.2 %) at 160 kg N/ha followed by 1.18% at 120 kg N/ha which are at par. Accordingly, it was significantly low 0.74% in control treatment. The findings were in harmony with that of Singh *et al.* (1998).

Likewise, Nitrogen content was higher in grains of the rice plants grown under wider spacing. It was high (1.05%) in 20 cm × 20 cm followed by 0.98% in 20 cm × 15 cm. Higher nitrogen content in wider spacing imply that nutrient availability is high as the per plant area coverage is high, roots can spread profusely and competition among plants is reduced.

Table 11 Interaction effect of spacing and levels of nitrogen on nitrogen content (%) at different growth period of rice during 2006 at Rampur, Chitwan.

Treatments	Spacing (cm^2)		
Level of nitrogen (kg/ha)	20x20	20x15	20x10
0	0.87^{cdef}	0.67^{f}	0.67^{f}
40	0.82^{def}	0.76^{ef}	0.88^{bcdef}
80	1.04^{abcde}	0.86^{cdef}	0.99^{abcdef}
120	1.26^{a}	1.13^{abcd}	1.16^{abc}
160	1.24^{a}	1.15^{abc}	1.20^{ab}
S.Em.	0.10		
LSD (0.05)	0.29		

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

Table 12 Effect of spacing and levels of nitrogen on nitrogen content (%) at different growth period of rice during 2006 at Rampur, Chitwan.

Treatment	Nitrogen content %
A. Spacing (cm^2)	
20x20	1.05[a]
20x15	0.91[b]
20x10	0.98[ab]
S. Em.	0.03
LSD (0.05)	0.08
B. Level of nitrogen (kg/ha)	
0	0.74[c]
40	0.82[bc]
80	0.96[b]
120	1.18[a]
160	1.20[a]
S. Em.	0.06
LSD (0.05)	0.17

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

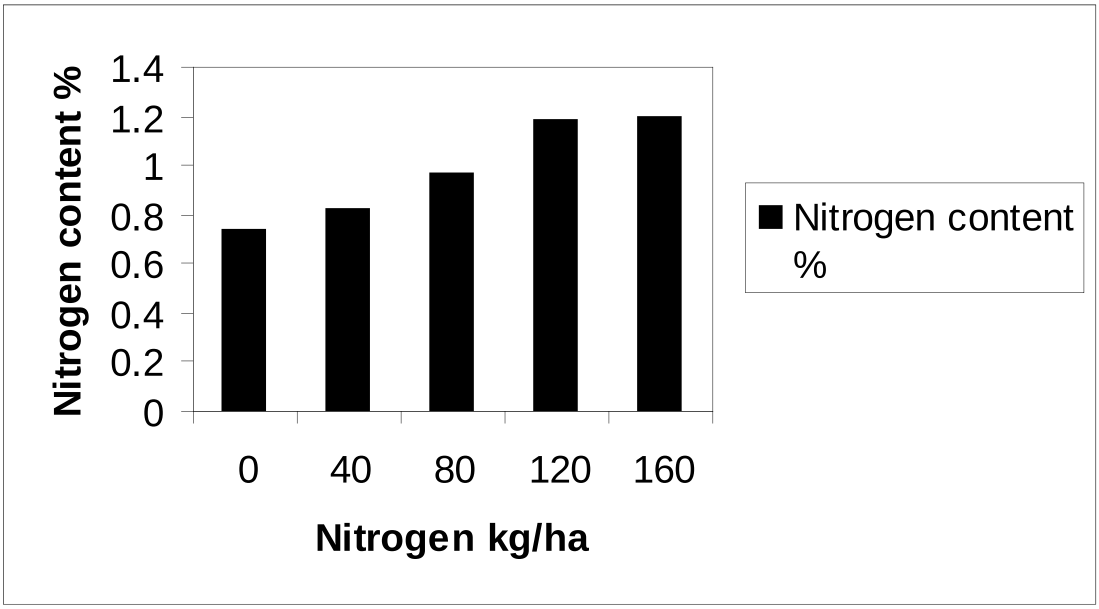

Figure 7 Effect of different levels of nitrogen on nitrogen content

4.3 Pre harvest biometrical characters

4.3.1 Effective tillers per meter row length

The perusal of data on effective tiller Table 13 showed that it was significantly high (73.73) in wider spacing of 20 cm × 20 cm followed by 59.07 and 57.33 at lower spacing of 20 cm ×15 cm and 20 cm ×10 cm respectively. The later two were at par. Thus, the effect of spacing was pronounced in number of effective tiller. This effect might be due to more space and nutrients available for the individual plant under wider spacing.

Similar result where maximum number of effective tiller was observed in wider spacing have been reported by Nayak *et al.* (2003) and Kewat *et al*. (2002).

Similarly, it was highest 72.89 in 120 kg N/ha followed by 69.89, 61.56 and 59.56 at 160, 80, 40 kg N/ha respectively which were at par. The lowest (53) was observed at control. However, the effective tiller count in control was at par with the observations at 40 and 80 kg N/ha. This suggests that higher number of effective tillers are attained with higher doses of N nevertheless the observation of highest productive tillers at 120 kg N/ha also suggest that increase in the level of N fertilizer was not only a governing factor and such increase in fertilizer dose was not always conducive to higher yields.

Higher productive tillers at higher doses of N have been observed by Gangaiah and Prasad, 1999 and Siddiqui *et al.,* (1999) in second years of the research trial.

The results obtained in this research confirm the findings of (Dwivedi, 1997), Chander and Pandey (1996) and Thakur (1993).

The interaction effect of different spacing and Nitrogen treatment was insignificant (Appendix 11).

Table 13 Effect of spacing and levels of nitrogen on yield attributes of rice during 2006 at Rampur, Chitwan.

