Response of Drought Tolerant Rainfed Rice Cultivars to Transplanting Dates Under Changing Climatic Condition in Nawalparasi, Nepal

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RESPONSE OF DROUGHT TOLERANT RAINFED RICE CULTIVARS TO TRANSPLANTING DATES

UNDER CHANGING CLIMATIC

CONDITION IN NAWALPARASI, NEPAL

DINESH BAHADUR KARKI

THESIS

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CERTIFICATE

This is to certify that the thesis entitled **"CROP PERFORMANCE UNDER CONSERVATION AGRICULTURE IN RICE-WHEAT CROPPING SYSTEM"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** with major in **Agronomy** of the Postgraduate Program, Institute of Agriculture and Animal Science, Rampur, is a record of original research carried out by **Mr. ANIL KHADKA, Id. No. R-2011-AGR-04 M,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

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Dinesh Bahadur Karki

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

%	Percentage
@	At the Rate of
^{0}C	Degree Celsius
AGDM	Above Ground Dry Matter
AGDP	Agriculture Gross Domestic Product
ANOVA	Analysis of Variance
APP	Agriculture Perspective Plan
CGR	Crop Growth Rate
CH4	Methane
cm	Centimeter
Co_2	Carbondioxide
CV	Coefficient of Variation
DAP	Di-Ammonium Phosphate
DAS	Days After Sowing
DAT	Days After Transplanting
DHM	Department of Hydrology and Meteorology
DMRT	Duncan's Multiple Range Test
et al.	et alii
FAO	Food and Agricultural Organization
FYM	Farm Yard Manure
g	Gram
GDD	Growing Degree Day
GDP	Gross Domestic Product

GHG	Green House Gases
HI	Harvest Index
HUE	Heat Use Efficiency
IAAS	Institute of Agriculture and Animal Science
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
kg	Kilo Gram
LAI	Leaf Area Index
LIBIRD	Local Initiatives for Biodiversity Research and Development
LSD	Least Significant Difference
m	Meter
m^{-2}	Meter Square
Max.	Maximum
Min.	Minimum
MoAD	Ministry of Agriculture and Development
MoP	Murate of Potash
N	Nitrogen
N.S.	Non-Significant
N_2O	Nitrous Oxide
NARC	Nepal Agricultural Research Council
NRRP	National Rice Research Programme
PI	Panicle Initiation
PRRI	Philippine Rice Research Institute
RH	Relative Humidity
SEM	Standard Error of Mean

t ha^{-1}	Ton Per Hectare
UNFCC	United Nations Framework Convention on Climate Change

1 INTRODUCTION

1.1 Background information

Rice is the major staple food of more than half of the world's population and the most important food crop of Nepal. In Nepal, Rice is grown in about 15, 31,493 ha with total production of about 50,72,248 mt and average productivity of 3.31 ton ha^{-1}. The recent area, production and productivity of rice in Nawalparasi district (central-terai) of Nepal is 44,890 ha, 1, 91,337 mt and 4.26 t ha^{-1}, respectively. The share of rice to the National Agriculture Gross Domestic Product (AGDP) is 20% and total food grain production is 56% (MoAD, 2011). It contributes more than 50% to the total calories requirement of Nepalese people (NARC, 2007). Rice straw and by-products provides about 32-37 % of total digestible nutrient for the livestock, mainly in dry season (NRRP, 1997).

Rainfed farming means the cultivation of crops on relatively dry land that lacks easy access to irrigation and the moisture requirement for the crop's growth and development totally depends upon rainfall. Rainfed farming area falls mainly in arid, semi-arid and dry sub-humid zones. The likelihood of increasing extreme weather events is seen in the recent few years. The variation in monsoon which includes delay in onset, long dry spells and early withdrawal, all of which strongly influence the productivity level of rice and other rainfed crops.

About 45% area of Asian rice is under rainfed condition (Balasubramanian *et al.*, 2007). In Nepal, only 49.96% rice production area is under irrigated condition, while 50.04 % area under rice production is still fully rainfall dependent (MoAD, 2011). About 80% rice grown in the central terai region of Nepal is still rainfall dependent (Amgai, 2011). The yield of rice under rainfed condition in Nepal is very low (2.55 t ha^{-1}), as compared to 3.65 t ha^{-1} under irrigated condition (MoAD, 2008).

Climate change refers to any change in climate over time, whether due to natural variability or anthropogenic forces. The main cause of climate change is the increase in concentration of Green house gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere mainly due to human activities such as fossil fuels utilization, conventional cultivation practices and change in land use patterns. Whereas, climatic variability refers to climatic parameter of a region varying from its long-term mean. Every year, in a specific time period, the climate of a particular location is different. Some years have below average rainfall, some have average or above average rainfall. This type of Climatic variability is a threat to food production. The change in climate is indicated by increase in temperature, change in rainfall pattern etc. These changes in climatic factors could lead to substantial modifications in land and water resources for rice production which, affect the productivity of rice crops grown in different parts of the world.

Temperature is increasing in Nepal and the rainfall is becoming more variable due to climate change. The temperature of Nepal is increased by 0.06^0c per year. Climate dynamics, particularly the projected increase in the variability of rainfall regimes, suggest that Nepalese agriculture is facing with immense challenges as seasonal drought is increasing.

Long-term climatic variability influences sowing date, crop duration, crop yield and the management practices adapted in rice production. The degree of vulnerability of crops to climatic variability depends mainly on the development stage of the crops. Climatic variability determines crops yield through direct effect on crop growth and development and also through indirect pathways such as farmers' decision on planting, cropping sequence/rotation etc. (Lansigan *et al.*, 2000). Climatic factors like temperature, solar radiation and rainfall influence effectively for all stages involved in grain production such as; vegetative growth, storage organs formation and grain filling (Yoshida, 1981).

The increased temperature may decrease rice potential yield up to 7.4% per degree increment of temperature. Increased temperature with variable rainfall condition create periodic drought in rice growing season. For producing one kg of rice, about 3000 liters of water evenly distributed over the growing period is required. Excess amount of water for few days and water scarce for many days does not avail such amount of water for rice production (Basnet, 2009). The current rice production systems rely on ample water supply and thus are more vulnerable to drought stress than other cropping systems (O'Toole, 2004). Due to increased temperature and changing rainfall pattern, water stress occurs at various growth stages of the rice. Due to not occurring monsoon in time, planting of rice is being delayed. The delayed planting tends to decline in number of days from seeding to maturity. It also causes decline in plant stand per square meter and number of filled grains per panicle which ultimately affects yield (Hayat *et al.*, 2003).

So, the optimum planting date of rice is very important in improving its growth and development leading to increasing yield. Rice is normally sown at the end of May and transplanted during the first week of July in Nepal. Different growth stage of rice requires different weather conditions which also vary with rice cultivars. So adjusting the transplanting time for different cultivars of rice in relation to changing climatic scenarios may be one of the coping strategies for the sustainable higher yield of rice. Appropriate planting time of the rice crop is important for three major reasons. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperatures and higher level of solar radiation. Secondly, the optimum planting time ensures the cold sensitive stage occurs when the minimum night temperatures are warmer. Thirdly, planting on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved (Farrell *et al.*, 2003).

The transplanting of rice in rainfed lowland condition sometimes gets delayed due to lack of sufficient rainfall for puddling operation in the rice growing areas of Terai and Inner-Terai of Nepal. Delayed planting particularly in late August, inhibits tillering, which leads to poor vegetative growth and ultimately low yield.

The drought condition likely to occur in rainfed lowland ecosystem seriously affects the growth and yield of rice. Most of the main season rice cultivars developed and released in Nepal are susceptible to long term drought condition. Nepal Agriculture Research Council has developed and released main season drought tolerant rice cultivars; Sukkha Dhan-1, Sukkha Dhan-2 and Sukkha Dhan-3 in 2011 for terai and foot hills of Nepal. Radha-4 is also a popular main season rice cultivar among farmers in relatively drought prone areas of mid hills and terai of Nepal. The Sukkha cultivars are early maturing (100−120 days) having yield potential of 3.5 t ha^{-1} (Tripathi *et al.*, 2012). Whereas cultivar Radha-4 matures at 124 days and yield potential is 3.7 t ha^{-1} (NARC, 2010).

Temperature based agrometerological index such as Growing Degree Days (GDD) have been reported quite useful in predicting the growth and yield of crops (Doraiswamy and Thompson 1982; Jones *et al.*, 2003). GDD is based on the concept that the real time to attain a phonological stage is linearly related to the temperature range between base temperatures (T_b) and optimum temperature (Monteith 1958). Heat use efficiency in terms of dry matter or yield is important aspect which has great practical applications (Amgai, 2011). The efficiency of conversion of heat into the dry matter depends upon the genetic factors, sowing time and crop type (Rao *et al.*, 1999).

The research work therefore was planned, executed and completed at farmers field under rainfed lowland condition of central Terai (Nawalparasi) to meet the following objectives;

1.2 Objectives

Broad objective

- To determine the productivity of various drought tolerant rice cultivars and appropriate transplanting dates under changing climatic scenarios

Specific objectives

- To evaluate the growth, phenology and yield of appropriate transplanting dates and drought tolerant rice cultivars
- To find out the interaction effect of transplanting dates and drought tolerant rice cultivars on growth, phenology and yield

2 LITERATURE REVIEW

2.1 Climate change

Global climate change is a burning issue at present. Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer, whether due to natural variability or as a result of human activities. Climate change is more due to external forces and less due to natural processes such as emission of volcanic gases, changes in ocean circulation, and fluctuations in solar radiation and so forth.

2.1.1 Causes and consequences

Increases in Greenhouse Gases (GHG) such as Methane (CH_4), Carbon Dioxide (CO_2) and Nitrogen Dioxide (N_2O) in the atmosphere, from various sources including fossil fuel burning, faulty agricultural practices and changes in land use, which leads to an increase in global temperatures by trapping the suns reflected energy in the atmosphere (UNFCC, 2007). The GHGs blocks infrared radiation escaping directly from the surface to the space resulting in warming of the atmosphere (Dahal, 2009). The elevated concentrations of green house gases means that heat is retained in the atmosphere for longer period causing atmosphere to heat up.

The earth's average surface temperature has risen by about 0.74 degrees Celsius (^oC) in the past 100 years and it could even rise by up to 5 ^oC by 2080 if the emissions of such GHGs are not decisively reduced. The consequences of climate change can be seen all over the world. It is also concluded that the number of natural disasters increases more and more. Tsunamis, floods and extreme drought occur more frequent than in times past.

Deforestation is the causes that areas around the equator become dryer and hotter. So, we should be very concerned about the causes and effects of climate change.

2.2 Climatic requirement of rice

Rice crop is grown from tropical to sub-tropical humid climate throughout the world, except extreme cold temperate zone (Dingkuhn and Miezan, 1995). Climatic factors such as temperature, rainfall, relative Humidity etc. affects the cultivation of rice in a particular area. The two major causes of yield variation in rice are due to fluctuation in temperature and rainfall. The Variation in temperature and rainfall independently affects yield of rice three to four times more than those caused by the variation in solar radiation. Rice production in temperate region is limited by temperature, but in rainfed tropical areas, the rice growth and development is determined by the rainfall pattern.

2.2.1 Temperature requirement

The temperature of a particular rice growing area greatly influences the crop duration and yield performance of the rice crop. Air and water temperature influence on growth and development of rice crop (Dingkuhn *et al.,* 1995). For the optimum growth and development, rice crop needs relatively high temperature. Temperature requirement of rice is different for different growth stages (Yoshida, 1978). The mean temperature, diurnal changes in temperature during the growing season may be highly correlated with grain yields (Moomaw *et al.,* 1966). The optimum temperature for the growth and development of rice crop falls between 25-30^{o}C. The day temperatures of 28-32^{o}C with night temperatures about 3^{o}C lower than that at day time are standard, for rice production (Cornell, 2004). High night temperatures are commonly associated with increased respiration rates, leading to a decline in yield (Mohammed and Tarpley, 2009). Heat accumulation over the crop period also determines the rice production. The accumulative temperature for the rice crop to reach to maturity stage from seeding date ranges from

$3,000^0C$ in high altitude and 5000^0C for the low altitude (Vernkatraman and Krishna, 1992). Critical temperatures for germination, tillering, inflorescence initiation and development and ripening of rice crop have been identified. Both low and high temperature has negative effect on rice production (Yoshida, 1978). The temperature effects on phenological development are twofold: one is as a general promoter of development through activation of enzymatic processes, except in the supra-optimal range; and the other is as a modifier of photoperiodism .

2.2.2 Effect of temperature difference on rice

The Increasing temperature shortened the growing season of rice crop leading to decreased yield in tropical areas. Variation in diurnal temperature affects the growth and development of rice especially at reproductive stage. The Low temperature during grain filling and maturity stage extend the crop duration which allows ample time for more assimilate development (De Datta, 1981). Long day length with higher solar radiation attributes high grain yield in temperate rice growing regions. It is one of regions for higher rice yield in temperate countries as compared to tropical countries taking long crop life span (Moomaw *et al.,* 1966).

2.2.3 Effects of high temperature on rice

According to IRRI (2010) day time temperature has been increased by 0.35^oc and night time temperature by 1.1^oc since 1979. The yield of rice was reported to strongly correlate to night time temperatures. Increased night temperature over a quarter century is responsible for rice yield reduction. Extreme high temperatures cause injury to the rice plant. In tropical regions, high temperatures are a constraint to rice production (Mackil *et al.,* 2010). Though rice is originated from tropics, high temperature of more than 35^0C during flowering stage reduces the seed setting causing low yield. High night temperature during ripening stages also decreases rice yield and grain quality (Tanaka *et al.,* 2009).

Further heat stress at the reproductive stage can cause leaf yellowing, accelerated development leading to low yield.

Also high temperature has damaging effect at anthesis leading to grain sterility. An increase in temperature will eventually shorten the duration of crop growth cycles. This shortening of such a cycle could result early senescence of crop showing an adverse effect on productivity. Studies on rice productivity under global warming situation also suggest that the productivity of rice and other tropical crops will decrease as global temperature increases.

It is common to have maximum daily temperatures from 35-41°C or higher in semi-arid regions and during hot months in tropical Asia. In these areas, a heat susceptible cultivar may suffer from a high percentage of sterility induced by high temperature (Satake and Yoshida, 1977). The detrimental effect of high temperature to spikelet fertility is most during flowering, followed by just before anthesis and post anthesis period of crop growth, respectively.

2.3 Effects of solar radiation on rice

Clear sunny weather during ripening and moist-humid during vegetative phase is desirable for rice crop. Low solar radiation would hamper ripening of grains and would increase chaff production enormously. But, because of high dependence of farmers growing rice under rainfed condition mostly on rainfall; they grow crops when there is low sunlight intensity in the tropics. On the other hand, where irrigation water is available, rice can be grown in the dry season and the grain yield will be higher than in the wet season because of the higher intensity of solar radiation, as in spring rice of Nepal. From panicle initiation to about 10 days before maturity, rice crop requires ample solar energy. The accumulated dry matter between panicle initiation and harvesting is highly correlated with grain yield (De Datta *et al.*, 1968). Prolonged and brighter sunshine is necessary for rice crop to enhance photosynthetic activity and higher yield. So, it should receive more than 300 sunshine hours during the last 45 days before harvest.

2.4 Rainfed rice in Nepal

About 50.04% rice growing area in Nepal is still fully rainfall dependent; leaving remaining rice production area under irrigated condition (MoAD, 2011). Complete crop failure usually occurs when severe drought stress takes place during the reproductive stages; which is the reason for low average yield (2.55 t ha^{-1}) under rainfed condition as compared to relatively more average yield (3.65 t ha^{-1}) under irrigated condition (MoAC, 2008). About 72.5% of the total rice production in Nepal was contributed by rainfed ecosystem (MoAC, 2008).

2.5 Rainfall pattern in Nepal

The summer monsoon is most important in Nepalese agriculture along with rice cultivation. In Nepal, 70-90% of the total annual rainfall occurs in summer monsoon period which falls between June and September. The onset of summer monsoon is normally from June 10 from eastern part of the country and advances westwards covering the whole country within a week (Nayava, 1980). During this monsoon period, the amount of rainfall is 10 mm per day in an average (Shrestha, 2000).

The total average annual rainfall of past 29 years (1982-2011 A.D.) in Nepal is 2332 mm; whereas average total rainfall during rice growing season is 1845 mm (DHM, 2012). This amount of rainfall is not found evenly distributed over the growing period. Yield of rainfed rice is limited to variability in the amount and distribution of rainfall. Due to this variability of rainfall, cropping calendar may be disturbed. Traditional rainfall in Jestha and Ashar (mid-July) has shifted in Shrawan and Bhadra, negatively affecting paddy production in Nepal (Pokhrel, 2011).

2.5.1 Rainfall and rice production

The onset, duration and cessation of the rainy season strongly determine the water availability of the rice crop. The onset of the rainy season is the most important variable for agriculture (Ingram *et al.*, 2002). It directly affects on farm management practices, especially time of sowing/ planting which in turn significantly affects crop yield. In rainy season evenly distributed rain even in low amount (1200-1500 mm) is beneficial for rice production (De Datta, 1981) than unevenly distributed high amount of rainfall, i.e more than 2000 mm in rice production (Mitin, 2009).

2.5.2 Shifting of rainfall pattern and rice production

The current projections of climate change scenarios include a strong likelihood of a shift in precipitation patterns in many regions of the world. It is predicted that, by 2050s, the area of land subjected to increasing water stress due to climate change will be more than double (Bates *et al.*, 2008). Change in rainfall pattern, quantity and quality of water severely affect the rice production in rainfed lowland area.

For nursery establishment and transplanting of rice crop, it is important to ensure that the rainfall is continuous and sufficient for better germination, growth and development of rice crop. Planting too early might lead to crop failure due to low soil moisture and in turn, planting too late might reduce crop yield by affecting the reproductive stages of crop due to low temperature. Late transplanting of rice also leads to loss of valuable growing time for next season crop. Delay of monsoon and its uneven distribution at the time of rice transplantation results old seedlings transplantation which increase plant mortality and reduce growth duration of crop, ultimately affecting yield. On the other hand, uneven distribution of rainfall after transplanting causes submergence of field or lodging at later stages of crop growth.

2.6 Effect of climate change on rice production

One of the most serious long-term challenges to achieve sustainable growth in rice production is climate change. Various factors of climate such as temperature, rainfall, solar radiation etc. produces different degree of effects on rice crop production. Crop yield responds to three sources of climatic variability;

- Change in the mean conditions, such as annual mean temperature and/or precipitation;
- Change in the distribution, such that there are more frequent extreme events (physiologically damaging temperatures or longer drought periods); and,
- Climate change alters the bio-physical environment, in which crops grow and crops response to factors of climate change, such as temperature, precipitation, and evapo-transpiration. Among the impacts of climate change are, increase in temperature and frequency, intensity, and duration of extreme climatic events such as droughts, floods, and tropical storms; changes in the intensity, timing and spatial distribution of rainfall; soil degradation and sea level rise resulting in loss of agricultural land.

Drought affects all stages of rice growth and development. The strong effects of drought on grain yield are large due to the reduction of tillering capacity, spikelet fertility and panicle exertion of the rice crop. Frequent drought not only reduces water supplies, but also increases the amount of water needed for plant transpiration.