Treatments	Panicle wt (g)	Length of panicle (cm)	Test weight (g)	Effective tiller/meter row length
Spacing				
20cmx20cm	21.74^{ab}	22.12^{a}	18.33^{a}	73.73^{a}
20cmx15cm	22.65^{a}	22.69^{a}	17.78^{b}	59.07^{b}
20cmx10cm	20.04^{b}	22.17^{a}	17.02^{c}	57.33^{b}
S.Em.	0.83	0.35	0.08	4.79
LSD (0.05)	2.43	1.01	0.24	13.98
Level of Nitrogen (kg/ha)				
0	18.69^{b}	20.90^{b}	17.23^{c}	53.00^{b}
40	20.14^{b}	21.14^{b}	17.33^{bc}	59.56^{ab}
80	21.42^{b}	21.46^{b}	17.67^{abc}	61.56^{ab}
120	26.29^{a}	26.82^{a}	18.31^{a}	72.89^{a}
160	20.84^{b}	21.33^{b}	18.01^{ab}	69.89^{a}
S.Em.	1.1	0.39	0.24	4.88
LSD (0.05)	3.21	1.14	0.7	14.25

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

4.3.2 Length of panicle

The analysis of data revealed that the effect of levels of Nitrogen was significant on length of panicle. Data on length of panicle is shown on (Table 13).

The highest length obtained was 22.69 cm followed by 22.17 cm and 22.12 cm at 20 cm×15 cm, 20 cm ×10 cm and 20 cm × 20 cm respectively and were at par with each other. Thus effect of spacing was not significant on length of panicle, still highest observation were recorded at wider spacing (20 cm ×15 cm) than that of closer spacing (20 cm × 10 cm). Similar report was advocated by Shivay and Singh (2003). However, significantly higher length (26.82 cm) was observed at 120 kg N/ha as compared to lowest (20.9 cm) at control. Also the lowest observation was at par with observations at 40, 80 and 160 kg N/ha.

Thus optimum doses of N are required for a plant to show higher yield attributing characters. This was in line with the observations of effective tiller (Table 13). Best performance of yield attributing characters of rice was seen at 120 kg N/ha.

The interaction effect of spacing and levels of nitrogen was insignificant in case of length of panicle (Appendix 11).

4.3.3 Weight of panicle

The analysis of data revealed similar results as that of length of panicle with regard to response to different levels of Nitrogen. The effect of levels of Nitrogen was significant on weight of panicle. But, effect of spacing was different. Data of weight of panicle is shown in (Table 13).

A significantly high panicle weight 22.65 g was obtained followed by 21.74 and 20.04 at 20 cm ×15 cm, 20 cm × 20 cm and 20 cm × 10 cm respectively. The observations under later two spacing 20 cm ×15 cm and 20 cm × 20 cm were at par. Thus effect of spacing on weight of panicle was not in line with length of panicle. Weight of panicle was seen to vary with spacing and it was higher in wider spacing.

Significantly higher weight (26.29 g) was observed at 120 kg N/ha as compared to lowest (18.69 g) at control. Also the lowest observation was at par with observations at 40, 80 and 160 kg N/ha.

Thus optimum doses of N are required for a plant to show higher yield attributing characters. This was in line with the observations of effective tiller and length of panicle (Table 13). Best performance of yield attributing characters of rice was seen in 120 kg N/ha.

The interaction effect of spacing and levels of nitrogen was insignificant in case of length of panicle (Appendix 11).The highest length of panicle was found to be 27.02 cm followed by 26.78 cm and 26.65 cm at 20 cm × 10 cm, 20 cm × 15 cm and 20 cm × 20 cm respectively at the nitrogen level at 120 kg N/ha. The lowest 20.12 cm was observed under 20 cm × 20 cm spacing with 160 kg N/ha. Thus increasing level of Nitrogen was seen to affect the yield attributing characters adversely.

As reported by Singh *et al.* (1997) nitrogen application up to 100 kg/ha resulted significant increase in panicles/hill, panicle length and panicle weight, grains per panicle. Further increase in dose to 150 kg N/ha rather decreased the grain yield.

There was strong positive correlation between length of panicle and weight of panicle (r=0.823**) (Appendix 5). This suggests that the treatment which favors length of panicle will definitely favor weight of panicle. The highest length and weight of panicle was observed at 120 kg N/ha and wider spacing.

4.3.4 Number of grains per panicle

The analysis of variance for number of grains (filled, unfilled and total are shown in (appendix 12). It shows that the effect of treatments were insignificant.

However, data presented in Table 14 show highest filled grain (92.62) in 20 cm × 20 cm spacing followed by 91.15 and 81.13 in 20 cm ×15 cm and 20 cm ×10 cm spacing. Though not significant, higher filled grains are observed in wider spacing. Unlike filled grains highest unfilled grain (22.16) was seen in 20 cm ×15 cm followed by 20.89 in 20 cm ×10 cm which were at par.

No. of filled grain per panicle had strong positive correlation with length and weight of panicle (r=0.539** and 0.8124** respectively) (Appendix 5). However lower correlation factor was seen among length and no of filled grain and higher with panicle weight which suggests that no of filled grain were higher in the panicles with higher weight, which is obvious.

Lower unfilled grain (18.76) seen under wider spacing of 20 cm × 20 cm. This higher count of filled grain and statistically lower count of unfilled grain in 20 cm × 20 cm was suggestive to the fact that wider spacing under proper management was favorable to attaining higher yields. Similarly highest total grains are at par under 20 cm × 20 cm and 20 cm ×15 cm spacing and (113.3) total grains at 20 cm × 15 cm was statistically higher then the lowest 102.0 at lowest spacing i.e. higher plant density under 20 cm × 10 cm. Low unfilled grains under wider spacing has also been reported by (Kewat *et al.*, 2002).

4.3.5 Thousand Grain weight (TGW)

The analysis of variance (Appendix 12) of test weight data shows that test weight was significantly affected by spacing and levels of nitrogen.

Significantly, highest test weight 18.33 was observed under 20 cm × 20 cm and lowest 17.02 under 20 cm ×10 cm spacing.

Similarly, highest test weight was observed at lower levels of nitrogen. 18.31, 18.01 and 17.67 at 120, 160 and 80 kg N/ha respectively. The lowest test weight 17.23 was observed at 0 kg N/ha followed by 17.33 at 40 kg N/ha and are at par. Thus test weight was also the yield attribute that was seen to increase with increasing levels of fertilizer and with wider spacing. This might be due to the sufficient spacing and nitrogen provided for plant. Similar result was reported by Verma *et al.* (1988) where test weight increases with the increasing in nitrogen dose.

4.3.6 Sterility percentage

The observed sterility percentage is shown in Table 14. It shows that effect of spacing and levels of nitrogen were not significant in sterility percentage. However, the lowest sterility percentage of 16.96% was observed in wider spacing of 20 cm × 20 cm as compared to highest 20.91% in 20 cm ×10 cm spacing, though the observations are at par. The difference was suggestive that wider spacing was conducive to supporting desirable yield attributing features in rice plant.

Table 14 Effect of spacing and levels of nitrogen on yield attributes of rice during 2006 at Rampur, Chitwan.

Treatment	Sterility (%)	Filled grain	Unfilled grain
Spacing			
20cmx20cm	16.96[a]	92.62[a]	18.76[b]
20cmx15cm	19.59[a]	91.15[a]	22.16[a]
20cmx10cm	20.91[a]	81.13[a]	20.89[a]
S.Em.	1.383	3.95	0.69
LSD (5%)	4.036	11.54	2.02
Level of Nitrogen kg/ha			
0	20.34 [ab]	92.87 [a]	23.71[a]
40	18.93 [ab]	84.80 [ab]	19.80[ab]
80	21.84 [a]	79.62 [b]	22.10[ab]
120	15.65 [b]	95.02 [a]	17.29[b]
160	18.99 [ab]	89.19 [ab]	20.11[ab]
S.Em.	1.717	4.04	1.96
LSD (0.05)	5.012	11.78	5.71

Means in the column followed by same letters don't differ significantly with each other by DMRT at P = 0.05

4.4 Yield

4.4.1 Grain

The average yield data in the Table 15 indicates that the grain yield of rice differed significantly with the different levels of nitrogen but different levels of plant population did not affect the grain yield significantly. Their analysis of variance is given in Appendix 13.

The highest average grain yield (5.88 t/ha) was obtained under 120 kg N/ha which was statistically superior over all the nitrogen treatments and control Figure 8. The grain yield obtained under 40, 80 and 160 kg N/ha being at par was significantly superior over control. The increase in levels of nitrogen beyond 120 kg N/ha was not responsive in terms of yield increment and resulted in lower grain yield per unit area which might be attributed to severe drought prevailing at the reproductive growth stage.

The finding that performance of rice plant declines after certain optimum dose of fertilizer is in line with the research finding of (Gunri *et al*., 2004). Accordingly, increasing the levels of fertilizer N significantly improved all the yield attributing characters up to 120 kg N/ha. Further increase in N levels could not bring about any significant changes.

Shivay and Singh (2003) had also observed similar findings that there was significant increase in grain yield of rice with an increase in level of Nitrogen, the response was linear up to 225 kg N/ha.

In the results of different nitrogen treatment reported by Bali *et al.* (1995), increase in N level from 0 to 120 kg N/ha significantly increased the grain yield.

Dalal and Dixit (1987) has suggested that higher yield with higher levels of N might be due to better N uptake leading to greater dry matter production and its translocation to the sink. Thakur (1993) also reported similar results.

The increase in yield due to 120, 80 and 40 kg N/ha was to the extent of 153, 81 and 50% respectively over control. However, at highest level of N 160 kg/ha, the reduction in yield was to the extent of 23% as compared to yield obtained under 120 kg N/ha. This increase in grain yield with increase in N dose was due to more number of productive tillers/row length (table 13).The findings confirm the results of AICRIP (1993) and Singh *et al*. (1995).

Similar increase of 62.04, 6.63, and 19.18 % was also observed by Singh *et al.* (1997) at 100 kg N/ha over 0, 50 and 150 kg N/ha.

The highest average grain yield (4.62 t/ha) was recorded under lowest level of plant population (20 cm × 20 cm). Though, it did not differ significantly with the remaining higher level of plant population (20 cm ×15 cm and 20 cm × 10 cm). Greater availability of nutrients owing to more space available per plant may be the possible cause for higher yield attributing characters in lower density i.e. wider spacing and hence higher yields.

A similar result where higher yields (5.4 t/ha) were recorded under 20 cm × 20 cm had been reported by Tripathi *et al.* (2004).

Evans *et al.* (2002) had reported higher grain yields at 20 cm × 20 cm spacing, in a study conducted in 2000 at Khumaltar and Bhaktapur as compared to 20 cm × 15 cm and 15 cm × 15 cm. The varieties used were Khumal-4, Khumal-6 and Taichung 176. Also, in 2001 an evaluation conducted at RARS Tarahara and on a farmer’s field in its command area with the popular variety mansuli yielded significantly high (8 t/ha) under 20 cm × 20 cm.

Higher yields with increased spacing were also suggested by Uphoff (2003), and Uprety (2005). It indicated that with the increase in spacing the performance of rice plants gets better and so higher yields were attained under wider spacing under SRI.

Among the yield attributing characters (length of panicle, weight of panicle, 1000 grain weight, no of filled grain and effective tillers/row length), grain yield had strong positive correlation with length of panicle (r=0.536**) (Appendix 5).