Due to climate change, rice diseases such as blast, sheath and culm blight could become more widespread. Altered wind patterns may change the spread of both wind-borne pests and disease of rice. The possible increases in pest infestations may bring about greater use of chemical pesticides to control them. Climate change may also affect weed ecology and the evolution of weed species over time (PRRI, 2011).

2.7 Climate change adaptation in rice

As mentioned by IPCC recent assessment, agricultural production in South Asia might fall by 30% at the end of 2050 if the existing rate of increasing temperature is not combat. Hence, to deal with such effect of climate change on agriculture along with rice production, there are some of adoptive options like development and release of site specific heat tolerant cultivars, adjustment of sowing/planting time and choice of cultivars with a growth duration allowing avoidance of peak stress periods are some of the adaptive measures against effect of global warming.

2.7.1 Adoption of crop management practices

Evenly distribution of rainfall throughout the crop growing period is more important than total seasonal rainfall to determine drought occurrence and its effects on rice productivity. We need to know efficient water use techniques to increase water use efficiency in rice production.

Adjustment of planting dates and choosing location and climate specific cultivars with different growth duration and/or improving crop rotation can be easily adopted by resource poor farmers. Short duration cultivars are suitable for time adjustment (Balasubramanian *et al.,* 2007). Adjustments of planting dates helps to prevent sensitive stages of crop such as flowering against adverse situations such as intense rainfall, extreme temperatures and drought etc. Seasonal weather forecast of past few years of a particular location may be very helpful in adjusting transplanting dates of rice cultivars growing at that place. Adjustment of planting dates according to the prevailing monsoon trends of the particular rice growing area offers sufficient water available for puddling at the time of transplanting.

2.7.1.1 Selection of appropriate transplanting date

Given that germination and emergence of rice seedlings are more likely to be limited by low temperatures than by high temperatures. As temperature varies from day to day and month to month, maintaining the right time of transplanting of rice crop is much important for crop establishment and avoiding the harmful effect of relatively low temperature during reproductive and grain filling period. The timing of farm operations are most important to successful growth of all crops, but particularly annuals which are susceptible to drought or late rainfall and are beyond the farmers' control (Youdeowei *et al.*, 1986). Planting rice after the optimum time may results in higher disease and insect incidence, tropical storm-related lodging and possible cold damage during heading and the grain filling period resulting in low yields (Groth and Lee, 2003).

2.8 Effect of transplanting date on growth and phenology of rice

Rice seeded before optimum time usually have slow germination and emergence; poor stand establishment, and increased damages from soil borne seedling diseases under cold condition (Linscombe *et al.*, 1999). Tillering is very sensitive with transplanting time and age of seedling in rice. When seedlings stay longer in nursery bed because of delay in transplanting, primary tiller buds on the lower nodes of the main culm often degenerate (Matsuo and Hoshikawa, 1993). In addition, rice plants require a particular temperature for reaching its phonological stages such as panicle initiation, heading, flowering and maturity and these requirement are very much influenced by the planting dates (Yoshida, 1981).

In rice, water stress at panicle initiation increased the proportion of unfilled grains and decreased thousand seeds weight (Wopereis, 1993: Wopereis *et al.*, 1996). Reduced availability of water at the vegetative stage resulted in reduced morphological measurements like tiller number and leaf area index in rice (Cruz *et al.*, 1986). A severe water deficit during reproductive stage will reduce panicle and grain number (Lilley and Fukai, 1994).

2.9 Effect of transplanting date on yield and yield attributing traits

Early sowing produces higher grain yield while delayed sowing generally decreases yield (Acikgoz, 1987; Chaudhry, 1984; Koirala, 1983; Kunwar and Shrestha, 1979). Planting time significantly affect the number of effective tillers m^{-2}, maximum spikelets $panicle^{-1}$, grain yield (t ha^{-1}) and harvest index (Aslam *et al.*, 2010). Moreover, Acikgoz (1987) observed that early seeding produced higher grain yield while delayed sowing reduced yield. Grain and straw yield gradually decreased after 10 August plantation in Banladesh as mentioned by Chowdhury *et al.* (2000). Khalifa (2009) reported that early sowing showed best performance for important growth and yield contributing traits such as plant height, number of tillers m^{-2}, leaf area index, effective panicles m^{-2}, panicle length and weight, number of grains $panicle^{-1}$, thousand grains weight (g). The earlier sown crop benefit from better sunshine and appropriate temperature that resulted into a more vigorous and extensive root system leading to increased vegetative growth means more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the spikeles and more leaf area index during grain filling period, thus results in to high yields in early seeding (Shah and Bhurer, 2005). The delayed sowing results in the poor emergence and reduced heading panicle per meter square and spikelets per panicle and ultimately yield is affected (Hayat *et al.*, 2003)

2.10 Interaction effect of transplanting dates and cultivars on rice yield

The optimum rice planting dates are regional and vary with location and genotypes (Bruns and Abbas, 2006). While studying of different planting dates from July 1 to July 31 in Pakistan with 10 days interval on six rice cultivars (98801, PK-5261-1-2-1, 97502, 98409, Basmati-385 and Super Basmati), Akram *et al.* (2007) found significantly different yield attributing parameters like number of effective tillers m^{-2}, filled grains $panicle^{-1}$, sterility percentage and thousand grains weight as affected by transplanting dates and cultivars. Basmati-385 and Super Basmati planted on July 11 and July 1 gave paddy yield 5.66 t ha^{-1} and 5.61 t ha^{-1}, respectively.

2.11 Selection of appropriate rice cultivars

Investigating drought tolerant cultivar is one of adaptation mechanism dealing with climatic constraint such as drought, which is currently the most prominent abiotic stress that causes large amounts of damage to rice yields and consequently, to income of small holder rice growing farmers, especially those in rainfed areas where poverty is wide spread (IRRI, 2010).

Some reputed traits of rice are identified which are appropriate to tolerate drought stress. Through the breeding program plant with small and erect leaves, extensive root system can be developed which may be helpful in adverse condition. In this line, Veeresh *et al.* (2011) advocated that cultivars significantly affect on the grain and straw yield. Heat avoidance mechanism such as highly efficient transpiration cooling is found in rice germplasm of some arid environments.

Drought is one of the major limiting factors for growing rice in rainfed lowland condition. Further, high temperature aggravates the condition. Drought is the most serious constraint to rice production in unfavourable rice-growing areas and most of the popular farmers' cultivars are susceptible to drought stress (Serraj *et al.,* 2009). Most of the popular cultivars collapse under these unfavourable conditions (Mackill *et al.,* 2010).

Farmers have been adopting different landraces to take advantage even in drought prone area. On the other hand, different improved drought tolerant cultivars have been developing. Drought tolerant rice cultivars such as Sahbhagi Dhan (IR74371-70-1-1) in India, Sahod Ulan 1 (IR74371-54-1-1) in the Philippines and Tarharra 1 (IR84011-B-49-1) in Nepal are being disseminated to farmers of drought-prone areas (Mottaleb *et al.*, 2012). These cultivars perform well even during unfavourable climatic condition and they can provide about 1 t ha^{-1} yield advantage under stress (PRRI, 2011). Some landraces also have proved effective drought tolerant capacity. A very short duration local rice cultivar, Sauthariya has been revealed to be drought tolerant when other cultivars fail as a result of drought (LIBIRD, 2009).

2.12 Drought tolerant rice cultivars and yield

Different rice cultivars have different abilities to tolerate high temperature, salinity, drought and floods. For example, rice cultivar, BKN6624-46-2 is found more tolerant to high-temperature induced sterility than N22 (Yoshida, 1981). Therefore, the selection of appropriate rice cultivars for particular climatic situation is a technical option for adaptation to global climate changes. The development of rice cultivars having good degree of tolerance to high temperature, salinity, drought and flood along with high yielding potential is the need of the day for augmenting rice productivity under various scenarios of changing climate.

2.13 Challenges and opportunities of rainfed rice

Because of global warming, it is sure that vulnerability of rainfed lowland ecosystem will increase. Sudden flooding and long term drought due to irregularity of rainfall are main problems of lowland rainfed condition created by changing climatic situation (Depledge, 2002).

Drought is the most serious constraint to rice production in rainfed ecosystem and most of the popular rice cultivars are susceptible to drought stress (Serraj *et al.*, 2009). The reproductive stage is highly susceptible to drought stress, specifically during flowering, but even drought in other stages can also lead to huge losses in rice yield (Liu *et al.*, 2006). Drought when combined with high temperature, reduce rice yield by bringing gradual change in metabolism, phonology and spikelet sterility. The occurrence of drought is quite unpredictable; because of changing climatic pattern which may lead to severe loss in rice yield of rainfed lowland ecosystem all over the world (Depledge, 2002). Globally, rainfed rice production area is often drought prone (Pandey *et al.,* 2007). Due to the harshness of the environment, the productivity of rainfed lowland systems remains low, with average yields of approximately 2.30 t ha^{-1} overall (Zeigler and Puckridge, 1995).

Although over two-thirds of the current rice supply comes from irrigated areas, which have been the traditional rice bowls following the success of the green revolution, an increase in the productivity of rainfed lowlands is essential to ensure food security, especially for the poorer segments of the population (Fukai *et al*., 1996)

2.14 Epilogue

Rice is the crops of 3 billion people of the world and top crops of Nepal envisaged by APP (APP, 1995). The lower productivity in Nepalese rice cultivars are associated with many factors like biotic and abiotic stresses, adverse climate change effect and lack of suitable crops cultivars and so many other yield reducing agronomic and socio-economic factors. Various works have been documented for rice research under irrigated conditions, however, there lacks proper investigation on rainfed rice on the following main themes and target for the present investigation.

- Rice cultivars suited to different agro-ecozones is lacking and their growth, phenology, yield and economic performance are to be studied.
- Climate change is real happenings of the location, but their empirical investigation and quantification is utmost needed to adapt the climate change adaptation measures and for increasing rice productivity in large areas.
- Change in sowing/transplanting time and selection of suitable crop cultivars may be no-cost technology options to adapt under the changing climatic scenarios, which could be rolled out by several agronomic experimentation and validation.

3 MATERIALS AND METHODS

Materials and method planned and executed during study has been described in detail under different sub headings given below.

3.1 Description of the field experiment

3.1.1 Location and cropping history

The field experiment was conducted at Dhobadi VDC of Nawalparasi district (235 masl.) in a farmer's field from June to November, 2012. The site is located about 76 km North-East from Parasi, Headquarter of Nawalparasi. Vegetable crops and Maize were cultivated in the experimental field before rice transplanting as winter and summer crop. Rice was totally new crop for the experimental field.

Figure 1. Map of Nawalparasi district sowing research site (Dhobadi VDC)

3.1.2 Weather condition during experimental period

The experimental site lies in the sub-tropical humid climate belt of Nepal. The area have sub-humid type of weather condition with cool winter, hot summer and distinct rainy season with average total annual rainfall of about 2332.8 mm (DHM, 2012). It is characterized by three distinct seasons: rainy season (June to October), cool winter (November to February) and hot spring (March to May). The meteorological data of a cropping season was obtained from the meteorological station located at Dumkauli, Nawalparasi which is at 10 km distance from research location.

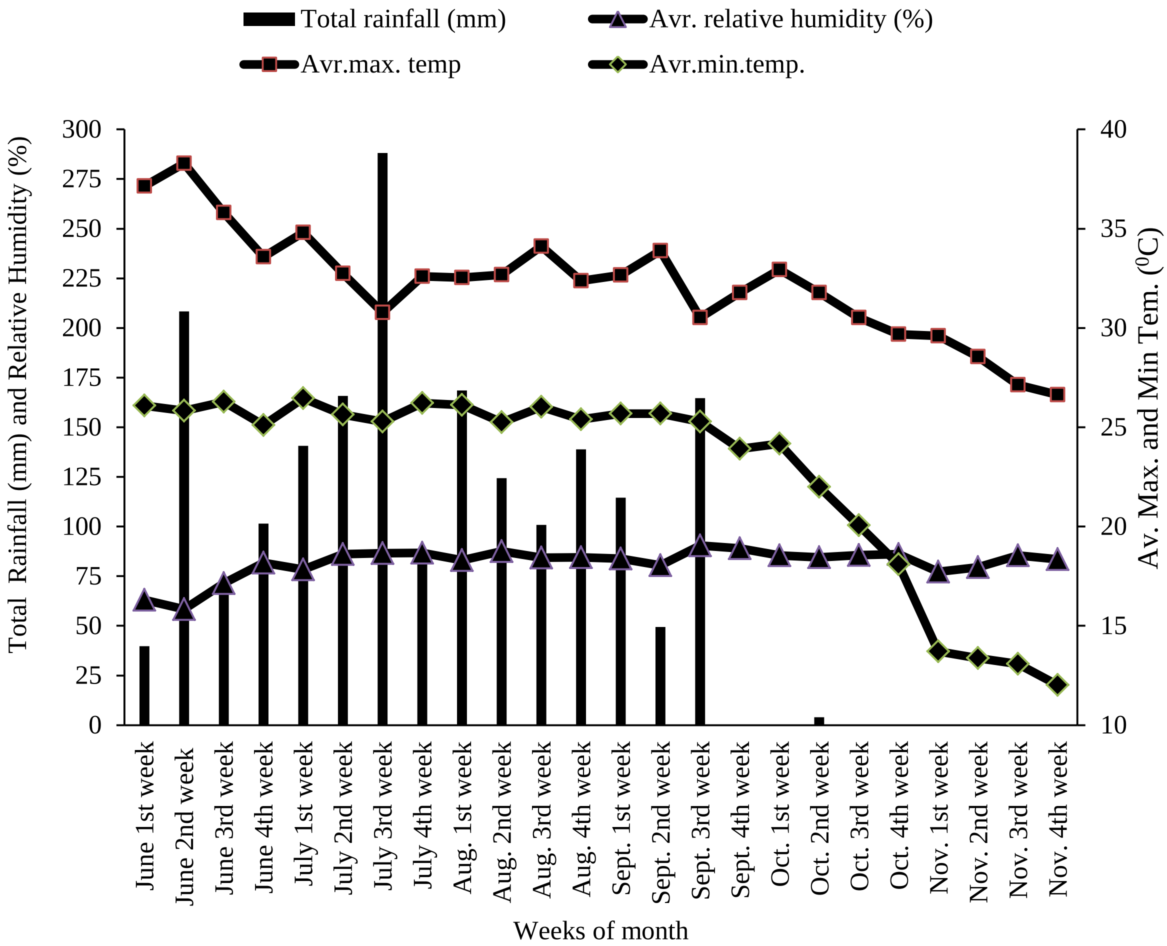

Figure 2. Weekly weather records during experimental period at Dhobadi, Nawalparasi, 2012 (Source: DHM, 2012)

The total rainfall of 2146.9 mm was received during the entire period of experimentation year, 2012. Whereas 1960.4 mm of rainfall was recorded in the rice growing period (June-November, 2012). However total annual rainfall of research year was lower than the average annual rainfall. Though the distribution of rainfall was not even over the period most of the rainfall was received during 4 months of growing (June to September). The highest average weekly rainfall was found in 3rd week of July (288.1mm) and no rainfall was received during October and November. The mean weekly maximum temperature reduced from 38.28 °C (2nd week of June) to 26.63 °C (4th week of November), whereas mean weekly minimum temperature decreased from 26.45 °C (1st week of July) to 12.02 °C (4th week of November) during the crop period. The maximum (90.5%) and minimum (58.41%) weekly Relative Humidity (R.H) was found during third week of September and second week of June, respectively.

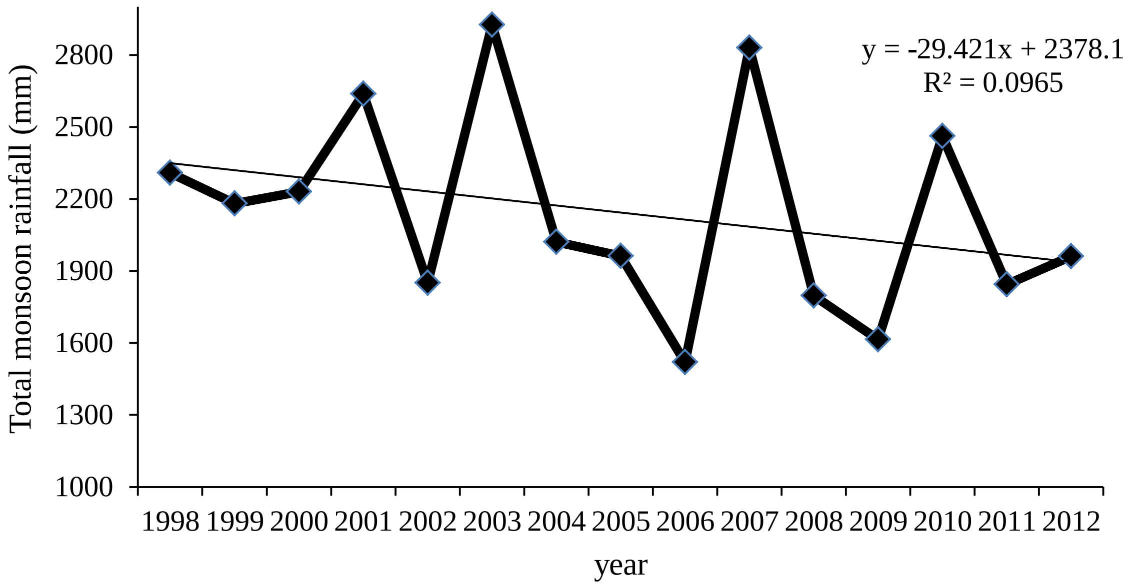

Figure 3. Total average annual monsoon rainfall trend of past 15 years recorded in Dumkauli meterological station, Nawalparasi (Source; DHM, 2012)

3.1.3 Physico-chemical characteristics of experimental soil

Composite soil samples from 0-15 cm depth of different eight locations were taken, using screw auger to record the initial soil physico-chemical properties of the experimental plots. Soil samples were analyzed in soil laboratory of NARC, Khumaltar.

The total nitrogen was determined by Kjeldhal distillation unit, available phosphorus by Spectrophotometer and available potassium by Ammonium acetate method.

Organic matter was determined by Walkey and Black method (1934), pH (1:2 soil: water suspensions) by Beckman glass electrode pH meter and soil texture by Hydrometer method. Physico-chemical properties of the experimental soil are presented in Table 1.

Table 1. Physico-chemical properties of the experimental soil at Dhobadhi, Nawalparasi, 2012

S.N.	Properties	Average content	Rating
1.	Physical properties		
	Sand (%)	25.4	
	Silt (%)	56.	
	Clay (%)	18.6	
	Soil type	silt loam	
2	Chemical properties		
	Soil pH	5.67	Acidic
	Soil organic matter (%)	1.58	Low
	Total nitrogen (%)	0.084	Low
	Available P_2O_5 (kg ha^{-1})	28.9	Low
	Available K_2O (kg ha^{-1})	185.7	Medium

Source: Soil science division, NARC, Nepal

Experimental soil was silt loam with acidic reaction (pH 5.67) and low in organic matter (%), total nitrogen (%) and available P_2O_5 (kg ha^{-1}) and medium in available K_2O (kg ha^{-1}). This soil analysis results revealed that the fertility status of the experimental soil was poor.