4.4.2 Straw

Significant effects of the treatments were found regarding the straw yield. However interaction effect was not found significant shown on Appendix 13. Grain yield and straw yield were seen to have strong positive correlation (r=0.686**) (Appendix 5).

Significantly high straw yield 7.33t/ha was obtained at wider spacing of 20 cm × 20 cm followed by 5.57 and 5.19t/ha under 20 cm × 15 cm and 20 cm × 10 cm respectively. The later two were at par.

Highest straw yield 7.03t/ha was attained at 160 kg N/ha followed by 7.01 and 6.39 at 120 and 80 kg N/ha which were at par (Figure 8). Significantly low 4.31t/ha was observed at control. The increase in straw yield with increase in N dose may be attributed to increase in dry matter production. Thus it is found that grain and straw yield increases with increasing level of nitrogen fertilizer but up to a certain dose which can be considered as optimum dose, after which the yield either stagnates or yield attributing characters start declining (table 13).The results supported the findings of Balasubramaniyam and Palaniappan (1991) and Dhal and mishra (1993).

Rao and Sitaramayya (1997) also reported similar results. Grain and Straw yield of rice increased significantly with the addition of fertilizer N. The result also revealed that the effect of 140 was at par with 120 kg N/ha.

4.4.3 Harvest index

The appraisal of data in Table 15 revealed that the effect of different spacing was insignificant but different levels of Nitrogen had significant effect on this parameter. The interaction effect is also seen insignificant. The analysis of variance is presented in appendix 13.

The harvest index at different spacing was 0.42, 0.40, and 0.37 under 20 cm × 15 cm, 20 cm × 10 cm, and 20 cm × 20 cm respectively which were at par.

Significantly higher harvest index 0.45 was obtained at 120 kg N/ha. The lowest 0.36 was at control but this low harvest index was at par with 40, 80 and 160 kg N/ha. This may be due to the nature of grain and straw yield obtained in the experiment (Table 15). Thus harvest index decreased after 120 kg N/ha. The harvest index is high in the treatments with higher yield. There was highly significant correlation(r=0.561**) between harvest index and grain yield.

The observed trend of decrease in harvest index after 120 kg N/ha was also reported by Sekharan and Mathan (1993). Accordingly there was significant increase in harvest index when N dose was increased from 0 to 120 kg N/ha. However further increase in N dose to 180 kg N/ha caused a decrease in harvest index. A decrease in harvest index at higher level of N was also reported by Narang *et al.* (1990).

Table 15 Effect of different spacing and levels of nitrogen on yields and harvest index of rice during 2006 at Rampur, Chitwan, Nepal.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
Spacing (cm^2)			
20 x 20	4.62[a]	7.33[a]	0.37[a]
20 x15	4.05[a]	5.57[b]	0.42[a]
20 x10	3.54[a]	5.19[b]	0.40[a]
S.Em.	0.55	0.24	0.03
LSD (0.05)	1.61	0.71	0.08
Nitrogen level (kg/ha)			
0	2.32[c]	4.31[c]	0.36[b]
40	3.48[b]	5.42[bc]	0.40[b]
80	4.20[b]	6.39[ab]	0.40[b]
120	5.88[a]	7.01[a]	0.45[a]
160	4.48[b]	7.03[a]	0.39[b]
S.Em.	0.39	0.40	0.01
LSD (0.05)	1.13	1.17	0.04