3.2 Experimental details

3.2.1 Field layout for experiment

The experimental plots were laid out in two factors factorial split-plot design consisted of transplanting dates in main plots and cultivars in sub-plots. The main plots consisted of four transplanting dates initiated from July 15 and ended on August 14 maintaining 10 days interval between two consecutive transplanting dates. Whereas sub-plots consisted of four drought tolerant rice cultivars. There was 16 treatments combination with three replication. Each replication was separated by 1m alley, while each plot was separated by 0.5m bund space. The size of the individual plot was 7.80 m^2 (3m × 2.6m). Crop geometry was 20 cm × 20 cm; row to row and plant to plant distance maintaining 15 rows with 13 hills per row in each plot. The central seven rows were considered as net plot rows for yield calculation and taking biometrical observations. One row on each side of net plot rows was considered as inter row. The two rows on each side of net plot rows were used to take destructive samples for growth analysis. The remaining one row on each side of destructive rows was considered as border row.

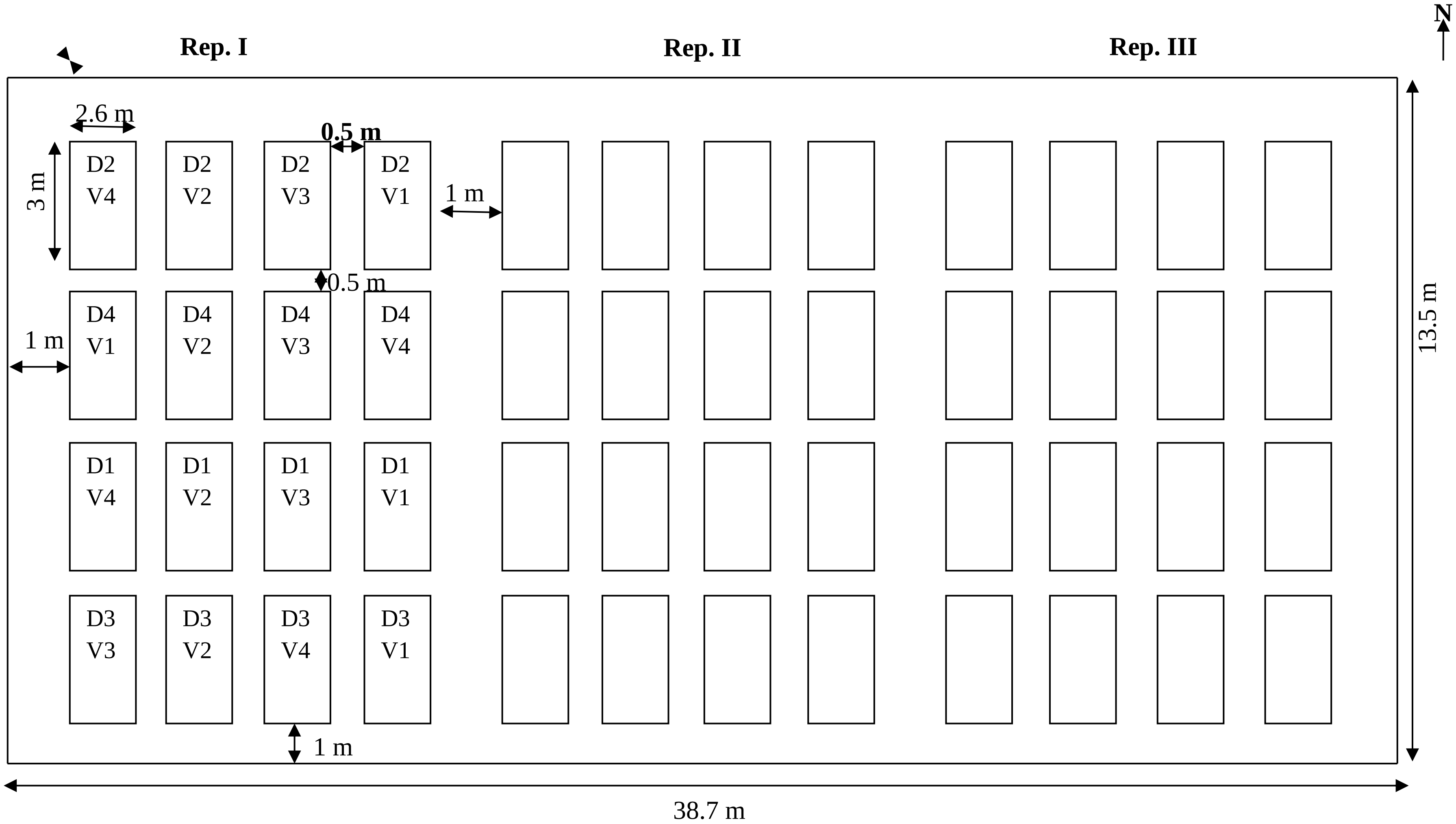

Figure 4. Layout of experimental field

24

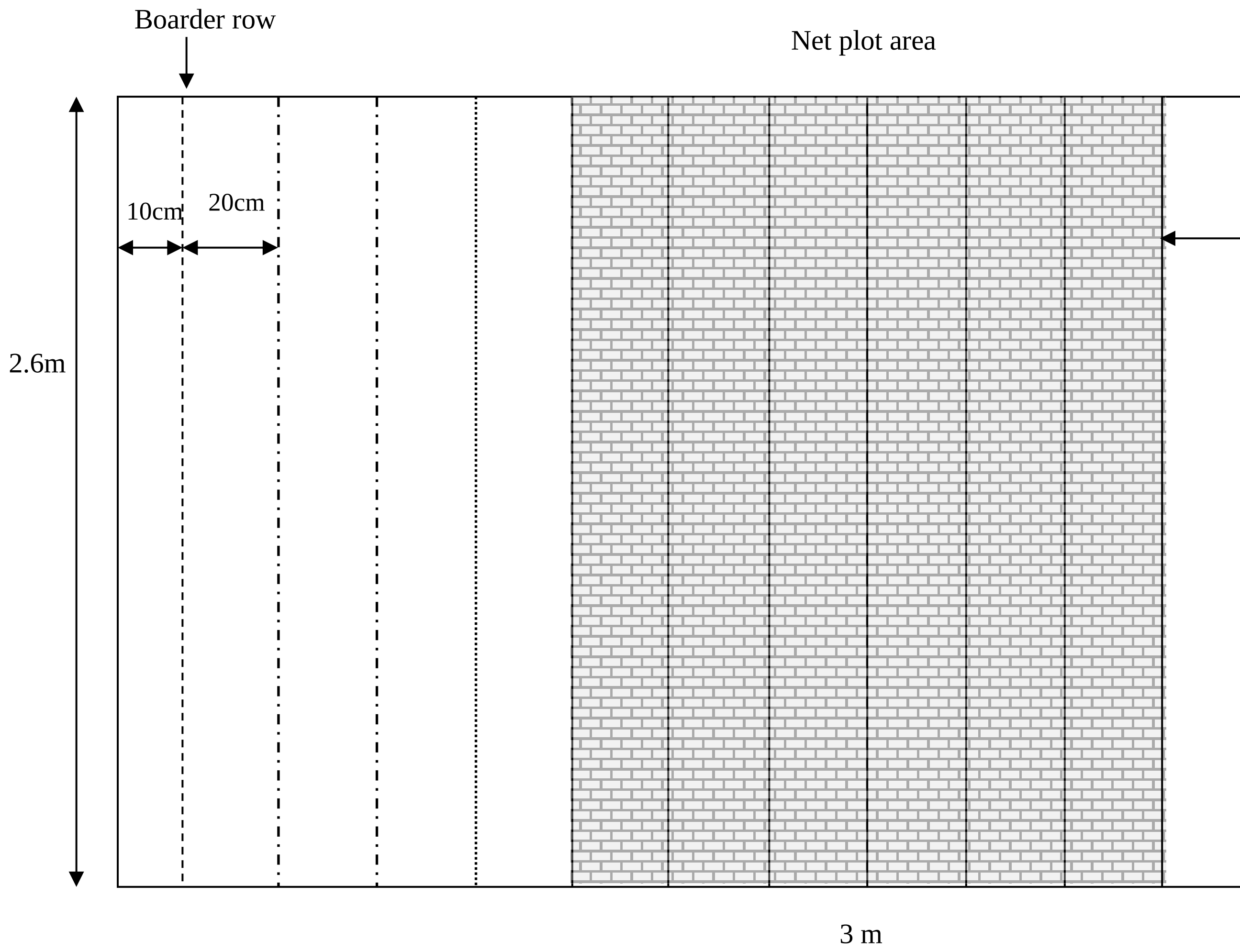

Figure 5. Layout of individual plot

3.2.2 Treatment details

Main- plot Factor (Transplanting date)

D_1 = July 15

D_2 = July 25

D_3 = August 4

D_4 = August 14

Sub- plot Factor (cultivar)

V_1 = Sukkha Dhan-1

V_2 = Sukkha Dhan-2

V_3 = Sukkha Dhan-3

V_4 = Radha-4

3.3 Description of tested rice cultivars

All of the tested rice cultivars were drought tolerant and hence suited for rainfed condition. These rice cultivars were obtained from Caritas Nepal. Brief description about these rice cultivars has been given below.

3.3.1 Sukkha cultivars

Main season rice cultivars: Sukha Dhan-1, Sukha Dhan-2, and Sukha Dhan-3 were released in January 2011 for the drought prone lowlands of Terai to mid-hills of Nepal. These new cultivars are favoured by farmers for their drought tolerance, early maturity (100−120 days), higher milling recovery (more than 65%), tolerance for diseases such as blast and bacterial leaf blight, lodging tolerance and easy threshing. Yield potential of these cultivars is 3.5 t ha^{-1}.

3.3.2 Radha-4

It was taken as local check for the research study. It is an improved rice cultivar developed by IRRI especially for upland conditions. It was released in Nepal in 1994 and recommended for rainfed lowlands of central Terai regions. It has been found very popular in Terai, inner Terai and lower foot hills of Nepal. Its production potentiality is about 3.7 t ha^{-1} and crop duration is of 124 days after seeding (NARC, 2010). The stable yield performance even under rainfed condition is the reason behind its popularity among farmers.

3.4 Cultivation practices

3.4.1 Calendar of operations

Calendar of operations of various cultural practices recorded for the rice from sowing to harvesting is presented below;

Table 2. Calendar of operations of various cultural practices in rice at Dhobadi, Nawalparasi, 2012

S.N.	Cultural operations	Date
1	Ploughing and Land preparation	06-07-2012
2	FYM application	08-07-2012
3	Layout and Leveling	10-07-2012
4	Nursery bed preparation and seed sowing	
4.1	1st date seed sowing	24-06-2012
4.2	2nd date seed sowing	05-07-2012
4.3	3rd date seed sowing	15-07-2012
4.4	4th date seed sowing	25-07-2012
5	Transplanting	
5.1	first transplanting	15-07-2012
5.2	Second transplanting	25-07-2012
5.3	Third transplanting	04-08-2012
5.4	Last transplanting	14-08-2012
6	first Hand weeding	
6.1	1st date's Weeding	14-08-2012
6.2	2nd date's Weeding	28-08-2012
6.3	3rd date's weeding	05-09-2012
6.4	4th date's weeding	15-09-2012
7	Second Hand weeding	
7.1	1st date's Weeding	15-09-2012
7.2	2nd date's Weeding	27-09-2012
7.3	3rd date's weeding	06-10-2012
7.4	4th date's weeding	16-10-2012
8	First top dressing of N_2 fertilizer	
8.1	for 1st transplanting date	15-08-2012
8.2	for 2nd transplanting date	29-08-2012
8.3	For 3rd transplanting date	06-09-2012
8.4	for 4th transplanting date	16-09-2012
9	Second top dressing of N_2 fertilizer	
9.1	for 1st transplanting date	30-08-2012
9.2	for 2nd transplanting date	13-09-2012
9.3	For 3rd transplanting date	21-09-2012
9.4	for 4th transplanting date	01-10-2012
10	Harvesting (Oct 17-Nov 19)	Continuous
11.1	Threshing and drying for 1st date	21-10-2012
11.2	Threshing and drying for 2nd date	31-10-2012
11.3	Threshing and drying for 3rd date	06-11-2012
11.4	Threshing and drying for 4th date	10-11-2012
12	Cleaning and weighing	Continuous

3.4.2 Nursery bed preparation

Nursery beds were prepared at four different dates (June 24, July 5, July 15 and July 25) for each transplanting date. Seedlings were raised in dry nursery bed. Well decomposed FYM was thoroughly mixed with pulverized soil while no chemical fertilizer was used. Each nursery beds were prepared maintaining 1.2 meter length and 1 meter width.

3.4.2.1 Seed rate and sowing

Seeds were sown @ 50 kg ha^{-1} for each cultivar. Seeds were soaked for 24 hours and were evenly broadcasted in well levelled nursery bed. Then rice seed was covered with sallow layer of pulverized soil. Finally, nursery bed was covered by green mulching of Bakaino plant for 5 days for protecting from birds. Slight Irrigation (sprinkler) was provided after sowing to ensure germination.

3.4.2.2 Uprooting of seedlings

Light irrigation through pipe was given 3 hour before uprooting for easier uprooting of seedling. Seedlings were uprooted manually just before land preparation.

3.4.3 Land preparation

The experimental field was ploughed criss-cross twice by using tractor and major weeds were removed seven days before transplanting. There after wet ploughing was done twice by bullock drawn local plough followed by puddling.

3.4.4 Manure and fertilizer application

FYM @ 6t ha^{-1} was applied at the time of first ploughing and it was incorporated in to the soil. N, P_2O_5 and K_2O were applied @ 80:40:30 kg ha^{-1} through urea (46% N), DAP (18% N and 46% P_2O_5) and MOP (60% K_2O). Half dose of Nitrogen, full dose of Phosphorus and Potash was applied during final land preparation as basal dose; while remaining N was applied in two split doses, one at active tillering stage (35 DAT) and another at panicle initiation stage (55 DAT) for all treatments.

3.4.5 Transplanting / gap filling

The 22-days old seedlings were transplanted in plots with two-three seedlings / hill maintaining 20 cm × 20 cm row to row and plant to plant distance. Seedlings were transplanted on July 15, July 25, August 4, and August 14 at 10 days interval. Gap fillings were done after a week of rice transplanting to maintain the desired plant population in the experimental plots.

3.4.6 Weed management

Herbicide was not applied to control weed since puddling was followed properly. One hand weeding operations was done at 30 days after transplanting (DAT) to reduce the competition between weeds and crop for nutrients, spaces light and moisture. Second light weeding was done at 45 DAT where weed density was found high.

3.4.7 Plant protection measures

Severe infestation of termites was seen during earlier stages (20-25 DAT) of crop growth in all experimented plots. The infestation was initiated from roots and gradually increases up to the inner side of stem resulting death of several tillers and finally the whole plant. A Chlorpyriphos 10 G granule @ 7.5 kg ha-1 was applied 3 times at 5 days interval.

3.4.8 Water management

Irrigation was applied only for puddling operation through motor operated pump from nearby channel and maintained rainfed entirely after transplanting to harvesting. Bund of 0.5m height was made between individual plots to stagnate the rain water.

3.4.9 Harvesting and threshing

The crop from the net plot area was harvested manually with the help of sickles. Harvested plants were left *in-situ* in the field for 3 days for sun drying. Thereafter, small handy bundles were tied and threshing was done manually. The grains were cleaned by winnowing and weighted at their exact moisture content. Before threshing total weight of above ground biomass was taken from net plot as biological yield.

3.5 Observations recorded in rice

3.5.1 Phonological observations

Ten hills were marked randomly from net plot area for taking phonological observations. For deciding calendar days required for attaining phonological stages (panicle initiation, booting, heading, flowering, milking, hard dough and physiological maturity), approximately 75% attainment of each stage was supposed to be completion of that particular stage. And the data recorded for each stage were expressed as days after sowing (DAS).

3.5.2 Growing degree days (GDD)

For estimating GDD and heat use efficiency, maximum and minimum temperature recorded during the experimental period was used. According to Rajput *et al.* (1987);

$$\text{Growing degree days (GDD)} = \sum_{i=1}^{n}\{\frac{(\text{Tmax} + \text{Tmin})}{2} - \text{Tb}\}$$

Where, Tmax and Tmin are maximum and minimum temperatures of the day, respectively. And Tb is the base temperature for rice crop which is 10^0C. i.e below this temperature, there is no crop growth.

3.5.3 Heat use efficiency (HUE)

Heat is one of component that influence directly to the physiological activities of the plant. Heat use efficiency is directly related with grain yield, other growth factors such as moisture remaining constant.

According to Rajput *et al.* (1987); HUE for grain yield was obtained as;

$$\text{Heat use efficiency (HUE)} = \frac{\text{Grain yield}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Accumulated heat units °C}}$$

3.5.4 Biometrical observations

3.5.4.1 Plant height (cm)

Randomly selected and tagged 10 plants from different rows other than border row and destructive row were used for the measurement of plant height at an interval of 15 days from 30 DAT up to harvesting. The average of 10 plant height was used for statistical analysis. It was measured from base to tip of the upper leaves or the tip of panicle, whichever is longer.

3.5.4.2 Number of tillers per square meter

Numbers of leaves were counted from randomly selected 10 plants at 15 days interval from 30 days after transplanting.

Tillers from randomly selected 10 hills in each growing stage were counted and average tiller per plant was calculated. Similarly tiller per m^2 was calculated form same value. Main stem was also included to calculate the total tillers per hill.

3.5.4.3 Leaf area index (LAI)

Leaf area of the functional leaves was taken at 15 days interval from 30 DAT to 75 DAT. Destructive sample was used for leaf area measurement. The leaf area was measured by Automated Leaf Area Meter. The leaf area so obtained was then used to calculate the leaf area index.

Leaf area index (LAI) = Leaf area (cm^{-2}) / Ground area (cm^{-2})

3.5.4.4 Above ground dry matter (AGDM)

Two destructive samples (hills) were taken randomly from the destructive rows of each experimental plot for the growth analysis i.e. calculating Above Ground Dry Matter (AGDM) from 30 DAT up to 75 DAT at 15 days interval. The samples excluding roots were dried at a temperature of 65 ^{0}C in hot air oven for 72 hours. These dry matters resulted were used to calculate the AGDM (g m^{-2}).

3.5.4.5 Crop growth rate (CGR)

The dry matter accumulation of the crop per unit land area in a unit time is referred to crop growth rate (CGR), expressed as g m^{-2} day^{-1}. The AGDM (g m^{-2}) calculated for each plots at different growth stages were used to obtain the CGR (g m^{-2} day^{-}1) during the sampling intervals by using the formula given by Brown (1984).

$$\text{Crop growth rate (CGR)} = \frac{W2-W1}{SA\ (T2-T1)}$$

Where, W1 and W2 are AGDM in gram at the time T1 and T2, respectively. And SA is Area occupied by the plant at each sampling.

3.5.5 Yield attributing characters of rice

3.5.5.1 Number of effective tillers per square meter

Number of effective tillers m^{-2} was calculated for each plot just before harvesting the crop.

3.5.5.2 Number of grains per panicle

Number of grains panicle$^{\mathbf{-1}}$ was manually counted and weighted in electronic balance by taking the grains from 10 panicles. At the same time, numbers of filled and unfilled grains were counted to determine the sterility percentage.

3.5.5.3 Grain sterility percentage

Not all the grains present in the panicle are filled. Number of unfilled grains in a panicle depends on genotype and growing environment. Percentage of empty grains is determined by air temperature during the critical growing stages, namely at the time of meiosis (9-12 days before flowering) and flowering (Shihua *et al.,* 1991). Very cold and hot temperature during meiosis or at flowering causes high sterility of grains.

Total number of grains and unfilled grains panicle^{-1} was used to calculate sterility percentage as per given formula;

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

3.5.5.4 Thousand grains weight (Test weight)

Thousand grains were selected randomly from the grain yield of each plot and weighed with the help of electronic balance at about 12% moisture content. The test weight is expressed in gram.

3.5.6 Grain and biomass yield

Biomass yield including grain yield was taken after harvesting from the net plot.. After threshing and winnowing, grain yield obtained from net harvested area of 3.64 m^2 from each plot was measured at their respective moisture content. 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).

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

Where, MC is the moisture content in percentage of the grains at the time of weighing. The straw obtained from net plot area (3.64 m^2) of each plots were sun dried for 3-4 days and weighed. The yields so obtained were translated into ton per hectare.

3.5.7 Harvest index (HI)

Harvest index is the ratio of grain yield and total above ground biomass which indicates the efficiency of plant to assimilate partition to the economic parts (eg. rice grain). Higher harvest index means plant is capable to deposit assimilates having economic importance from the source (leaf, leaf sheath, stem, flag leaf) to the panicle (sink) specially grain in case of cereals.

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

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield}}{(\text{Grain yield} + \text{straw yield})}$$

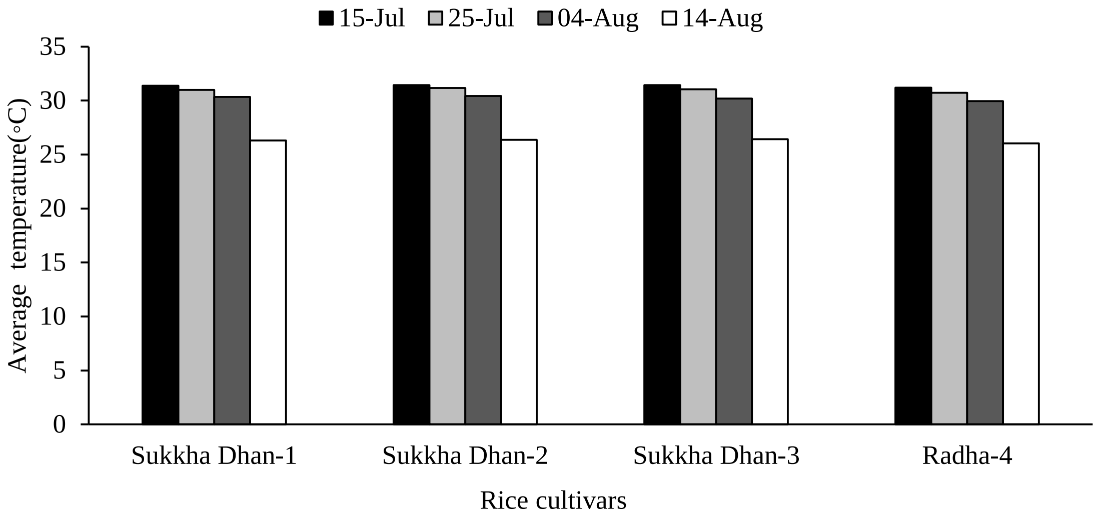

Figure 6. Average temperature received by various rice cultivars under different transplanting dates at Dhobadi, Nawalparasi, 2012

3.6 Statistical analysis

All the recorded data were subjected to factors and variance analysis. Mean separation was performed by Duncan's Multiple Range Test (DMRT) at 5% significance level, as suggested by Gomez and Gomez (1984). A simple correlation and regression analysis was run between selected parameters. Microsoft word 2007 was used for word processing; MS excels for tables, graphs, and simple statistical analysis. MSTAT-C Microsoft computer program was used for statistical analysis and SPSS was used for the correlation analysis. ANOVA was done to test the significance difference for each parameter.

4 RESULTS AND DISCUSSION

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

4.1 Effect of transplanting dates and cultivars on phonological stages of rice

The day's interval between rice sowing and panicle initiation, booting, heading, flowering, dough and maturity stages were observed under different transplanting dates and cultivars of drought tolerant rice.

Table 3. Effect of transplanting dates and cultivars on phonological stages of rice at Dhobadhi, Nawalparasi, 2012

Treatments	Phonological stages (DAS)						
	PI	Booting	Heading	Flowering	Milking	Hard dough	Maturity
Transplanting dates							
July 15	53[a]	66[a]	76[b]	79[a]	86[a]	97[a]	106[a]
July 25	53[a]	68[a]	77[a]	79[a]	86[a]	98[a]	104[b]
August 4	52[b]	66[a]	75[b]	78[a]	84[b]	97[a]	104[b]
August 14	49[c]	60[b]	72[c]	75[b]	81[c]	91[b]	101[c]
SEM (±)	0.17	0.57	0.36	0.28	0.44	0.48	0.32
LSD (p=0.05)	0.59	1.98	1.25	0.98	1.51	1.66	1.10
Cultivars							
Sukkha Dhan-1	50[c]	64[c]	72[c]	75[b]	82[b]	94[b]	103[b]
Sukkha Dhan-2	50[c]	62[d]	72[c]	75[b]	82[b]	93[b]	102[b]
Sukkha Dhan-3	52[b]	65[b]	74[b]	76[b]	83[b]	94[b]	103[b]
Radha -4	55[a]	69[a]	81[a]	85[a]	90[a]	101[a]	108[a]
SEM (±)	0.15	0.30	0.22	0.42	0.35	0.45	0.57
LSD (p=0.05)	0.45	0.88	0.63	1.22	1.01	1.32	1.68
CV (%)	1.03	1.61	1.00	1.87	1.42	1.64	1.92
Grand Mean	52	65	75	78	84	96	104

DAS=Days After Sowing; PI= Panicle Initiation; Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

4.1.1 Panicle initiation stage (PI)

The panicle initiation stage begins when the primordial of the panicle has differentiated and becomes visible. In a short duration cultivar (105 days from seed to maturity), the panicle primordial starts to differentiate at about 40 days after seeding and becomes visible 11 days later as a white feathery cone 1.0-1.5 mm in length (De Datta, 1981).

The time interval between seed sowing and Panicle initiation was significantly influenced by transplanting dates and cultivars (Table 3). The time taken for reaching PI stage ranged from 49 to 53 DAS among transplanting dates and 50 to 55 DAS among cultivars. The average time took to reach at PI stage was observed 52 DAS in the experiment. Days to PI recorded under first transplanting date (July 15) and second transplanting date (July 25) were statistically similar (53 DAS). And the days required to PI was found to be decrease for third (August 4) and last (August 14) transplanting dates which were 52 and 49 DAS, respectively.

In case of cultivars, Radha-4 took more time (55 DAS) to reach at PI stage (Table 3). Whereas Sukkha Dhan-1 and Sukkha Dhan-2 cultivars required less time for attaining PI stage with statistically at par value (50 DAS).

Interaction effect between transplanting dates and cultivars were found significant on PI stage (Appendix 15). Cultivar Radha-4 transplanted on July 25 took longest duration (57 DAS) and Sukkha Dhan-1 transplanted on August 14 required shortest times (47 DAS) to reach at PI stage. Relatively long duration cultivar (Radha-4) took little more time to reach PI stage as compare to short duration cultivars (Sukkha cultivars) for all transplanting dates.

4.1.2 Booting stage

This is the stage at which the sheath of the flag leaf shows some swelling and it is generally occurs two weeks (12-18 days) after panicle initiation stage.

The booting stage was also found significantly influenced by transplanting dates and cultivars (Table 3).The time taken for attaining booting stage ranged from 60 - 68 DAS for transplanting dates and 62 - 69 DAS for cultivars. The average time required to reach at booting stage for rice cultivars was recorded 65 DAS. The calendar days required to attain this stage for earlier three transplanting dates were found statistically similar being maximum for July 25 transplanted rice i.e. 68 DAS. Whereas the August 14 transplanted rice showed shortest time (60 DAS) to reach at booting stage.

While, among cultivars, Radha-4 took maximum time (69 DAS) and Sukkha Dhan-2 took minimum time (62 DAS) to came at booting stage (Table 3).

Interaction effect between transplanting dates and cultivars were found significant on days to booting stage (Appendix 15). Radha-4 cultivar transplanted on July 15 and July 25 required more time (72 DAS for both dates) to reach at booting stage. Whereas Sukkha Dhan-3 transplanted on August 14 took minimum time (58 DAS) to reach this stage.

4.1.3 Heading stage

Booting stage is followed by the emergence of panicle tip (heading) out of the flag leaf sheath. Generally, heading starts three weeks after panicle initiation (Prasad, 1999). The time taken for attaining the heading stage ranged from 72-77 DAS among transplanting dates and 72-81 DAS among cultivars (Table 3). The average time required for the rice cultivars to reach heading stage was 75 DAS in the experiment. Maximum time (77 DAS) was taken for the rice transplanted on July 25 to reach at heading stage followed by July 15 and August 4 transplanted rice with statistically at par values. Whereas August 14 transplanted rice took shortest time (72 DAS) to reach at heading stage.

Whereas in case of cultivars, Radha-4 came into heading stage in longest time (81 DAS) and at significantly and Sukkha Dhan-1 and Sukkha Dhan-2 attained their heading stage at comparatively shorter duration (72 DAS for both cultivars) (Table 3).

The combined effect of transplanting dates and cultivars were found significant on days to heading (Appendix 15). Cultivar Radha-4, transplanted on July 25 took longest time (83 DAS) and Sukkha Dhan-1 transplanted on August 14 showed shortest time (69 DAS) to reach at this stage.

4.1.4 Flowering stage

Anthesis or flowering refers to a series of events between the opening and closing of the spikelet, lasting about 1-2.5 hours. It takes 7-10 days for all the spikelets within the same panicle to complete anthesis; most of the spikelets complete anthesis within 5 days. It takes about 15-20 days for all the spikelets of a crop to complete anthesis (Yoshida, 1981).

The time taken for flowering varied from 78-79 DAS for transplanting dates and 75-85 DAS among cultivars (Table 3). The average time taken for the rice cultivars to reach at flowering stage was found 78 DAS in the experiment. The rice transplanted on July 15 and July 25 reached into flowering stage at the same time (79 DAS) followed by August 4 transplanted rice with statistically at par value. Whereas August 14 transplanted rice took shortest time (75 DAS) for flowering.

The cultivars Sukkha Dhan-1, Sukkha Dhan-2 and Sukkha Dhan-3 have shorter durations from seeding to flowering i.e 75, 75 and 76 DAS, respectively. Whereas Radha-4 cultivar took longest time (85 DAS) for flowering (Table 3).

There was no significant interaction effect of transplanting dates and cultivars on days to flowering.

4.1.5 Milking stage

In this stage, the grain begins to fill with a milky material. The time taken for reaching milking stage varied from 81-86 DAS for transplanting dates and 82-90 DAS among cultivars (Table 3). The average time taken by the rice cultivars to reach this stage in the experiment was found 84 DAS. The July 15 and July 25 transplanted rice took maximum time (86 DAS for both dates) to reach this stage. Whereas August 14 transplanted rice showed shortest time (81 DAS) for reaching into milking stage.

The cultivars, Sukkha Dhan-1, Sukkha Dhan-2 and Sukkha Dhan-3 reached into milking stage at relatively shorter time i.e 82, 82 and 83 DAS, respectively. Whereas Radha-4 cultivar took longest time (90 DAS) to reach into milking stage (Table 3).

Days to milking stage was found significantly influenced by the combined effect of transplanting dates and cultivars (Appendix 15). July 25 transplanted Radha-4 cultivar showed maximum time (93 DAS) to reach at milking stage. Whereas August 14 transplanted Sukkha Dhan-1, Sukkha Dhan-2 and Sukkha Dhan-3 cultivars showed similar minimum time (80 DAS) to attend this stage among treatment combinations.

4.1.6 Hard dough stage

When ripening advances, thick milky liquid in grains become thicker and finally attains hard dough stage (Prasad, 1999).

The time taken to reach into hard dough stage varied from 91-98 DAS for transplanting dates and 93-101 DAS for cultivars (Table 3). On an average, at 96 DAS, rice cultivars attainded into dough stage in the experiment. The rice transplanted on earlier three dates; July 15, July 25 and August 4 required shorter durations i.e 97, 98 and 97 DAS, respectively to reach into hard dough stage. Whereas August 14 transplanted rice showed shortest duration (91 DAS) for reaching hard dough stage from time of sowing.

Among cultivars, Radha-4 attained its hard dough stage by taking maximum time (101 DAS). Whereas Sukkha Dhan-1, Sukkha Dhan-2 and Sukkha Dhan-3 took shorter time; 94, 93 and 94 DAS for reaching into hard dough stage, respectively (Table 3).

Days to hard dough stage was also found to be significantly influenced by the interaction of transplanting dates and cultivars (Appendix 15). Cultivar Radha-4 transplanted on August 4 required more time (103 DAS) and Sukkha Dhan-1 transplanted on August 14 required less time (88 DAS) to reach this stage.

4.1.7 Physiological maturity stage

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

The time taken for the rice crop to become physiologically mature was ranged from 101-106 DAS within transplanting dates and 102-108 DAS within cultivars. (Table 3) The mean time taken for the crop to reach at this stage was found 104 DAS in the experiment. The longest time (106 DAS) was taken by July 15 transplanted rice to become physiologically mature. And shortest time (101 DAS) was taken by August 14 transplanted rice to reach into this stage.

In case of cultivars, Sukkha Dhan-1, Sukkha Dhan-2 and Sukkha Dhan-3 took shorter durations; 103, 102, 103 DAS, respectively to become physiologically mature. Whereas Radha-4 became physiologically mature at longest time (108 DAS) (Table 3).

The interaction effect between transplanting dates and cultivars were found non-significant on days to physiological maturity.

This result agreed with the finding of Mannen *et al.* (2009) and Salam *et al.* (2004) who had mentioned that crop growth duration of the genotypes decreased with advancement of the planting date.

4.2 Growing degree days (GDD)

In the absence of extreme conditions such as unseasonal drought or disease, plants grow in a cumulative stepwise manner which is strongly influenced by the ambient temperature. Growing degree days take aspects of local weather into account and allow gardeners to predict the plants pace toward maturity. Growing degree day (GDD) is defined as the number of temperature degrees above a certain threshold base temperature, which varies among crop species. The base temperature is that temperature below which there is no plant growth.

Table 4. Accumulated growing degree days at phonological stages of drought tolerant rice as affected by transplanting dates and cultivars at Dhobadhi, Nawalparasi, 2012

Treatments	Growing degree days, ^{0}C day						
	PI	Booting	Heading	Flowering	Milking	Hard dough	Maturity
Transplanting dates							
July 15	1027[a]	1671[a]	1936[b]	2032[a]	2251[a]	2568[a]	2830[a]
July 25	1035[a]	1712[a]	1976[a]	2039[a]	2249[a]	2590[a]	2780[b]
August 4	1008[b]	1662[a]	1911[b]	2013[a]	2198[b]	2559[a]	2768[b]
August 14	941[c]	1487[b]	1834[c]	1911[b]	2098[c]	2390[b]	2689[c]
SEM (±)	3.52	17.00	10.61	8.55	12.89	14.24	9.02
LSD (p=0.05)	12.21	3.53	36.74	10.62	44.61	49.28	31.24
Cultivars							
Sukkha Dhan-1	973[c]	1586[c]	1843[c]	1926[b]	2132[b]	2488[b]	2748[b]
Sukkha Dhan-2	972[c]	1554[d]	1835[c]	1931[b]	2134[b]	2454[b]	2703[b]
Sukkha Dhan-3	1008[b]	1639[b]	1887[b]	1936[b]	2161[b]	2485[b]	2734[b]
Radha-4	1057[a]	1753[a]	2093[a]	2201[a]	2367[a]	2681[a]	2881[a]
SEM (±)	3.10	8.80	6.30	12.46	10.05	13.15	17.05
LSD (p=0.05)	9.05	25.69	18.42	36.37	29.34	38.39	49.76
CV (%)	1.07	1.87	1.14	2.16	1.58	1.80	2.13
Grand Mean	1002.67	1633.03	1914.44	1998.65	2198.65	2526.99	2766.56

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

It was observed that the effect of transplanting dates and cultivars on heat unit (GDD) was significant at all the phonological stages (Table 4). The accumulated GDD decreased gradually for each delay in transplanting (i.e. sowing). The crop sown on July 25 accumulated maximum GDD for all phonological stages except milking and maturity stages; for which July 15 transplanted rice accumulated more heat. While the requirement of heat units (GDD) was lower for August 14 transplanted rice for all phonological stages. This was due to the shorter time taken to reach all the phonological stages under August 14 transplanted rice. Highest GDD (2830 ^{0}C) was accumulated at the maturity stage of July 15 transplanted rice. Whereas August 14 transplanted rice attained its maturity stage at lowest GDD (2689 ^{0}C).

In case of cultivars, Radha-4 was found to accumulate comparatively more GDD for all phonological stages. Whereas Sukkha Dhan-1 and Sukkha Dhan-2 cultivars required relatively lower GDD for attaining all phonological stages (Table 4).

The interaction effect of transplanting dates and cultivars were found significant on accumulated GDD at phonological stages of drought tolerant rice except flowering and physiological maturity stages (Appendix 16). Cultivar Radha-4 transplanted on July 25 accumulated higher GDD (^{0}C) at phonological stages such as PI (1100 ^{0}C), heading (2159 ^{0}C) and milking (2460 ^{0}C). Whereas same and higher GDD (1823 ^{0}C) was found in booting stage of Radha-4 cultivar transplanted on July 15 and July 25. Again Radha-4 cultivar, transplanted on August-4 gathered maximum GDD (2754 ^{0}C) at hard dough stage. While, cultivar Sukkha Dhan-1 transplanted on August 14 showed minimum GDD for PI (906.2 ^{0}C), heading (1746 ^{0}C) and hard dough stage (2313 ^{0}C). In booting stage, cultivar Sukkha Dhan-3 transplanted on August 14 acquired minimum GDD (1422 ^{0}C). In case of milking stage, Sukkha Dhan-1 and Sukkha Dhan-2 transplanted on August-14 accumulated same and minimum GDD (2061 ^{0}C).

Sandhu *et al.* (1999); Rajput *et al.* (1987); Paul and Sarker (2000); Rajput and Sastry (1985); Masnoi *et al.* (1990) and Bishnoi *et al.* (1995) also reported that requirement of GDD decreased for different phonological stages with delay in sowing. Finding of this research is also aligned with the result of Pandey *et al.* 2001 i.e. the GDD were higher under July 20 (3698 ^{0}C) and August 5 planted rice (3278 ^{0}c) than that of August 20 planting (3061 ^{0}C) at maturity. Thus, it may inferred that the GDD requirement differ from crop to crop and also from genotype to genotype (Pal *et al.*, 1996).

4.3 Heat use efficiency (HUE)

The HUE was calculated at the maturity stage of the crop. July 15 transplanted rice resulted comparatively higher heat use efficient (87%) followed by July 25 (77%) and August 4 (64%) transplanted rice (Table 10). whereas August 14 transplanting showed relatively lower HUE (11%).