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

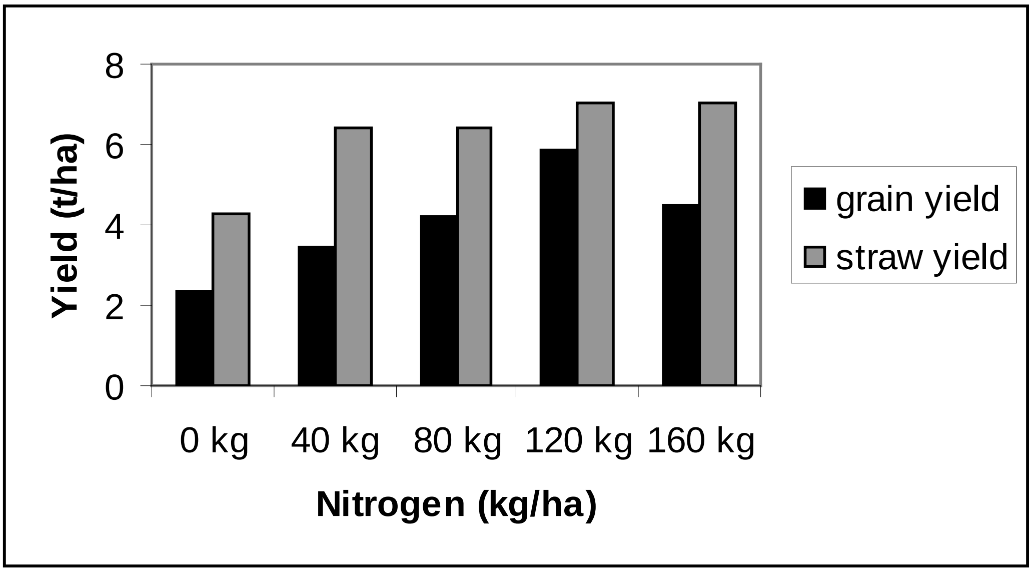

Figure 8 Effect of nitrogen levels on grain and straw yields of rice

4.5 Economics of N fertilization

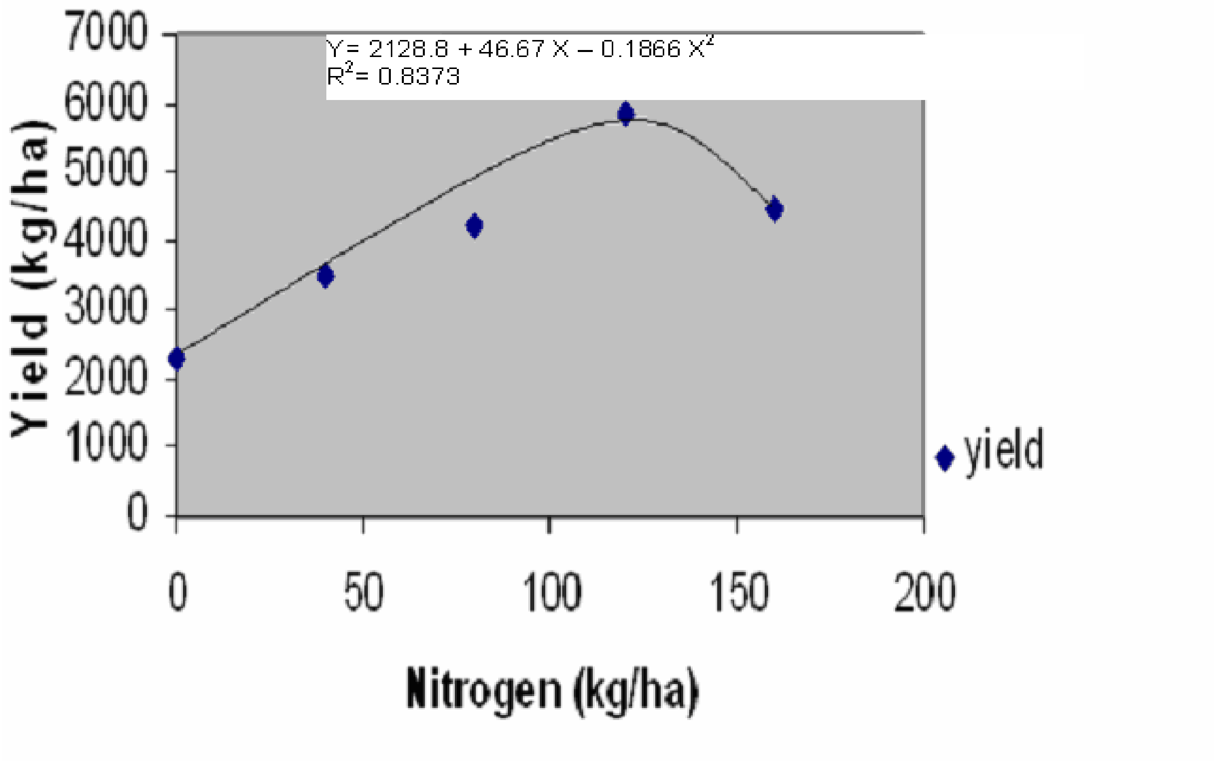

Figure 9 Response curve of yield on nitrogen levels

The quadratic equation between grain yield and N levels was fitted as following.

$Y = 2128.8 + 46.67\,X - 0.1866\,X^2$

$R^2 = 0.8373$

The response equation is $Y = 2128.8 + 46.67\,X - 0.1866\,X^2$

The economic dose is calculated by the formula

$$\frac{1}{2C}\,(q/p - b)$$

Where,

q = price of nutrient (N) per kg

p = price of yield (rice) per kg

b and c are the values from equation

Now, according to the market price

Price of nutrient (N) per kg = Rs. 43.48 considering urea as Rs. 20/kg.

Price of rice per kg = Rs. 12

b = 46.67

c = 0.1866

Substituting all values in above formula, we get the economic optimum dose of nitrogen. It was 115.33 kg/ha. From the study of the data on biometrical, yield and yield attributing characters it could be observed that the rice plant responded well under 120 kg N/ha which is very close to the calculated economic dose of Nitrogen fertilizer.

4.6 Economic analysis

The economics of rice through SRI under different spacing and levels of nitrogen was worked out with details of cost of different inputs in the experiment appended in (appendix 4). It reveals that the different treatment had significant effect on cost of cultivation and returns.

Application of higher doses of Nitrogen was beneficial as compared to lower doses similarly; planting at wider distance was seen to be beneficial then planting at closer distance.

The results in Table 16 Showed that different levels of N significantly increased gross return and net return and B:C ratio as compared to no nitrogen application. The gross return was 40690 NRs. /ha at 0 kg N/ha, and it increased with increasing dose of Nitrogen It was significantly high 83070 NRs. /ha at 120 kg N/ha. Similarly net return was significantly high 60200 NRs. /ha at 120 kg N/ha and it was the lowest 23040 NRs. /ha at 0 kg N/ha.

Significantly high B:C ratio of 2.6 was observed at 120 kg N/ha followed by 2.2 at 80 kg N/ha as against the lowest of 1.3 in 0 kg N/ha.

Cost of cultivation showed marked variation due to plant spacing (Appendix 4). Maximum cost 25175 NRs./ha was incurred under the closest spacing 20 cm × 20 cm and 160 kg N/ha. The lowest cost was 17175 NRs./ha under 20 cm × 10 cm and under control. However, the additional cost in wider spacing was balanced by returns under wider spacing.

Regarding the effect of spacing on economics of rice production; as the lower cost of transplanting in wider spacing significantly high gross return, net return and B:C ratio(72310 NRs./ha, 50620 NRs./ha and 2.27 respectively) was observed in wider spacing of 20 cm × 20 cm. As against the wider spacing of 20 cm × 20 cm the lowest economic indicators were observed in closer spacing of 20 cm × 10 cm. The gross return, net return and B:C ratio was significantly low, 58070 NRs./ha, 37410 NRs./ha and 1.79 respectively. Latif *et al*. (2005) also confirms these results of the economics returns under SRI.

Table 16 Economic analysis of different treatments for rainfed rice production during 2006 at Rampur, Chitwan.