In case of cultivars, Sukkha Dhan-2 proved as efficient heat user by consuming comparatively higher heat unit (71%) and Sukkha Dhan-3 was found lower heat use efficient (51%). received

4.4 Biometrical observations

4.4.1 Plant height

Plant height was significantly influenced by transplanting dates as well as cultivars for all observations taken (Table 5). The mean plant height varied from 50.64 cm (at 30 DAT) to 99.18 cm (at 90 DAT). The increase in height was found rapid while going from 30-60 DAT and increase was less after 60 DAT up to 90 DAT for all transplanting dates and cultivars. This is obvious because plant height increase rapidly at vegetative stage and become slow at reproductive stage because most of photosynthate starts accumulating in reproductive part at latter stage.

Table 5. Effect of transplanting dates and cultivars on plant height of rice at Dhobadhi , Nawalparasi, 2012

Treatments	Plant height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Transplanting dates					
July 15	55.69[a]	77.34[a]	97.57[a]	110.4[a]	115.6[a]
July 25	53.33[a]	68.82[b]	82.67[b]	94.79[b]	99.90[b]
August 4	50.51[b]	67.25[b]	82.66[b]	93.78[b]	98.18[b]
August 14	43.05[c]	56.99[c]	69.64[c]	79.16[c]	83.05[c]
SEM (±)	0.69	0.92	1.35	1.67	1.73
LSD (p=0.05)	2.39	3.20	4.68	5.78	5.98
Cultivars					
Sukkha Dhan-1	50.72[c]	67.29[c]	82.82[c]	93.89[c]	98.40[c]
Sukkha Dhan-2	51.82[b]	69.79[b]	86.20[b]	98.45[b]	103.3[b]
Sukkha Dhan-3	53.21[a]	71.86[a]	88.87[a]	102.1[a]	107.3[a]
Radha -4	46.82[d]	61.47[d]	74.64[d]	83.67[d]	87.67[d]
SEM (±)	0.28	0.34	0.63	0.66	0.68
LSD (p=0.05)	0.81	0.98	1.84	1.92	1.98
CV (%)	1.89	1.72	2.62	2.41	2.36
Grand Mean	50.64	67.60	83.13	94.53	99.18

DAT=Days After Transplanting: Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Plant heights were observed maximum on July 15 transplanted rice for all observations taken. Whereas minimum plant heights were recorded on August 14 transplanted rice for all observations. These minimum plant heights were due to insufficient rainfall and unfavourable temperature during the crop growing period, creating severe drought in earlier period when tillering and vegetative growth supposed to be faster. At 90 DAT, highest plant height (115.6 cm) was recorded on July 15 transplanted rice. Whereas at the same observation, August 14 transplanted rice resulted lowest plant height (83.05 cm).

In case of cultivars, Sukkha Dhan-3 showed higher plant heights for all the observations taken followed by that of Sukkha Dhan-2 and Sukkha Dhan-1 (Table 5). Whereas plant heights of Radha-4 were found significantly lower for all stages of observation taken.

The interaction effect between transplanting dates and cultivars on plant heights were found significant for all observation dates (Appendix 17). Sukkha Dhan-3 transplanted on July 15 has higher plant height for all observations taken. Whereas Radha-4 planted on August 14 has lower plant height for all observations among treatment combinations.

These results are in line with Khakwani *et al.* (2006) and Paraye and Kandalkar (1994) who reported that plant height is significantly affected by sowing dates. Saikia *et al.* (1989); Mannan *et al.* (2009) and Gravois and Helms (1998) reported that early sowing of rice produced taller plants than delayed sowing.

4.4.2 Number of tillers per square meter

The number of tillers per square metre was significantly influenced by transplanting dates for all observations and by cultivars for all observations except 75 DAT (Table 6). The mean number of tillers m^{-2} varied from 152.3 (at 30 DAT) to 206.33 (at 90 DAT). The number of tillers m^{-2} was observed to be increased rapidly from 30 DAT up to 60 DAT for all transplanting dates and cultivars. This trend was seen to be decreased when going towards later stages (75 DAT and 90 DAT) for all transplanting dates and cultivars.

Table 6. Effect of transplanting dates and cultivars on number of tillers per square meter of rice at Dhobadhi, Nawalparasi, 2012

Treatments	Number of tillers m^{-2}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Transplanting dates					
July 15	161.00[a]	236.60[b]	253.70[a]	237.40[a]	214.40[a]
July 25	160.40[a]	259.90[a]	250.10[a]	240.30[a]	212.50[a]
August 4	158.60[a]	210.90[c]	247.10[a]	232.50[a]	206.00[a]
August 14	129.20[b]	198.60[d]	208.20[b]	200.10[b]	192.40[b]
SEM (±)	3.33	2.22	2.17	2.89	2.51
LSD (p=0.05)	11.53	7.67	7.52	9.99	8.72
Cultivars					
Sukkha Dhan-1	172.90[a]	236.00[a]	228.20[c]	223.34	208.40[ab]
Sukkha Dhan-2	152.00[b]	214.00[c]	234.40[c]	226.42	210.90[a]
Sukkha Dhan-3	151.90[b]	233.90[a]	241.50[b]	225.78	200.30[c]
Radha -4	132.30[c]	222.10[b]	255.00[a]	234.76	205.80[b]
SEM (±)	1.95	1.75	2.45	4.5	1.35
LSD (p=0.05)	5.70	5.10	7.15	N.S	3.96
CV (%)	4.44	2.67	3.54	6.86	2.28
Grand Mean	152.3	226.5	239.8	227.57	206.33

DAT =Days After Transplanting; NS=Non Significant; Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

The number of tillers m^{-2} was observed to be decreased as the transplanting was delayed in most of the observations. But the numbers of tillers m-2 of earlier three transplanting dates were found statistically at par but was significantly more from that under August 14 transplanting. While, August 14 transplanted rice gave significantly lower number of tillers m^{-2} in all observations. At 90 DAT, the number of tillers m^{-2} varied from 192.40 (August 14 transplanted rice) to 214.40 (July 15 transplanted rice). More number of tillers m^{-2} of earlier planted rice was due to longer period for their vegetative growth as compared to those plated later. Whereas fewer numbers of tillers m^{-2} observed in August 14 transplanted rice was due to severe drought condition over the growing period.

In case of cultivar, Sukkha Dhan-2 showed highest number of tillers m^{-2} (210.9) and Sukkha Dhan-3 showed lowest number of tillers m^{-2} (200.3) at 90 DAT (Table 6).

There was significant interaction effect between transplanting dates and cultivars on number of tillers m^{-2} at 30, 45, 60 and 75 DAT (Appendix 18). Radha-4 transplanted on July 25 gave maximum number of tillers m^{-2} (276.3) at 75 DAT. Whereas the same cultivar transplanted on August 14 gave minimum number of tillers m^{-2} (193) at the same observation.

Gangwar and Sharma (1997) observed more number of tillers in early transplanting than in late transplanting. The difference in tiller production among cultivars may be attributed to varietal characters (Chandrashekhar *et al.*, 2001) as well as soil moisture constant in the field. Singh and Jain (2000) observed that tiller production increased sharply from active tillering to panicle initiation stage and declined gradually toward flowering and remained almost constant during ripening phase.

4.4.3 Leaf area index (LAI)

The leaves of a plant are normally its main organ of photosynthesis. The total area of leaves per unit ground area is called leaf area index (LAI). It has been proposed by Watson (1947) as the best measure of the capacity of a crop producing dry matter. Ghosh and Singh (1998) observed a strong and positive correlation of LAI with grain yield. They stated that LAI at flowering showed yield variation of 79% and delay in planting by 15 days drastically affected LAI of rice.

Table 7. Effect of transplanting dates and cultivars on Leaf Area Index (LAI) of rice at Dhobadi, Nawalparasi, 2012

Treatments	Leaf Area Index (LAI)			
	30 DAT	45 DAT	60 DAT	75 DAT
Transplanting dates				
July 15	3.05	3.79[a]	4.48[a]	3.52
July 25	2.22	2.78[b]	2.99[b]	2.65
August 4	2.79	3.43[ab]	3.92[ab]	3.12
August 14	2.06	2.46[b]	2.75[b]	2.28
SEM (±)	0.31	0.27	0.36	0.26
LSD (p=0.05)	N.S	0.95	1.25	N.S
Cultivars				
Sukkha Dhan-1	2.42	3.03	3.56	2.76
Sukkha Dhan-2	2.46	3.03	3.50	2.80
Sukkha Dhan-3	2.72	3.30	3.72	3.03
Radha,m-4	2.54	3.11	3.36	2.98
SEM (±)	0.18	0.21	0.27	0.20
LSD (p=0.05)	N.S	N.S	N.S	N.S
CV %	25.31	23.06	26.71	24.96
Grand Mean	2.53	3.12	3.54	2.89

DAT=Days After Transplanting; NS=Non Significant; Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

LAI was found to be influenced by transplanting dates at 45 and 60 DAT only. Whereas there was not significant effect of cultivars on LAI for any observations (Table 7). Similarly, there was not significant interaction effect between transplanting dates and cultivars on LAI at any observations taken. The mean LAI increased gradually when going from 30 DAT (2.53) to 60 DAT (3.54). After that, the LAI was found decreased (2.89) at 75 DAT.

July 15 transplanted rice showed comparatively higher LAI values in all observations taken. Whereas August 14 transplanted rice showed comparatively lower LAI values in all observations taken. The increase in LAI was contributed by an increased in number of leaves and size of leaves. Whereas, the Lower values of LAI under August 14 transplanted rice might be due to fewer and smaller leaves as influenced by stunted growth of crop due to insufficient soil moisture.

Although there was not significant effect of cultivars on LAI, Sukkha Dhan-3 showed relatively more LAI among varieties.

Krishnan and Nayak (1997) reported that LAI decreased with delay in planting. Yamuda (1963) has mentioned that shorter duration of the vegetative phase of the crop leads to the presence of a much smaller leaf area at the time of flowering and the smaller LAI at the time of flowering becomes yield limiting. July 15 transplanted rice has LAI between 3-5 in all of the observations from 30 DAT to 75 DAT. Similarly all of the cultivars showed LAI value ranged from 3-4 at 45, 60 and 75 DAT. These findings are in line with that of Gardner *et al.* (1985); who wrote that an LAI of 3-5 is necessary for maximum dry matter production of most cultivated crops. Shin and Kwon (1985) reported that the green leaf area at 30 days after heading is positively correlated with grain weight.

4.4.4 Above ground dry matter (AGDM)

High production of total dry matter per unit area is the first prerequisite for high yield. The amount of dry matter production depends on effectiveness of photosynthesis of crop and furthermore, on plants whose vital activities are functioning effectively. The total yield of dry matter is the total amount of dry matter produced, less the photosynthates used for respiration.

Table 8. Above ground dry matter of rice as affected by transplanting dates and cultivars at Dhobadi, Nawalparasi, 2012

Treatments	Above ground dry matter (g m^{-2})			
	30 DAT	45 DAT	60 DAT	75 DAT
Transplanting dates				
July 15	91.07[a]	237.50[a]	442.20[a]	581.60[a]
July 25	71.29[b]	222.40[b]	400.10[b]	471.00[b]
August 4	92.14[a]	231.40[a]	364.60[c]	440.60[c]
August 14	78.39[b]	213.90[c]	293.80[d]	321.00[d]
SEM (±)	2.43	2.26	6.79	3.00
LSD (p=0.05)	8.40	7.84	23.51	10.37
Cultivars				
Sukkha Dhan-1	83.66	222.90[c]	367.32	453.40[b]
Sukkha Dhan-2	82.04	224.20[bc]	369.36	458.70[b]
Sukkha Dhan-3	82.59	229.80[a]	373.71	431.10[c]
Radha-4	84.59	228.30[ab]	390.28	471.00[a]
SEM (±)	1.35	1.69	6.27	4.16
LSD (p=0.05)	N.S	4.93	N.S	12.13
CV (%)	5.62	2.58	5.79	3.17
Grand Mean	83.22	226.30	375.17	453.55

DAT=Days After Transplanting; N.S= Non Significant. Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of confidence

AGDM at 45 and 75 DAT only were significantly influenced by cultivars (Table 8). Mean value for AGDM ranged from 83.22 g m^{-2} at 30 DAT to 453.55 g m^{-2} at 75 DAT. The transplanting dates produced significant effect on AGDM for all observations taken. AGDM was seen higher at 60 and 75 DAT on July 15 transplanted rice, which tends to decreased with delayed in transplanting. Whereas August 14 transplanted rice gave lower AGDM for all observational stages. At 75 DAT, July 15 transplanted rice showed the highest AGDM (581.60 g m^{-2}) followed by July 25 and August 4 transplanted rice. And August 14 transplanted rice gave the lowest AGDM (321 g m^{-2}) at 75 DAT.

In case of cultivar, Radha-4 gave the highest AGDM (471 g m^{-2}) and Sukkha Dhan-3 gave the lowest AGDM (431.10 g m^{-2}) at 75 DAT. (Table 8).

Interaction effects between transplanting dates and cultivars were also found significant on AGDM (g m^{-2}) at 45, 60 and 75 DAT (Appendix 19). Sukkha Dhan-1 transplanted on July 15 has comparatively higher AGDM (587.40 g m^{-2}) at 75 DAT. Whereas Sukkha Dhan-1cultivar transplanted on August 14 gave statistically lower AGDM (314.60 g m^{-2}) at 75 DAT.

This result was similar with that of Pandey *et al.,* (2001) who indicated that dry matter goes on decreasing as the planting is delayed beyond the optimum time of transplanting.

4.4.5 Crop growth rate (CGR)

The dry matter accumulation of the crop per unit land area in unit of time is referred to CGR, expressed as g m^{-2} day^{-1}. CGR of 20 g m^{-2} day^{-1} is considered achievable for most of the crops particularly C_3 types. Whereas CGR of 30 g m^{-2} day^{-1} is obtainable from C_4 types such as maize (Gardner *et al.*, 1985).

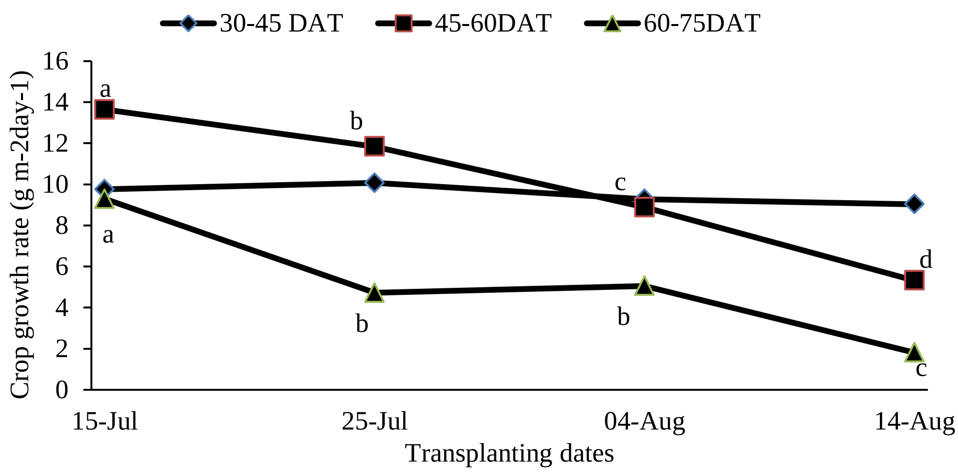

Figure 7. Effect of transplanting dates on crop growth rate of rice at Dhobadi, Nawalparasi, 2012

CGR was found significantly influenced by transplanting dates during 45-60 and 60-75 DAT (Figure 7). In the experiment, average crop growth rate recorded during 30-45, 45-60 and 60-75 DAT were 9.53, 9.92 and 5.22 g m^{-2} day^{-1}, respectively. July 15 transplanted rice showed the higher crop growth rates of 13.64 and 9.29 g m^{-2} day^{-1} during 45-60 and 60-75 DAT, respectively. Whereas August 14 transplanted rice gave comparatively lower CGR for all the observations.

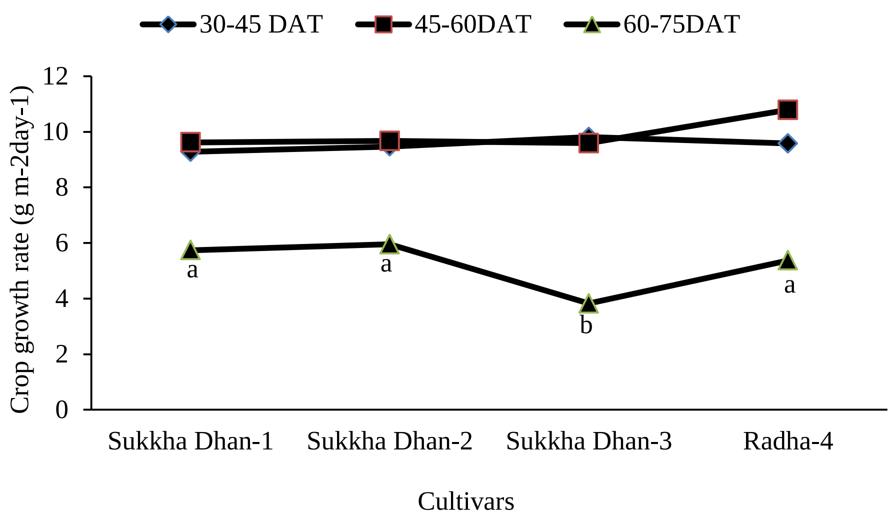

Figure 8. Effect of cultivars on crop growth rate of rice at Dhobadi, Nawalparasi, 2012

The CGR was significantly influenced by cultivars only during 60-75 DAT (Figure 8). Sukkha Dhan-2 showed maximum CGR (5.95 g m^{-2} day^{-1}) and Sukkha Dhan-3 showed minimum CGR (3.82 g m^{-2} day^{-1}) during 60-75 DAT.

Interaction effect of transplanting dates and cultivars also influenced CGR (g m^{-2} day^{-1}) during all observations (Appendix 20). During 30-45 DAT, Radha-4 cultivar transplanted on July 25 gave statistically higher (10.61 g m^{-2} day^{-1}) CGR. Whereas Radha-4 cultivar transplanted on August 4 gave comparatively lower (8.51 g m^{-2} day^{-1}) CGR during 30-45 DAT. But Radha-4 cultivar transplanted on August 4 has comparatively higher (15.17 g m^{-2} day^{-1}) CGR during 45-60 DAT. whereas Sukkha Dhan-2 rice transplanted on August 4 gave comparatively lower (4.39 g m^{-2} day^{-1}) CGR at 45-60 DAT.

Again Sukkha Dhan-1 cultivar transplanted on July 15 has comparatively higher (10.71 g m^{-2} day^{-1}) and Sukkha Dhan-2 cultivar transplanted on August 14 gave comparatively lower (1.11 g m^{-2} day^{-1}) CGR during 60-75 DAT.

4.5 Effect of transplanting dates and cultivars on yield attributing traits of rice

4.5.1 Effective tillers per square meter

Among yield attributing components, productive tillers are very important because the final yield is mainly a function of the number of tillers bearing panicles per unit area. The effective tillers m^{-2} was not influenced by transplanting dates significantly. There was significant effect of cultivars on effective number of tillers m^{-2} (Table 9). Average effective tillers m^{-2} recorded in the experiment was 193.52.

Among cultivars, Sukkha Dhan-2 showed comparatively higher effective tillers m^{-2} (203.90) (Table 9). Whereas comparatively lower (187.40) effective tillers m^{-2} was given by Sukkha Dhan-3. Significant difference in effective tillers m^{-2} among the cultivars might be due to their genotypic characteristic. The difference in tiller production among cultivars may be attributed to varietal characters (Chandrashekhar *et al.*, 2001).

Interaction effect between transplanting dates and cultivars was found non-significant on number of tillers per square meter. However, July 25 transplanted rice showed maximum (207.47) number of tillers m^{-2} and August 14 transplanted rice has minimum (177.91) tillers number m^{-2}.

Table 9. Yield attributing traits of rice as influenced by transplanting dates and cultivars at Dhobadi , Nawalparasi, 2012

Treatment	Yield Attributes				
	Effective tillers m^{-2}	Total grains $panicle^{-1}$	Filled grains $panicle^{-1}$	Sterility percentage	Test weight (g)
Transplanting dates					
July 15	183.66	134.90[a]	110.60[a]	18.29[b]	23.84[a]
July 25	207.47	135.50[a]	108.70[a]	19.97[b]	23.81[a]
August 4	205.06	135.40[a]	107.20[a]	21.03[b]	22.35[ab]
August 14	177.91	124.50[b]	91.63[b]	26.70[a]	21.02[b]
SEM (±)	12.67	1.40	1.83	0.77	0.53
LSD (p=0.05)	N.S	4.86	6.34	2.66	1.84
Cultivars					
Sukkha Dhan-1	192.80[ab]	140.40[a]	113.60[a]	19.30[b]	23.09
Sukkha Dhan-2	203.90[a]	139.10[a]	114.30[a]	17.90[b]	22.97
Sukkha Dhan-3	187.40[b]	125.20[b]	94.15[b]	24.99[a]	22.23
Radha-4	190.10[b]	125.70[b]	96.02[b]	23.80[a]	22.73
SEM (±)	4.08	2.64	2.74	0.60	0.55
LSD (p=0.05)	11.91	7.70	8.00	1.78	N.S
CV (%)	7.30	6.89	9.09	9.80	8.32
Grand Mean	193.52	132.59	104.52	21.50	22.75

N.S = Non Significant; Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

4.5.2 Number of total grains per panicle

Transplanting dates and cultivars significantly influenced the number of total grains panicle per panicle (Table 9). The average number of grains $panicle^{-1}$ was found 132.59. Rice transplanted on July 25 has higher (135.50) total grains panicle $^{-1}$. And the lowest (124.50) number of grains $panicle^{-1}$ was given by August 14 transplanted rice. Comparatively higher number of grains $panicle^{-1}$ in July 15, July 25 and August 4 transplanted rice might be due to comparatively higher effective tillers m^{-2} of rice transplanted on these days. Whereas fewer number of grains $panicle^{-1}$ on August 14 transplanted rice might be due to soil moisture stress during the tillering and grain filling period because of less rainfall at that time. Late transplanting, shortened the growth period of the plant which reduced the leaf area and leaf duration which ultimately reduce assimilate development thereby reducing number of grains panicle^{-1} than early transplanting.

In case of cultivar, comparatively higher (140.40) total grains panicle^{-1} was found in Sukkha Dhan-1 followed by Sukkha Dhan-2 with statistically at par value (Table 9). Whereas Sukkha Dhan-3 cultivar showed comparatively lower (125.20) total grains panicle^{-1} followed by Radha-4. The more filled grains panicle^{-1} in Sukkha Dhan-1 and Sukkha Dhan-2 might be due to their genotypic characteristics.

The interaction effect of transplanting dates and cultivars was found non-significant on total number of filled grains per panicle.

The results is in agreement with the findings of Shah and Bhurer (2005) who reported that more number of grains panicle^{-1} was obtained in the earlier transplanted rice and declined gradually in the successive transplanting dates. According to Biswas and Salokhe (2001) grains panicle^{-1} showed better response with early sowing.

4.5.3 Number of filled grains per panicle

Number of filled grains per panicle was significantly influenced by transplanting dates and cultivars (Table 9). Average number of filled grains panicle^{-1} was found 104.52 in the experiment. Maximum (110.6) number of filled grains panicle^{-1}was found on July 15 transplanted rice followed by July 25 and August 4 transplanted rice. Whereas August 14 transplanted rice gave the lowest (91.63) filled grains panicle^{-1}. This might be due to insufficient soil moisture during the later growth stages resulting inhibition of tillering and moisture stress in critical growth stages.

Among cultivars, Sukkha Dhan-2 showed maximum (114.30) number of filled grains panicle^{-1} (Table 9). Whereas Sukkha Dhan-3 gave minimum (94.15) number of filled grains panicle^{-1}.

The interaction effect between transplanting dates and cultivars was found non-significant.

4.5.4 Grain sterility percentage

The transplanting dates and cultivars influenced the grain sterility percentage significantly (Table 9). July 15 transplanted rice has minimum sterility percentage (18.29) and August 14 transplanted rice showed maximum sterility percentage (26.70). The average sterility percentage was found 21.50 in the experiment. Less sterility percentage of rice transplanted on July15 was due to more filled grains panicle^{-1} as favoured by sufficient rainfall and conducive temperature during the growing period. Whereas more sterility percentage of rice transplanted on August 14 was due to more unfilled grains panicle^{-1}, which might be due to insufficient soil moisture during late tillering and early reproductive period as a result of less rainfall at that time. Also the exposure of critical reproductive phases of rice plant to cold temperature and infestation of bugs during milking stage might increase grain sterility percentage in August 14 transplanted rice.

Among cultivars, minimum (17.90) sterility percentage was given by Sukkha Dhan-2 and maximum (24.99) was shown by Sukkha Dhan-3 (Table 9).

There was no significant interaction effect of transplanting dates and cultivars on grain sterility percentage.

4.5.5 Thousand grains weight (Test weight)

Only transplanting dates influenced the thousand grains weight significantly. (Table 9). The average test weight observed was 22.76 g in the experiment. Comparatively higher (23.84 g) test weight was found on July 15 transplanted rice followed by July 25 and August 4 transplanted rice. Higher test weight in earlier three dates of transplanting might be because of sufficient soil moisture available over the rice growing period along with conducive temperature for the crop growth. Whereas August 14 transplanted rice gave the minimum (21.02 g) test weight. The highest thousand grain weight of Super Basmati rice transplanted on July 11 was reported by Akram *et al.*, 2007.

Although there was no significant effect of cultivars on test weight, Sukkha Dhan-1 has relatively higher (23.09 g) test weight, followed by Sukkha Dhan-2. Whereas minimum (22.23 g) test weight was found in Sukkha Dhan-3. (Table 9).

Also there was no interaction effect of transplanting dates and cultivars on test weight of rice.

4.6 Effect of transplanting dates and cultivars on yield and harvest index

4.6.1 Grain yield

Grain yield is determined by the yield attributing traits of the crop. The yield of particular crop (cultivar) in a location is a combined effect of genetic makeup of the cultivar, growing environment and the crop management practices. Inherent character and yield potentialities of cultivars causes yield variation among the cultivars growing under same environment. Generally, level of management and growing environment modify the yield attributes thereby final yield.

Grain yield is a function of various yield attributing components, primarily productive tillers, number of grains per panicle and thousand grains weight etc. The grain yield of rice is determined by the assimilate deposited mainly in vegetative stage. Carbohydrates produced before heading mainly accumulate in the leaf sheath and stem and translocate to the panicles during grain filling (Fageria, 2007). Murata and Matsushima (1975) reported that the contribution of the carbohydrates produced before heading to the final grain yield appeared to be in the range of 20–40 %. Hence, about 70% of the grain yield is produced from the carbohydrates produced after heading and photosynthesis after heading is vital for yield sustainability.

Table 10. Effect of transplanting dates and cultivars on grain yield, straw yield, harvest index and heat use efficiency of rice at Dhobadi, Nawalparasi, 2012

Treatments	Yield, Harvest Index and Heat Use Efficiency (HUE)			
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index	HUE (%)
Transplanting Dates				
15-Jul	2.46[a]	6.65	0.26[a]	87
25-Jul	2.15[a]	7.21	0.22[a]	77
4-Aug	1.76[a]	6.54	0.21[a]	64
14-Aug	0.30[b]	4.39	0.07[a]	11
SEM (±)	0.29	0.98	0.02	
LSD (p=0.05)	1.015	N.S	N.S	
Cultivars				
Sukkha Dhan-1	1.67	6.29	0.20	62
Sukkha Dhan-2	1.94	5.93	0.22	71
Sukkha Dhan-3	1.48	5.52	0.19	51
Radha -4	1.58	7.05	0.15	55
SEM (±)	0.24	0.52	0.02	
LSD (p=0.05)	N.S	N.S	N.S	
CV (%)	49.63	28.87	31.65	
Grand Mean	1.67	6.20	0.19	

N.S = Non Significant. Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Effect of date of transplanting on grain yield was significant (Table 10). Maximum grain yield was obtained under July 15 transplanting (2.46 t ha^{-1}) while minimum grain yield was obtained under August 14 transplanting (0.30 t ha^{-1}). Grain yield obtained under July 15, July 25 and August 4 being statistically at par but was significantly superior over August 14 transplanting. The reduction in grain yield due to successive delay of 10 days from July 15 was to the extent of 12.6% and 28.6% respectively. However August 14 transplanting resulted 87.89% decrease in grain yield as compared to July 15 transplanting and the decrease was significant.

The effect of cultivar on grain yield was non-significant (Table 10). However, Sukkha Dhan-2 yielded highest (1.94 t ha^{-1}) and Sukkha Dhan-3 yielded lowest (1.48 t ha^{-1}). The grain yield could not be affected significantly due to the interaction between date of transplanting and cultivar (Appendix 21).

Maximum grain yield of July 15 transplanted rice may be due to more number of filled grains $panicle^{-1}$, less grain sterility percentage and more test wt. (g) and regular and sufficient rainfall after transplanting and throughout the growing period. Whereas the low yield of August 14 transplanted rice might be due to soil moisture stress during critical vegetative and reproductive growth stages. Also the infestation of termites during the early vegetative stage and the infestation of rice Gundhi bug during milking stage of grain resulted in to low yield. Relatively higher grain yield of Sukkha Dhan-2 may be due to more number of effective tillers, filled grains $panicle^{-1}$ and less sterility percentage as compare to that of other cultivars.

It is natural process that the crop which had taken more number of days from seeding to maturity might have a more vigorous and extensive root system, increased growth rate during vegetative growth, more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the spikelets and longer leaf area index during grain filling period (Diouf *et al*., 2000). So, this might be the possible reason to have high yields in earlier transplanting (Shah and Yadav, 2001).

The results were in conformity with the result of Vange and Obi (2009) who obtained highest yield from June 23 sowing (15^{th} July transplanting). Maximum yield from July 15 transplanting was mainly contributed by regular rainfall after transplanting. Aslam *et al.* (2010) reported that higher grain yield (4.04 t ha^{-1}) was recorded in July 15 transplanting. Higher grain yield recorded in crop planted during third week of June (July 15 transplanting) was ascribed to more number of effective tillers m^{-2}, optimum number of spikelets panicle^{-1} and higher thousand grains weight. The results of Singh *et al.* (1997) and Hong *et al.* (1996) are in line with these findings, who reported that yields were higher with early seeding than with late seeding. They also stated that major yield components were number of effective tillers, number of spikelets panicle^{-1} and thousand grain weight. Too early or too late planting causes yield reduction due to lower number of productive tillers and crop sterility. The result observed by Rosh *et al.* (1983) revealed the highest yield from 20th July transplanting and the lowest yield from 5th May and 5th August transplanting. Too early and late transplanting both reduced grain yield (Mannen *et al.,* 2009). Rakesh and Sharma (2004) found that delay in planting resulted in significant decrease in the number of productive tillers m^{-2} and ultimately the paddy yield.

Azhiri-Sigari *et al.* (2005) while studying different rice lines under the adverse climatic condition of rainfed lowland ecosystem to identify growth and development; the line, IR36 yielded the highest (2.55 t ha^{-1}). PSB Rc60 failed to produce any yield because of late panicle emergence (22-24 October). Fourteen dihaploid lines produced grains with the yield greatly varying from 0.27 t ha^{-1} in IR68586-CA-24 to 2.16 t ha^{-1} in IR68586-CA-20.

4.6.2 Straw yield

Straw yield was not found to be significantly influenced by transplanting dates and cultivars (Table 10). The average straw yield was found 6.20 t ha^{-1} in the experiment. Maximum straw yield was observed on July 25 transplanted rice, i.e 7.21 t ha^{-1} and minimum yield was found on rice transplanted on August 14, i.e. 4.386 t ha^{-1}. The higher straw yield in early planted crop may be due to longer vegetative growth period that produced higher amount of biomass than the late planted crops.

In case of cultivars, comparatively more (7.05 t ha^{-1}) straw yield was found in Radha-4 and relatively less yield was seen in Sukkha Dhan-3, i.e. 5.52 t ha^{-1}.

There was no significant interaction effect between transplanting dates and cultivars on straw yield.

4.6.3 Harvest index (HI)

There was no significant effect of transplanting dates and cultivars on harvest index (Table 10). The mean value for HI was found 0.19 in the experiment. However rice transplanted on July 15 has maximum (0.26) HI and that transplanted on August 14 gave minimum (0.07) HI.

Among the cultivars, Sukkha Dhan-2 gave comparatively higher HI (0.22) and Radha-4 showed relatively lower HI (0.15).

The harvest index was not found to be significantly influenced by the interaction effect of transplanting dates and cultivars.

4.7 Reduction in grain yield due to delayed transplanting

Among four transplanting dates, the best grain yield was recorded under July 15 transplanting. The reduction in grain yield due to successive delay of 10 days from July 15 was to the extent of 12.6 and 28.6% respectively. However, August 14 transplanting resulted 87.89% decrease in grain yield as compared to July 15 transplanting and the decrease was significant (Figure 9).

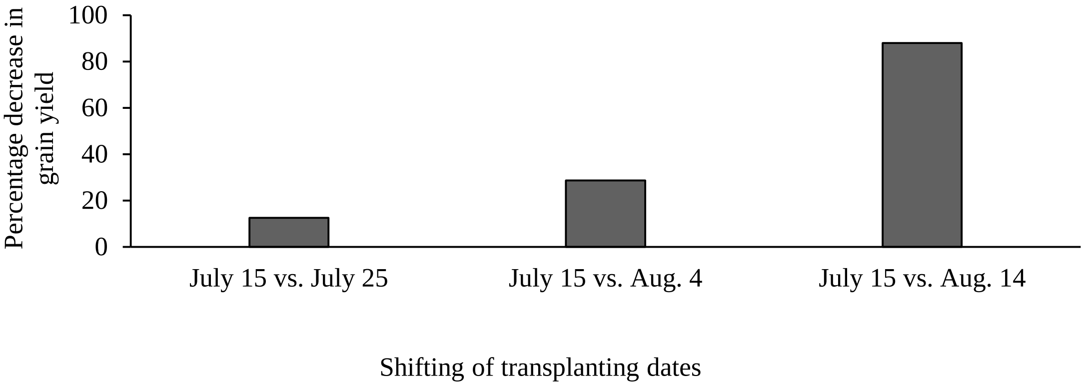

Figure 9. Percentage decrease in grain yield due to delay in transplanting of rice at Dhobadi, Nawalparasi, 2012

4.8 Correlation regression studies

To assess relationship between growth parameters, yield attributing traits and grain yield, simple correlation coefficients were worked out. The significant positive correlation were seen between grain yield and yield attributing traits like number of effective tillers m^{-2} (r= 0.516**), number of filled grains $panicle^{-1}$ (r= 3.91**) and test weight (r= 3.74**). Likewise, the relationship between grain yield and harvest index was also observed positively correlated and highly significant (r= 0.878**) (Appendix 22).

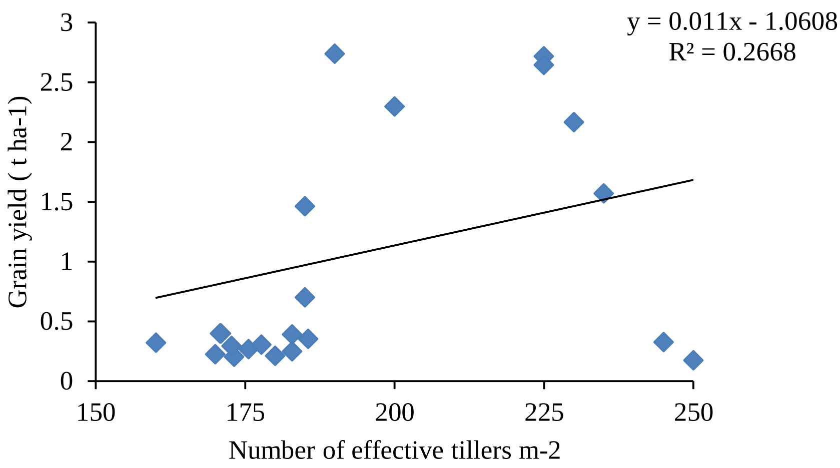

Figure 10. Relationship between grain yield and number of effective tillers per square meter of rice at Dhobadi, Nawalparasi, 2012

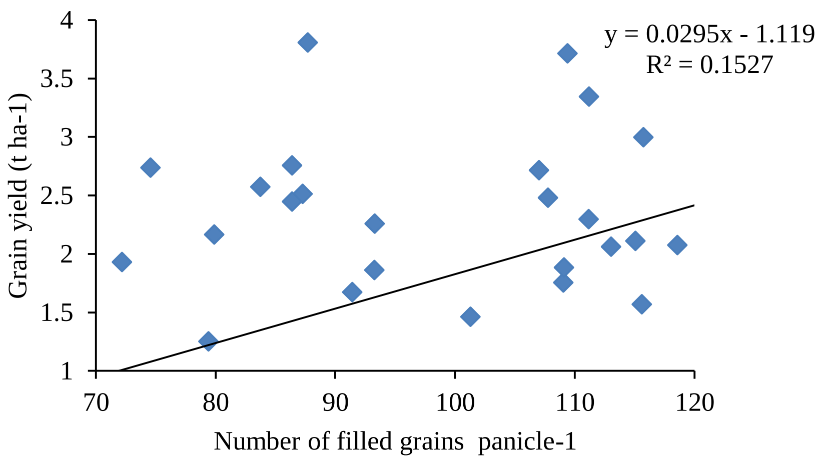

Figure 11. Relationship between grain yield and number of filled grains per panicle of rice at Dhobadi, Nawalparasi, 2012

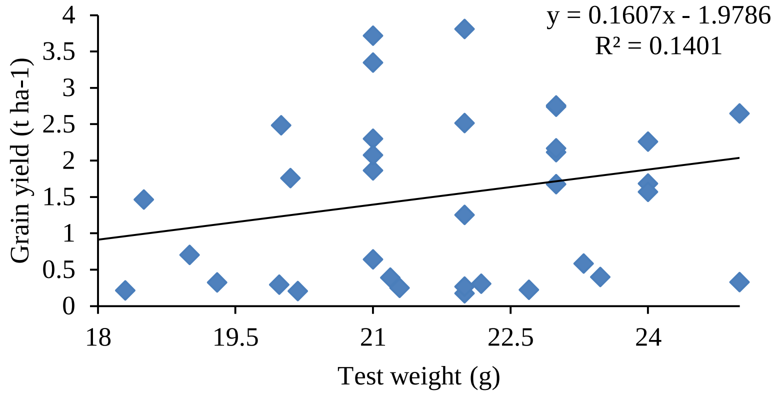

Figure 12. Relationship between grain yield and test weight of rice at Dhobadi, Nawalparasi, 2012

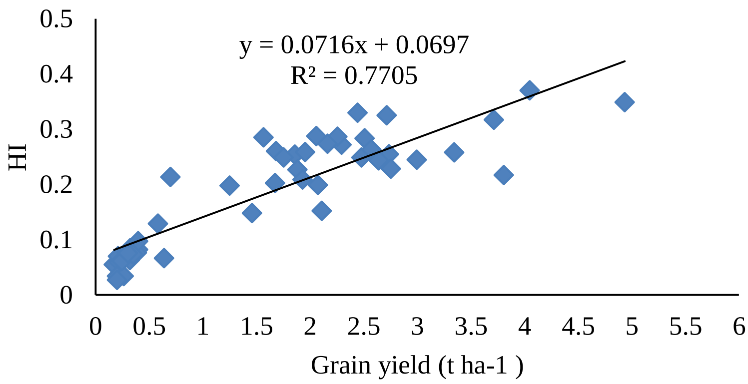

Figure 13. Relationship between grain yield and harvest index of rice at Dhobadi, Nawalparasi, 2012

The number of effective tillers m^{-2} contribute approximately 26.6% ($R^2 = 0.266$) on the grain yield. Whereas the remaining 74% increase in grain yield may be due to variables other than effective tillers m^{-2} (Figure 10). Similarly, approximately 15.2% ($R^2 = 0.152$) contribution was given by number of filled grains per panicle on grain yield (Figure 11). And the remaining 84.8% part was contributed by the variables other than filled grains per panicle. Again, test weight input about 14% ($R^2 = 0.14$) share on grain yield and the left over 86% increase in grain yield was due to other variables except test weight (Figure 12). Whereas, grain yield contributed about 77% ($R^2 = 0.77$) towards increase in the harvest index (Figure 13). And the remaining 23% contribution for increasing yield was given by the variables other than harvest index.