Treatments	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit cost ratio
A. Spacing (cm^2)			
20x20	72310[a]	50620[a]	2.27[a]
20x15	65390[b]	44330[b]	2.04[b]
20x10	58070[c]	37410[c]	1.78[c]
S. Em.	371	546	0.01
LSD (0.05)	1082	1594	0.03
B. Level of nitrogen (kg/ha)			
0	40690[e]	23040[d]	1.30[d]
40	58070[d]	38680[c]	1.99[c]
80	69580[c]	48440[b]	2.25[b]
120	83070[a]	60200[a]	2.60[a]
160	74870[b]	50260[b]	2.02c
S. Em.	543	944	0.01
LSD (0.05)	1586	2756	0.04

Means in the column followed by same letters don’t differ significantly with each other by DMRT at P = 0.05

5 SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was conducted on "System of Rice Intensification under different plant population and levels of nitrogen" at the Institute of Agriculture and Animal Science, Rampur, Chitwan in rainy season of 2006. "Rampur masuli" variety of the rice was used for the study. The experiment was conducted in split plot design with three replication and 15 treatments. The treatments included: (a) three spacing (20 cm × 20 cm, 20 cm × 15 cm and 20 cm × 10 cm.) and (b) five levels of nitrogen (0, 40, 80, 120 and 160 kg N/ha). The result of the experiment has been summarized here.

1. The plant height increased as the age of crop advanced and maximum plant height was observed at 85 DAT in all spacing and nitrogen treatments. Significantly maximum plant height (36.39 cm) was recorded at 20 cm × 10 cm spacing and 20 cm × 20 cm spacing resulted significantly lowest plant height. At 25 DAT and 40 DAT the highest plant height (37.2 cm and 50.51 cm respectively) was observed at 120 kg N/ha and 160 kg N/ha. At 85 DAT plant height at 120 and 160 kg N/ha were 101.3 cm and 102.8 cm and they were at par. This reveals the fact that plant height responds to high dose of nitrogen fertilizer during the vegetative growth stages. After active tillering phase i.e. 55 DAT onwards the lowest plant height was under control but it was statistically at par with 40 kg N/ha at 55 DAT, with 40 kg N/ha and 80 kg N/ha at 70 and 85 DAT. The effects of nitrogen were significant in early stages of rapid growth. The effect of nitrogen slowly decreases as the rice plants attain maturity.

2. The tiller count was seen increasing up to 55 DAT after which it was almost constant. It was because of plant was at maximum vegetative growth and active tillering stage up to 55 DAT. At 40 DAT significantly high tiller count (23.27 tillers/hill) was observed at 160 kg N/ha under 20 cm × 20 cm followed by 18.6 tillers/hill at 120 kg N/ha under 20 cm × 20

cm. Thus, tillering is furnished under wider spacing as compared to closer spacing. It also attributed to the fact that transplanting of single young seedlings (10 days old) under wider spacing exerts less competitive pressure within plants in one hill and among plants in the field as a result tillering was higher under wider spacing.

3. At 30 DAT dry weight was significantly higher (6.38gm) under 20 cm × 15 cm and significantly lower (5.32gm) under 20 cm × 10 cm. But at 60 DAT it was significantly high (29.91gm) under 20 cm × 10 cm. This rapid gain in dry matter of plants under closer spacing could be due to vertical growth of rice plants at closer spacing as compared with horizontal tillering in wider spacing. Unlike, above observations, it was significantly high (200.4gm) under wider spacing of 20 cm × 20 cm at harvest. This suggests that wider spacing influences profuse growth of yield attributing characters as compared to vegetative growth. This could be the cause of higher dry matter observations during the later phase of plant development. Regarding the effect of different levels of Nitrogen, at 30 and 60 DAT the DM accumulation was high (6.33gm and 34.17gm respectively) at 120 kg N/ha and at harvest DM accumulation was significantly high (233.1gm) in 160 kg N/ha, followed by (202.7 gm) in 120 kg N/ha.

4. Leaf area index was highest 0.72, 3.21 and 3.58 at 30, 60 and 90 DAT respectively under higher plant population i.e. 20 cm x 10 cm spacing, whereas it was significantly lower under wider spacing (lower plant population). At 30 and 60 DAT LAI was significantly high (0.64, 2.63) at lower level (80 and 120 kg N/ha) but at the reproductive stage LAI increased successively with successive increment in the level of Nitrogen so that the highest LAI was 3.79 at 160 kg N/ha at 90 DAT.

5. Nitrogen content of the grain increases with spacing and levels of nitrogen. Higher nitrogen content in wider spacing imply that nutrient availability is high as the per plant area coverage is high, roots can spread profusely and competition among plants is reduced.

6. Yield attributes (effective tiller, panicle length, filled grain, panicle weight and test weight) increased as the spacing and levels of nitrogen increased up to optimum dose (120 kg N/ha). A significantly high panicle weight 22.65gms was obtained at 20 cm × 15 cm followed by 21.74 and 20.04 at, 20 cm × 20 cm and 20 cm × 10 cm respectively. The highest length of panicle was found to be 27.02 cm at 20 cm × 10 cm followed by 26.78 cm and 26.65 cm under 20 cm ×15 cm and 20 cm × 20 cm respectively at the nitrogen level of 120 kg N/ha.

7. The grain yield of rice differed significantly with the different levels of nitrogen but different levels of plant population did not affect the grain yield significantly. The highest average grain yield (5.88 t/ha) was obtained under 120 kg N/ha which was statistically higher over all the nitrogen treatments and control. The increase in levels of nitrogen beyond 120 kg N/ha was not responsive in terms of yield increment and resulted in lower grain yield per unit area.

8. Significantly high straw yield 7.33 t/ha was obtained at wider spacing of 20 cm × 20 cm and regarding with level of nitrogen highest straw yield (7.03 t/ha) was attained at 160 kg N/ha. The increase in straw yield with increase in N dose may be attributed to increase in dry matter production. The effect of different spacing was insignificant but different levels of Nitrogen had significant effect on harvest index. Significantly higher harvest index 0.45 was obtained at 120 kg N/ha. The lowest 0.36 was at control. The harvest index decreased after 120 kg N/ha.