5 SUMMARY AND CONCLUSION

5.1 Summary

To find out the best transplanting dates and best cultivars from yield point of view, a field experiment was conducted at farmer's field in Dhobadi V.D.C, Nawalparasi during 2012. To carry out this experiment, four drought tolerant main season rice cultivars; Sukkha Dhan-1, Sukkha Dhan-2, Sukkha Dhan-3 and Radha-4 were transplanted under four different dates; July 15, July 25, August 4 and August 14 at 10 days interval. The treatment combinations were arranged in split-plot design i.e transplanting dates in main-plot and cultivars in sub-plot. The treatments were replicated three times in the experiment.

The total rainfall throughout the entire crop growing period (June to November) was observed 1960.40 mm. Whereas the mean weekly maximum temperature decreased from 38.28 ^oC (2^{nd} week of June) to 26.63 ^oC (Last week of November); and mean weekly minimum temperature reduced from 26.45 ^oC (1^{st} week of July) to 12.02 ^oC (Last week of November). The type of experimental soil was determined silt loam with acidic reaction (5.67). Soil organic matter (1.58%), total nitrogen (0.08%), available P_2O_5 (28.9 kg ha^{-1}) and available K_2O (185.7 kg ha^{-1}) was observed. In general, the fertility status of experimental soil was observed poor.

The time duration for attaining different phonological stages by the drought tolerant rice cultivars was significantly influenced by transplanting dates and cultivars. Interaction between transplanting dates and cultivars also influenced the days to Panicle Initiation (PI), booting, heading, milking and hard dough stage. The calendar days required for reaching maturity stage was highest (106 DAS) for rice transplanted on July 15. Whereas the days to maturity were seen lowest (101 DAS) for August 14 transplanted rice. Cultivar, Radha-4 took longer time to attain all phonological stages as compared to Sukkha cultivars.

Accumulated Growing Degree Days (GDD) received by rice cultivars was found significantly highest (2830 ^{o}C) for July 15 transplanted rice at maturity stage. Whereas August 14 transplanted rice received significantly lowest GDD (2689 ^{o}C) while attaining maturity stage. While, Radha-4 cultivar showed significantly higher GDD requirements for all phonological stages and Sukkha cultivars showed comparatively lower GDD requirements for reaching different phonological stages. July 15 transplanted rice cultivars were observed more heat use efficient (87%) and August 14 transplanted rice were seen less heat use efficient (11%) at the time of maturity. Among cultivars, Sukkha Dhan-2 was observed more heat use efficient (71%) and Sukkha Dhan-3 was seen less heat use efficient (51%) at maturity.

At 90 DAT, plant height was recorded significantly highest (115.6 cm) under July 15 transplanting. While August 14 transplanted rice showed significantly lowest plant height (83.05 cm). Sukkha Dhan-2 showed significantly highest plant height (107.3 cm) and Radha-4 showed significantly lowest plant height (87.67 cm) at 90 DAT. Number of tillers m^{-2} was observed maximum (214.4) for July 15 transplanted rice at 90 DAT. Whereas August 14 transplanted rice showed significantly lowest (192.4) number of tillers m^{-2} at the same observation. Sukkha Dhan-2 showed comparatively higher (210.9) number of tillers m^{-2} and Sukkha Dhan-3 showed significantly lowest (200.30) number of tillers m^{-2} at 90 DAT. Study of Above Ground Dry Matter (AGDM) revealed that July 15 transplanted rice gave significantly highest AGDM (581.6 g m^{-2}) at 75 DAT; which decreased significantly as transplanting date delayed. Whereas, Radha-4 gave significantly highest AGDM (471 g m^{-2}) and Sukkha Dhan-3 gave significantly lowest AGDM (431.10 g m^{-2}) at 75 DAT. The Crop Growth Rate (CGR) was seen higher from 30-60 DAT. And then the growth rate was observed decreased and steady from 60DAT onwards up to harvesting.

Yield attributing traits were also found to be influenced by transplanting dates and cultivars. Total grains per panicle of rice planted on earlier three dates were statistically at par and higher than that of August 14 transplanted rice. Similarly, filled grains per panicle of rice cultivars transplanted on earlier three dates were statistically at par and higher than that of August 14 transplanted rice. Maximum filled grains per panicle were observed in Sukkha Dhan-2. Sterility percentage of rice cultivars was observed minimum (18.29) for July 15 transplanted rice. This value was found increased as transplanting date was delayed. The average grain sterility percentage was calculated 21.5% in the experiment. Thousand grains weight was influenced by transplanting dates only. Comparatively higher test weight (23.84 g) was observed on July 15 transplanted rice; while comparatively lower test weight (21.02 g) was recorded on August 14 transplanted rice. The average test weight calculated in the experiment is 22.75 g.

Effect of date of transplanting on grain yield was significant .Maximum grain yield was obtained under July 15 transplanting (2.46 t ha^{-1}) while minimum grain yield was obtained under August 14 transplanting (0.30 t ha^{-1}). Grain yield obtained under July 15, July 25 and August 4 being statistically at par but was significantly superior over August 14 transplanting. The reduction in grain yield due to successive delay of 10 days from July 15 was to the extent of 12.6% and 28.6% respectively. However August 14 transplanting resulted 87.89% decrease in grain yield as compared to July 15 transplanting and the decrease was significant. The effect of cultivar on grain yield was non-significant .However, Sukkha Dhan-2 yielded highest (1.94 t ha^{-1}) and Sukkha Dhan-3 yielded lowest (1.48 t ha^{-1}). The grain yield could not be affected significantly due to the interaction between date of transplanting and cultivar. Straw yield was not influenced significantly by transplanting dates and cultivars. However, straw yield was recorded maximum (7.21 t ha^{-1}) on July 25 transplanted rice. Again, higher straw yield (7.05 t ha^{-1}) was seen in

Radha-4 and less straw yield (5.52 t ha^{-1}) was seen in Sukkha Dhan-3. Relatively higher Harvest Index (HI) was calculated for July 15 transplanted rice i.e. 0.26. While, Sukkha Dhan-2 cultivar gave comparatively higher HI (0.22) and Radha-4 gave lower HI (0.15).

5.2 Conclusion

The grain yield of July 15 and July 25 transplanted rice were recorded statistically superior over August 4 and August 14 transplanted rice under rainfed condition. So under such condition, we can transplant rice up to July 25 by taking any drought tolerant rice cultivar which are tested in the experiment, as the grain yield among cultivars were observed statistically at par. The significant difference in grain yield under different transplanting dates might be due to changing climatic parameters (temperature, rainfall, R.H etc) during the crop growing period. Monsoon rainfall trend of past 15 years of experimental site revealed that the amount of rainfall is in decreasing trend. Due to the less amount of rainfall, the rice crop might face severe water stress during critical growth stages under rainfed condition. For reducing the effect of changing climate on rice production, selection of appropriate transplanting dates might be the farmer's level technology which helps to achieve optimum rice yield by providing favourable growing condition. However, at least two years of multi-location research is needed to validate this research further.

LITERATURE CITED

Acikgoz, N. 1987. Effect of sowing time and planting method on rice yield per day. IRRN.12: 1-34.

Agriculture Perspective Plan,1995. National Planning Commission, Government of Nepal.

Akram, H.M., A. Ali, M.A. Nadeem and M.S. Iqbal. 2007. Yield and yield components of rice cultivars as affected by transplanting dates. J. Agric. Res. 45: 105-111.

Amgain, L.P. 2011. Agro-meterological indices in relation to phenology of promising rice cultivars in Chitwan, Nepal. Nepal Agriculture Research Journal. 11: 52- 59.

Aslam, M., S.H. shah and M.S. Nazir. 2010. Agronomic traits of direct seeded fine rice as affected by seeding density and planting time. International Journal of Agriculture & Biology 1: 35-38.

Azhiri-Sigari, T., L. J. Wade, C. G. McLaren, S. T. Amarante, C. G. Ramos, M. C. Casimero and L. S. Sebastian. 2005. Delayed planting of rainfed lowland rice in areas with short- season rains. Philippine Journal of Crop Science. 29: 51-58.

Balasubramanian, V., M. Sie, R.J. Hijmans and K. Otsuka. 2007. Increasing rice production in sub-Saharan Africa, Challenges and opportunities. Adv.Agron. 94: 55-133.

Basnet, B. S. 2009. Effect of climate change on agriculture. *In:* L.R. Joshi (ed.) Hamro Sampada, Kathmandu, Nepal: Hydal press Pv. Ltd. pp. 19-20.

Bates,B. C., Z. W. Kundzewicz and J. P. Palutikof. 2008. Climate change and water, technical paper of the IPCC Secretariat. Geneva. 105 p.

Bishnoi, O.P., S. Singh and R. Niwas. 1995. Effect of temperature on phenological development of wheat (*Triticum aestivum* L.) crop in different row orientations. Indian J. Agric. Sci. 65: 211-214.

Biswas, P.K. and V.M. Salokhe. 2001. Effects of planting date, intensity of tiller separation and plant density on the yield of transplanted rice. J. Agric. Sci. 137: 279-287.

Bruns, H.A. and H.K. Abbas .2006. Planting date effects on Bt and Non-Bt corn in the mid-south USA. Agron. J. 98: 100-106.

Chandrasekhar, J., G. R. Rao., B. Ravindranath and K.B. Reddy. 2001. Physiological analysis of growth and productivity in hybrid rice (*Oryza sativa*). Indian J. Plant Physio. 6: 142-146.

Chaudhry, M. 1984. Effect of sowing date on growth and performance of six rice cultivars in Western Turkey. IRRN. 9: 2- 24.

Chowdhury, M. J. U., S. M. A. Hossain, M.A. Gaffer and M.A. Islam .2000. Hill distribution an effective transplanting arrangement in the late transplanted aman rice. Bangladesh J. Crop Sci. 11: 9-16.

Cornell. 2004. Condition for rice growing. Available on: htp:ricelab.plbr.cornell.edu/docs [Retrieves 2nd March, 2012]

Cruz, R.T., J.C. Otoole., M.Dingkuhn, E.B. Yambao., M. Thangaraj., S.K. De Datta. 1986. Shoot and root responses to water deficits in rainfed lowland rice. Aust. J. Plant Physiol. 13: 567–575.

Dahal, N.M. 2009. Emerging trend of change in rainfall pattern and its impacton traditional farming system: a case study of paddy cultivation in kirtipur municipality. Thesis. Pokhara University.

De Datta , S.K. 1981 . Principles and practices of rice production. New York, John Willey and Sons. 618 p.

De Datta, S. K. 1970. The environment of rice production in tropical Asia. *In:* Rice production manual. University of the Philippines College of Agriculture in cooperation with the International Rice Research Institute. Los Baños, Philippines. pp 53-76.

De Datta, S. K., A. C. Tauro, and S. N. Balaoing. 1968. Effect of plant type and nitrogen level on the growth characteristics and grain yield of indica rice in the tropics. Agron. J. 60:643-647.

Depledge, J. 2002. Climate change in focus: IPCC Third Assessment Report. Royal Institute of International Affairs, Briefing Paper New Series, No. 29. Feb. 2002.

Dingkuhn, M. and K.M. Miezan. 1995. Climatic determinants of irrigated rice performance in the Sahel. II. Validation of photothermal constants and characterization of genotypes. Agricultural Systems. 48: 411-434.

Dingkuhn, M., A. Sow, A. Samb, S. Diack and F. Asch. 1995. Climatic determination of irrigated rice performance in the Sahel. *In* photothermal and micro climatic responses of flowering. Agricultural Systems. 48: 385-410.

Diouf, M., A.Nonguierma., A. Abou.,A.Royer., B.Some. 2000. Fight against drought in Sahel:achievements and perspective. Drought. 4:257-266

Doraiswamy, P.C. and D.R, Thompson., 1982. A crop moisture stress index for large areas and its application in the production of spring wheat phenology. Agri. Meterol. 27: 290-294.

Fageria, N. K.2007. Yield Physiology of Rice. Journal of Plant Nutrition 30: 843 -879.

FAO, 2008. Climate change adaptation and mitigation in the food and agriculture sector. High level conference on food security, the challanges of climate change and bioenergy. Rome, 3-5, June, 2008.12p.

Farrell, T.C., K. Fox, R. L.Williams, S. Fukai and L.G. Lewin. 2003. Avoiding low temperature damage in Australia’s rice industry with photoperiod sensitive cultivars. Proceedings of the 11th Australian Agronomy Conference. 2-6 February, 2002, Geelong.35 p.

Fukai,S. M.Cooper and J. Salisbury. Proceedings of Australian Centre for International Agriculture Research. International workshop on breeding strategies for rainfed lowland rice in drought prone environments, November 5-8, 1996, Ubon Ratchathani, Thiland.. 13 p.

Gangwar, K.S. and S.K. Sharma. 1997. Influence of planting dates on productivity of traditional scented rice varieties. IRRN.22: 42p.

Gardner, F.P., R.B. Pearce and R.L. Mitchell. 1985. Physiology of crop plants. Iowa, America, the Iowa State University Press. pp. 38-40.

Gomez, K. and A. Gomez. 1984. Statistical Procedures for Agricultural Research .2nd Ed. John Wiley and Sons, New York. 108p.

Gravois, K. A. and R.S. Helms. 1998. Seeding date effects on rough rice yield and head rice and selection for stability. Euphytica 102: 151-161.

Groth, D.E. and F.N, Lee.2003. Rice diseases. *In* :C.W. Smith and R.H. Dilday (Eds.). Rice: Origin, history, technology, and production. John Wiley and sons, Hoboken, New Jersey, pp. 413-436.

Hayat, K., I.U. Awan and G. Hassan. 2003. Impact of seeding dates and varieties on weed infestation, yield and yield components of rice under direct wet seeded culture. Pak. J. Weed Sci. Res. 9: 59-65.

Hong, K.P., J.Y. Kim, J.D. Kang, G.M. Shon and W.K. Shin. 1996. Effect of cool and hot weather on growth and yield in various growing seasons and cropping patterns of rice (*Oryza sativa L.)*. RAD. J. Agric. Sci. 38: 8-291.

Ingram, K.T., M.C. Roncoli and P.H. Kirshen, 2002. Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. Agricultural Systems 74:331–349.

IRRI, 2010. Scuba Rice: Breeding Flood Tolerance into Asia's Local Mega Rice Cultivars. International Rice Research Institute, .Los Banos Philippines: Available on www.eiard.org/media/uploads/documents/case_studies/dfid_impact_case_study_sub1_rice [Retrieve on 10th September, 2012].

Jones, J.W., G .Hoogenboom, C.H .Porter, K.J Bootee, W.D .Batchelor, L.A Hunt, P.W .Wilkens

Khakwani, A.A., M. Zubair, M. Mansoor, K. Naveed, I.H. Shah, A. Wahab, M. Ilyas and I. Ahmed. 2006. Agronomic and morphological parameters of rice crop as affected by date of transplanting. J. Agron. 5: 248-250.

Khalifa, A. 2009. Physiological evaluation of some hybrid rice varieties under different sowing dates. Aust. J. Crop Sci. 3: 178-183.

Koirala, G.P. 1983. Effect of seeding dates on performances of improved rice cultivars. Paper presented in 11th Summer Crops Workshop held during 30 Jan.-1 Feb., 1985 at NRRP, Parwanipur.

Krishnan, P. and S.K. Nayak. 1997. Effect of seedling age and planting time on growth and yield of photosensitive rice (*Oryza sativa*) cultivars. Indian J. of Agric. Sci. 67: 77p.

Kunwar, M.N. and G.L. Shrestha. 1979. Studies on date of seeding, nitrogen levels and varietal responses on rice under Parwanipur conditions. Paper presented on Sixth Summer Crops Seminar held at Department of Agriculture, Hariharbhavan, Lalitpur, Nepal.

Lansigan, F.P., W.L. Santos and J.L.O. Coladilla .2000. Agricultural Ecosystems and Environment. Agronomic impacts of climate variability on rice production in the Philippines. 82: 129-137.

LIBIRD. 2009. Climate change and agro biodiversity in Nepal: Opportunity to include biodiversity maintenance to support Nepal's National Adaptation Program of Action (NAPA). Local Initiatives for Biodiversity Research and Development (LIBIRD), Gairapatan ,Pokhara, Nepal.

Lilley, J.M.and S. Fukai, 1994. Effect of timing and severity of water deficit on four diverse rice cultivars. Field Crops Res. 37: 215–223.

Linscombe, S.D., J.K. Saichuk, K.P. Seilhan, P.K. Bollich, and E.R. Funderburg .1999. General agronomic guidelines. *In:* Louisiana rice production hand book. Louisiana State Univ. AgCenter Coop. Ext. Service. Publ. 2321. Louisiana State Univ., Baton Rouge, LA. 5-22.

Liu, J.X., D.Q. Liao, L. Estenor, X.E. Yang, Z.C. Li, J. Bennett. 2006. Genetic variation in the sensitivity of anther dehiscence to drought stress in rice. Field Crops Res. 97:87-100.

Mackill, D.J., A.M. Ismail, A. Kumar, and G.B. Gregorio.2010. The role of stress-tolerant cultivars for adapting to climate change. Euphytica. 172:31-34.

Mannan,M.A., M.S.U. Bhuiya, S.M.A. Hossain and M.I. M. Akand.2009. Study on phenology and yielding ability of basmati fine rice genotypes as influenced by planting date in aman season. Bangladesh J. Agri. Res. 34: 373-384.

Masoni, A., L. Ercoli and F. Massantini, 1990. Relationship between number of days, growing degree days and photothermal units and growth in wheat (*Triticum aestivum* L.) according to seeding time. Agricultura-Mediterrancea 120: 41-51.