9. Gross return, net return and benefit: cost ratio (B/C ratio) were significant among the treatments. Application of 120 kg N/ha and 20 cm × 20 cm spacing was found more profitable than other treatments and gave highest net return of Rs. 60200 and B:C ratio of 2.60 at 120 kg N/ha and highest net return of Rs. 50620 and B:C ratio of 2.27 under 20 cm × 20 cm. Optimum level of nitrogen and low plant population gave highest return and B:C

ratio. Nitrogen beyond 120 kg N/ha did not show higher increment in return and it might be detrimental to the crop due to excess nitrogen and wastage of money.

5.2 Conclusion

From the aforementioned results of Rampur Masuli under SRI, it could be concluded that following the techniques of SRI could be beneficial both in terms of yield and seed saving. From the economic analysis, 20 cm × 20 cm spacing with 120 kg N/ha was found effective for obtaining higher yields. This could make the production system more economical under SRI. Further experiment is needed for the confirmation of the results on spacing and level of nitrogen under different spacing depending upon soil characteristics and climatic variations in different agroecological zones.

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APPENDICES

Appendix 1. Weather record during the experimental period during 2006 at Rampur, Chitwan.

Months	Maximum temperature	Minimum temperature	Total rainfall (mm)	Relative humidity (%)
May	35.08	23.22	15.54	76.35
June	34.65	24.86	17.60	79.27
July	34.31	26.56	13.05	83.97
August	34.71	25.55	19.30	80.13
September	33.36	24.09	21.29	85.53
October	32.93	19.92	12.12	83.77

Appendix 2. General cost of cultivation (Rs/ha) of rice during 2006 at IAAS, Rampur.

Particular	Unit	Quantity	Rate	Total (Rs)
Nursery raising (8m2)				
1. Land preparation and seed bed preparation	Labour	4	100	400
2. Plastic	Kg	16	40	640
3. Cost of seed	Kg	8	20	160
4. Fertilizer cost @ 100:80:40 kg/ha				
Urea	Kg	1.16	20	23.2
DAP	Kg	1.4	30	42
MOP	Kg	0.53	18	9.54
5. Seed sowing	Labour	1	100	100
6. Application of fertilizer and pesticide	Labour	1	100	100
7. Cost of uprooting and seeding	Labour	8	100	800
Total				2274.74
Transplanted field (1ha)				
1. Land ploughing (2 ploughing) with disc				
Harrow	Hours	2	660	1320
2. Bund making and digging	Labour	6	100	600
3. Planking and puddling	Hours	1.5	660	990
4. Uprooting seedling	Labour	5	100	500
5. Labour for irrigation	Labour	2	100	200
6. Irrigation 6 times	Hours	15	60	900
7. Rogar	ml	200	1.95	390
8. Hinosan	ml	200	1.65	330
9. Harvesting	Labour	25	80	2000
10. Bunding and transporting	Labour	8	100	800
11. Threshing	Labour	10	100	1000
12. Cleaning, drying and storge	Labour	10	80	800
Total				9830
Total Cost				12104.74

Appendix 3. Variable cost (Rs/ha) of different treatments of rice during 2006 at IAAS, Rampur.

Treatment	Notation	Particular	Quantity	Rate (Rs.)	Total cost (Rs/ha)
1	P_1N_0				
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	25 Labour	80	2000
Total					6110
2	P_1N_1				
		Urea	87 kg	20	1740
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	25 Labour	80	2000
Total					7850
3	P_1N_2				
		Urea	174 kg	20	3480
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	25 Labour	80	2000
Total					9590
4	P_1N_3				
		Urea	261 kg	20	5220
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	25 Labour	80	2000
Total					11330
5	P_1 N_4				
		Urea	348 kg	20	6960
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	25 Labour	80	2000
Total					13070

6	P_2 N_0				
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	17 Labour	80	1360
Total					5470
7	P_2 N_1				
		Urea	87 kg	20	1740
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	17 Labour	80	1360
Total					7210
8	P_2 N_2				
		Urea	174 kg	20	3480
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	17 Labour	80	1360
Total					8950
9	P_2 N_3				
		Urea	261 kg	20	5220
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	17 Labour	80	1360
Total					10690
10	P_2 N_4				
		Urea	348 kg	20	6960
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	17 Labour	80	1360
Total					12430
11	P_3 N_0				
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	12 Labour	80	960
Total					5070

12	P_3 N_1				
		Urea	87 kg	20	1740
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	12 Labour	80	960
Total					6810
13	P_3 N_2				
		Urea	174 kg	20	3480
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	12 Labour	80	960
Total					8550
14	P_3 N_3				
		Urea	261 kg	20	5220
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	12 Labour	80	960
Total					10290
15	P_3 N_4				
		Urea	348 kg	20	6960
		SSP	313 kg	10	3130
		MOP	50 kg	18	900
		Application	1 Labour	80	80
		Transplanting	12 Labour	80	960
Total					12030

Appendix 4. Economic analysis of using different spacing and levels of nitrogen in rice cultivation during 2006 at IAAS, Rampur, Chitwan.

Treatment	Notation	Gross income (Rs/ha)	Total Cost (Rs/ha)	Net profit (Rs/ha)	Benefit cost ratio
1	P_1N_0	45870	18215	27655	1.52
2	P_1N_1	63330	19955	43375	2.17
3	P_1N_2	77880	21695	56185	2.59
4	P_1N_3	93360	23434	69926	2.93
5	P_1 N_4	81120	25175	55945	2.22
6	P_2 N_0	36480	17575	18905	1.08
7	P_2 N_1	57150	19315	37835	1.96
8	P_2 N_2	77820	21055	56765	2.70
9	P_2 N_3	82230	22795	59435	2.61
10	P_2 N_4	73260	24535	48725	1.99
11	P_3 N_0	39720	17175	22545	1.31
12	P_3 N_1	53730	18915	34815	1.84
13	P_3 N_2	53040	20655	32385	1.57
14	P_3 N_3	73620	22395	51225	2.29
15	P_3 N_4	70230	24135	46095	1.91

Appendix 5. Correlation coefficient due to different spacing and levels of nitrogen in various parameters of rice

Parameters	Grain yield	Straw yield	Harvest index	Length of panicle	Panicle weight	1000 grain weight	No. of filled grain	Nitrogen content %
Grain yield	-	0.686**	0.561**	0.536**	0.256	0.006	0.034	0.511**
Straw yield	-	-	-0.163	0.274	0.053	-0.104	-0.086	0.559**
Harvest index			-	0.367*	0.241	0.136	0.087	0.129
Length of panicle				-	0.823**	-0.121	0.539**	0.302*
Panicle weight					-	-0.215	0.814**	0.106
1000 grain weight						-	-0.225	-0.242
No. of filled grain							-	0.003
Nitrogen content %								-

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

Appendix 6. Correlation coefficient due to different spacing and levels of nitrogen in various parameters of rice

Parameters	LAI 30 DAT	LAI 60 DAT	LAI 90 DAT	DM 30 DAT	DM 60 DAT	DM 90 DAT	DM at harvest	Straw yield (t/ha)	Grain yield (t/ha)
LAI 30 DAT	-	0.558**	0.388**	0.215	0.013	-0.291	-0.136	0.445**	0.231
LAI 60 DAT	-	-	0.519**	-0.262	0.681**	-0.077	0.097	0.605**	0.455**
LAI 90 DAT			-	-0.073	0.387**	0.599**	0.470**	0.431**	0.362*
DM 30 DAT				-	-0.075	0.168	-0.060	0.077	0.197
DM 60 DAT					-	0.254	0.190	0.469**	0.521**
DM 90 DAT						-	0.722**	0.083	0.213
DM at harvest							-	0.212	0.253
Straw yield (t/ha)								-	0.686**
Grain yield (t/ha)									-

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

Appendix 7. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Plant height				
		25 DAT	40 DAT	55 DAT	70 DAT	85 DAT
Replication	2	20.615	42.579	47.698	98.844	268.483
Factor A	2	9.664	17.539	0.686	17.67	85.088
Error	4	2.846	22.733	22.053	26.468	59.971
Factor B	4	20.298**	91.686**	196.311**	358.468**	170.321**
AB	8	10.189*	3.87	9.536	31.301	79.931**
Error	24	4.157	8.358	7.422	26.883	22.235

Appendix 8. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Dry matter accumulation			
		30 DAT	60 DAT	90 DAT	Harvest
Replication	2	0.517	2.084	66.213	35.506
Factor A	2	4.44**	48.009**	2001.839**	2362.342**
Error	4	0.023	0.199	14.219	1.289
Factor B	4	1.143**	266.182**	3550.592**	8264.669**
AB	8	1.957**	99.468**	1492.509**	9279.003**
Error	24	0.268	0.143	9.361	0.905

Appendix 9. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Leaf area index		
		30 DAT	60 DAT	90 DAT
Replication	2	0.00	0.00	0.00
Factor A	2	0.426**	12.988**	6.31**
Error	4	0.00	0.00	0.00
Factor B	4	0.025**	1.276**	4.109**
AB	8	0.028**	0.817**	2.256**
Error	24	0.00	0.00	0.00

Appendix 10. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	No. of tiller				
		25 DAT	40 DAT	55 DAT	70DAT	85 DAT
Replication	2	8.499	29.718	3.908	1.324	16.918
Factor A	2	1.875*	20.812*	46.651*	35.18	23.244
Error	4	0.165	3.398	5.072	14.942	30.414
Factor B	4	3.95*	30.479*	15.019	19.053	22.95
AB	8	3.95**	10.476**	8.55	12.491	15.422
Error	24	1.024	8.162	13.193	16.035	16.796

Appendix 11. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Panicle weight	Length of panicle	Effective tiller	Nitrogen content
Replication	2	17.697	3.533	193.889	0.059
Factor A	2	26.4	1.498	1217.689	0.067
Error	4	10.433	1.794	344.256	0.01
Factor B	4	74.42**	57.065**	581.589	0.39**
AB	8	11.114	1.457	158.106	0.008
Error	24	10.884	1.371	214.467	0.029

Appendix 12. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Filled grain	Unfilled grain	Total grain	Sterility %
Replication	2	175.784	32.039	59.876	36.839
Factor A	2	586.955	44.26	547.906	60.663
Error	4	234.306	7.164	179.788	28.682
Factor B	4	347.37	53.486	316.698	47.237
AB	8	281.511	15.732	321.771	18.469
Error	24	146.653	34.46	183.627	26.535

Appendix 13. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Grain yield	Straw yield	Harvest index	Test weight
Replication	2	1.543	2.993	0.004	0.009
Factor A	2	4.374	19.596**	0.009	6.498**
Error	4	4.574	0.898	0.011	0.098
Factor B	4	15.501**	12.236**	0.01**	1.841*
AB	8	1.337	1.629	0.001	2.922
Error	24	0.937	1.444	0.002	0.514

Appendix 14. Mean squares from ANOVA for various parameters of rice tested to different spacing and levels of nitrogen.

Source of variation	df	Gross income	Net income	Benefit Cost Ratio
Replication	2	1179.822	2296.689	0.01
Factor A	2	760967402.222**	654739289.089**	0.922**
Error	4	91.822	367.422	0.00
Factor B	4	2438044992.22**	1775109852.91**	2.049**
AB	8	95603277.22	95741088.23	0.18
Error	24	31.989	148.789	0.00