Matsuo, T. and K. Hoshikawa .1993. Science of the Rice Plant. Food and Agriculture Policy Research Center, Tokyo. 686 p.

Mitin, A. 2009. Documentation of selected adaptation strategies to climate change in rice. East Asia rice working group, Philippines: Action for economic reform.

MoAD. 2011. Statistical Information on Nepalese Agriculture. Government of Nepal. Ministry of Agriculture and Cooperatives. Agri. Business Promotion and Statistics Division. Singh Durbar, Kathmandu, Nepal.

MoAD.2008. Statistical information on Nepalese Agriculture: Time series information. Ministry of Agriculture and Cooperatives. Sinha Durbar, Kathmandu.

Mohammed A.R., L. Tarpley. 2009. Impact of high night time temperature on respiration, membrane stability, antioxidant capacity and yield of rice plants. Crop Science.49:313-322.

Monteith J.L.1958. The heat balance of soil beneath crops. *In:* Climatology and micro climatology. UNESCO, Paris.

Moomaw, J. C., V. P. Novero, and A. C. Tauro. 1966. Rice weeds control in tropical monsoon climates: problems and prospects. Inernational Rice Communication Newsletter. 15:1-16.

Mottaleb, K.A., R.M.M. Rejesus, S. Mohanty, M.V.H. Murty, T.H.G. Velera and M.K.Gumma.2012. Ex-ante impact assessment of drought tolerant rice cultivars in presence of climate change. Paper presented at Agricultural Applied Economics Association’s annual meeting, August, 2012.

Murata, Y., and S. Matsushima. 1975. Rice. *In:* T. Evans (Ed.). Crop physiology: Some case histories. London,Cambridge University Press. Pp.73-99.

NARC. 2010. Released and registered crop cultivars in Nepal from 1960-2010.

NARC.2007. Research highlights: 2002/03-2006/07. Communication, Publication and Documentation Division, NARC, Khumaltar, Lalitpur. 17 p.

Nayava, J.L.1980. Rainfall in Nepal. The Himalayan Review: Nepal Geographic Society. 12:1-19.

NRRP. 1997. 25 years of Rice Research in Nepal. National Rice Research program, NARC, Nepal.

Otoole, J.C. 2004. Rice and water: the final frontier. Paper presented at the First International Conference on Rice for the Future, 31 August-2 September 2004, Bangkok, Thailand.

Pal, S.K., V.N. Verma, M.K. Singh and R. Thakur. 1996. Heat unit requirement for phenological development of wheat (*Triticum aestivum* L.) under different levels of irrigation, seeding date and fertilizer. Indian J. Agric. Sci. 66: 397-400.

Pandey, N., A.K. Verma and R.S. Tripathi. 2001. Effect of planting time and nitrogen on tillering pattern, dry matter accumulation and grain yield of hybrid rice. Indian J. Agric. Sci. 71: 337-338.

Pandey, S., H. Bhandari, and B. Hardy. 2007. Economic cost of Drought and Rice Farmers' coping mechanisms: A cross- country comparative analysis. International Rice Research Institute, Manila, Philippines. 203p.

Paraye, P.M. and V.S. Kandalkar. 1994. Effect of seedling age on long-duration, rain fed cultivars of rice under delayed transplanting. Indian J. Agric. Sci. 64: 187-188.

Paul, N.K. and D.K. Sarker. 2000. Accumulated heat units and phenology relationships in wheat as influenced by sowing dates. Bangladesh J. Bot. 29:49- 54.

Pokhrel, P. 2011. Class, Caste and Climate Change: A Vulnerability Analysis in Nepal. Pesticide Action Network, Asia.

Prasad, R. 1999. Nutrient management. A text book of rice agronomy. New Delhi, Sunil Kumar Jain Brothers. pp. 99-130.

PRRI.2011. Climate change and rice production. Philippine Rice Research Institute, Maligaya,series no 19. pp 8-11.

Rajput, R.P. and P.S.N. Sastry. 1985. Comparative performance of three cultivars of rain fed soybean in a monsoon climate. *In* Proceeding of International Symposium. 88 p.

Rajput, R.P., M.R. Deshmukh and V. K. Paradkar 1987. Accumulated heat unit and phenology relationships in wheat (*Triticum aestivum* L) as influenced by planting dates under late sown conditions. J. Agron. Crop Sci. 159: 345- 348.

Rakesh, K. and H.I. Sharma. 2004. Effect of dates of transplanting and varieties on dry matter accumulation, yield attributes and yield of rice (*Oryza sativa* L.). Himachal J.Agric. Res., 30:1-7.

Rosh, D., N. Haq, A. Said and P. Shah .1983. Effect of transplanting dates and the yield of rice in the sub-mountainous region of swat, Pakistan. Pakistan Journal of Agriculture Research 4:224-227.

Saikia, L., K. Chandra and T.C. Mahanta. 1989. Performance of late transplanting rice in Assam. Intl. Rice Res. Newsletter 14: 21 p.

Sandhu, I.S., A.R. Sharma and H.S. Sur. 1999. Yield performance and heat unit requirement of wheat (*Triticum aestivum* L.) cultivars as affected by sowing dates under rain fed conditions. Indian J. Agric. Sci. 69: 175-179.

Satake, T. and S. Yoshida. 1977. Mechanism of sterility caused by high temperature at flowering time in indica rice. *JARQ* 11:127-128.

Serraj, R., A. Kumar., K.L. Mcnally., I. Slamet-Loedin., R. Bruskiewich., R.Mauleon., J. Cairns., R.J. Hijmans. 2009. Improvement of drought resistance in rice. Adv. Agron. 103:41-99.

Shah, M.L. and K.P. Bhurer. 2005. Response of wet seeded rice cultivars to sowing dates. Nepal Agric.Res. J. 6: 35-38.

Shah, M.L., R .Yadav. 2001. Response of rice varieties to age of seedlings and transplanting dates. Nepal Agric. Res. J. 4 & 5: 14-17.

Shihua, C., S. Zongxiu and S. Huamin. 1991. Simulation of the effect of temperature on spikelet fertility in rice and its consequences for rice production. *In:* F.W.T. Penning de Vries, H.H. van Laar, and M.J. Kropff (Eds.). Simulation and systems analysis for rice production. Pudoc, Wageningen. pp 73-78.

Shin, J.C., Y.W. Kwon. 1985. Different mode of segregation in late-season culture in the characters associated with grain filling in F2 progenies of the rice plants. Agric. Res. Seoul Natl. Univ. 10:47-61.

Shrestha, M.L. 2000. Interannual variation of summer monsoon rainfall over Nepal and it relation to southern oscillation index. Meteorology and Atmospheric Physics. 75: 21–28.

Singh, K.M., S.K. Pal, U.N. Verma, R. Thakur and M.K. Singh. 1997. Effect of time and methods of planting on performance of rice (*Oryza sativa* L.) cultivars under medium lands of Bihar Plateau. Indian J. Agron. 42: 443–445.

Singh, S.P. and N.G. Jain. 2000. Response of rice cultivars to nitrogen. *Oryza*. 43:123-145.

Tanaka K., R. Onishi, M. Miyazaki, Y. Ishibashi, T. Yuasa, M. Iwaya-Inouer . 2009. Changes in NMR relaxation times of rice grains, kernel quality and physicochemical properties in response to a high temperature after flowering in heat-tolerant and heat-sensitive rice cultivars. Plant Prod. Sci. 12:185-192.

Tripathi, B.P., R.K. Mahato, R.B. Yadav, S.N. Sah and B.B. Adhikari. 2012. Adapting Rice Technologies to Climate Change. Hydro Nepal Special Issues. 71p.

U. Singh, A.J Gijsman and J.T .Ritchie. 2003. The DSSAT cropping system model. European Journal of Agronomy. 18: 235-265.

UNFCC, 2007. Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries.

Vange, T. and I.U. Obi. 2009. Effect of planting date on some agronomic traits and grain yield of upland rice cultivars at Makurdi, Benue state, Nigeria. J. Sust. Develop. Agric. Environ. 2: 1-9.

Veeresh, D.B., K.S. Vishwanatha, S.N. Anilkumar, S. Rao and A.S. Halepyati. 2011. Growth and yield of rice (*Oryza sativa* L.) cultivars as influenced by different methods of planting under aerobic method of cultivation. Research J. Agric. Sci. 2: 298-300.

Vernkataraman, S. and A. Krishnan. 1992. Crops and weather: Indian Council of Agricultural Research. Pp.325-343.

Wopereis, M.C. 1993. Quantifying the impact of soil and climatic variability on rainfed rice production. Ph.D. Thesis. Wageningen Agricultural University, The Netherlands, 188 p.

Wopereis, M.C., M.J. Kropff., A.R. Maligaya., T.P. Tuong.1996. Drought-stress responses of two lowland rice cultivars to soil and water status. Field Crops Res. 46: 21–39.

Yamuda, N.1963. Photosynthesis and dry matter production in rice plant. International Rice Commission (IRC) News letter. pp. 87-96.

Yoshida, S .1981. Fundamentals of Rice Crop Science. International Rice Research Institute, Los Baños, Philippines. 269p.

Yoshida, S. 1978. Tropical climate and its influence on rice. IRRI Research Paper .Series 20. Los Baños, Philippines, IRRI.

Youdeowei, A., F.O.C. Ezedinma and O. C. Onazi,. 1986. Introduction to Tropical Agriculture. Longman Group Ltd., London, UK.

Zeigler, R.S. and D. W. Puckridge, 1995. Improving sustainable productivity in rice-based rainfed lowland systems in Southeast Asia. Geo Journal. 35: 307–324.

APPENDICES

Appendix 1. Details of treatments combination of the experiment at Dhobadi, Nawalparasi, 2012

Treatments	Notation	Transplanting date + cultivar
T_1	D_1v_1	July 15+ Sukkha Dhan-1
T_2	D_1v_2	July 15+ Sukkha Dhan-2
T_3	D_1v_3	July 15+ Sukkha Dhan-3
T_4	D_1v_4	July 15+ Radha-4
T_5	D_2v_1	July 25+ Sukkha Dhan-1
T_6	D_2v_2	July 25+ Sukkha Dhan-2
T_7	D_2v_3	July 25+ Sukkha Dhan-3
T_8	D_2v_4	July 25+ Radha-4
T_9	D_3v_1	August 4+ Sukkha Dhan-1
T_{10}	D_3v_2	August 4+ Sukkha Dhan-2
T_{11}	D_3v_3	August 4+ Sukkha Dhan-3
T_{12}	D_3v_4	August 4+ Radha-4
T_{13}	D_4v_1	August 14+ Sukkha Dhan-1
T_{14}	D_4v_2	August 14+ Sukkha Dhan-2
T_{15}	D_4v_3	August 14+ Sukkha Dhan-3
T_{16}	D_4v_4	August 14+ Radha-4

Appendix 2. ANOVA table for split- plot design

Source of variation	Degree of freedom	MS	SS	F-cal	F-tab 0.05	F-tab 0.01
Replication (r)	(r-1) =(3-1)=2					
Date of transplanting (A)	(a-1) =(4-1)=3					
Error (a)	(r-1) (a-1)=2*3=6					
Cultivar (B)	(b-1) =(4-1)=3					
Error (b)	a(r-1)(b-1)=4*2*3=24					
A*B	(a-1)(b-1)=3*3=9					
Total error	(r*a*b)-1=(3*4*4)- 1=47					

Appendix 3. Weekly weather records of the experimental site at Dhobadi, Nawalparasi from June to November 2012

Months	Weeks	Avr. Max. Temperature (^{0}C)	Avr. Min. Temperature (^{0}C)	Total Rainfall (mm)	Relative Humidity (%)
June	1	37.14	26.09	39.80	62.97
June	2	38.29	25.83	208.40	58.41
June	3	35.80	26.29	69.40	71.41
June	4	33.58	25.10	101.50	81.73
July	1	34.80	26.46	140.70	78.32
July	2	32.74	25.63	165.80	86.15
July	3	30.77	25.29	288.10	86.58
July	4	32.60	26.22	81.60	86.80
August	1	32.54	26.11	168.60	83.10
August	2	32.69	25.26	124.30	87.59
August	3	34.11	26.03	100.80	84.35
August	4	32.38	25.40	138.80	84.51
September	1	32.66	25.69	114.60	83.82
September	2	33.89	25.69	49.40	80.42
September	3	30.51	25.29	164.60	90.50
September	4	31.78	23.91	0	88.99
October	1	32.94	24.17	0	85.38
October	2	31.77	22.00	4.00	84.48
October	3	30.51	20.06	0	85.57
October	4	29.68	18.09	0	86.17
November	1	29.60	13.71	0	77.17
November	2	28.56	13.37	0	79.45
November	3	27.14	13.09	0	85.40
November	4	26.63	12.02	0	83.51

Appendix 4. Rainfall data recorded over the past 15 years (1998-2012) in Dumkauli Meterological station, Nawalparasi

Year	Monsoon rainfall (June- September)
1998	2307.90
1999	2179.90
2000	2229.70
2001	2637.80
2002	1850.20
2003	2925.60
2004	2021.00
2005	1962.30
2006	1519.10
2007	2829.90
2008	1797.40
2009	1614.80
2010	2461.30
2011	1843.30
2012	1960.40

Appendix 5. Rating chart to determine the physic-chemical properties of soil

Rating	OM (%)	N%	P_2O_5 kg/ha	K_2O Kg/ha
Low	1.0-2.5	0.05-0.1	10-30	55-110
Medium	2.5-5	0.1-0.2	30-55	110-280
High	5.0-10.0	0.2-0.4	55-110	280-500
Soil reactions				pH Value
Moderately acidic				5.3-5.9
Nearly neutral				6.6-7.0
Moderately alkaline				7.6-8.3

Source: Soil science division, NARC, Nepal

Appendix 6. Mean squares from ANOVA of effect of transplanting dates and cultivars on phonological stages (DAS) of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	PI	Booting	Heading	Flowering	Milking	Hard dough	Maturity
Replication	2	6.52	2.25	0.25	18.25	0.44	5.15	0.75
Factor A	3	59.85**	138.02**	49.89**	48.47**	72.36**	118.61**	47.91**
Error A	6	0.35	3.944	1.56	0.97	2.30	2.76	1.22
Factor B	3	49.52**	108.13**	199.17**	252.31**	181.36**	150.39**	87.35**
A*B	9	3.48	9.34	4.28	4.69	3.86	5.74	2.61
Total Error	24	0.29	1.10	0.56	2.10	1.44	2.47	3.97

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 7. Mean squares from ANOVA of effect of transplanting dates and cultivars on growing degree days (^{0}C day) of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	PI	Booting	Heading	Flowering	Milking	Hard dough	Maturity
Replication	2	2546.62	1940.83	212.84	16253.34	338.74	4347.38	610.65
Factor A	3	22231.53**	119326.20**	42729.83**	42199.87**	61771.07**	101793.37**	41283.29**
Error A	6	149.51	3467.54	1352.99	878.45	1994.12	2433.19	977.84
Factor B	3	19323.82**	91556.50**	176123.03**	219075.76**	152986.76**	129451.07**	74326.11**
A*B	9	1372.53	7924.61	3748.46	3885.69	3191.02	4921.47	2240.60
Total Error	24	115.42	929.97	477.70	1863.53	1212.68	2076.32	3487.81

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 8. Mean squares from ANOVA of effect of transplanting dates and cultivars on plant height (cm) of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	6.43	27.01	57.57	117.75	120.41
Factor A	3	361.70**	835.90**	1563.32**	1954.65**	2123.54**
Error A	6	5.71	10.24	21.98	33.43	35.87
Factor B	3	90.26**	242.44**	458.02**	764.40**	866.41**
A*B	9	2.26	7.17	14.76	14.68	16.65
Total Error	24	0.92	1.35	4.75	5.18	5.49

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 9. Mean squares from ANOVA of effect of transplanting dates and cultivars on number of tillers per square meter of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	621.81	1260.38	721.44	550.44	12.94
Factor A	3	2860.93**	8976.33**	5397.56**	4149.38**	1191.29**
Error A	6	133.22	59.02	56.73	100.02	76.18
Factor B	3	3300.90**	1278.73**	1601.19**	296.27	248.41**
A*B	9	364.74	1249.36	877.70	914.49	36.43
Total Error	24	45.77	36.68	72.05	243.51	22.10

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 10. Mean squares from ANOVA of effect of transplanting dates and cultivars on leaf area index of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	0.12	0.65	1.35	0.70
Factor A	3	2.60	4.38*	7.83*	3.50
Error A	6	1.18	0.90	1.58	0.80
Factor B	3	0.22	0.19	0.27	0.21
A*B	9	0.17	0.66	0.87	0.41
Total Error	24	0.41	0.52	0.89	0.52

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 11. Mean squares from ANOVA of effect of transplanting dates and cultivars on above ground dry matter (g m^{-2}) of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	60.65	35.71	303.97	90.55
Factor A	3	1227.42**	1279.63**	47370.17**	137750.56**
Error A	6	70.66	61.59	553.91	107.74
Factor B	3	15.47	127.84**	1303.74	3341.07**
A*B	9	30.78	160.73	7005.54	6953.72
Total Error	24	21.84	34.18	472.21	207.23

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 12. Mean squares from ANOVA of effect of transplanting dates and cultivars on crop growth rate (g m^{-2} day^{-1}) of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	30-45 DAT	45 -60 DAT	60-75 DAT
Replication	2	0.80	2.43	0.35
Factor A	3	2.63	159.00**	113.89**
Error A	6	0.66	1.70	1.63
Factor B	3	0.58	4.07	11.16**
A*B	9	0.65	35.37	8.02
Total Error	24	0.28	2.12	0.87

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 13. Mean squares from ANOVA of effect of transplanting dates and cultivars on yield attributing traits of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	Effective tillers m^{-2}	Total grains $panicle^{-1}$	Filled grains $panicle^{-1}$	Sterility percentage	Thousand grains weight
Replication	2	1377.90	12.95	21.16	0.95	0.57
Factor A	3	2674.44	346.97**	907.70**	159.66**	21.85**
Error A	6	1925.95	23.69	40.28	7.09	3.41
Factor B	3	628.98*	816.48**	1431.66**	141.20**	1.74
A*B	9	213.50	11.33	9.92	1.13	1.04
Total Error	24	199.82	83.42	90.28	4.44	3.59

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 14. Mean squares from ANOVA of effect of transplanting dates and cultivars on grain yield, straw yield and harvest index of rice at Dhobadi, Nawalparasi, 2012

Source of variation	df	Grain yield	Straw yield	Harvest index
Replication	2	5.00	6.98	0.02
Factor A	3	10.93*	18.50	0.08**
Error A	6	1.03	11.46	0.006
Factor B	3	0.48	5.09	0.01
A*B	9	0.43	4.14	0.003
Total Error	24	0.68	3.20	0.004

* Significant at 0.05 level of significance; **Significant at 0.01 level of significance

Appendix 15. Interaction effect of transplanting dates and cultivars on phonological stages of rice at Dhobadhi, Nawalparasi 2012

Treatments	Phonological stages (DAS)						
	PI	Booting	Heading	Flowering	Milking	Hard dough	Maturity
July15+Sukkha Dhan-1	52^{fg}	64^{ef}	73^{fg}	76	84^{cde}	97^{bc}	106
July 15+ Sukkha Dhan-2	51^{h}	64^{ef}	72^{gh}	77	84^{cde}	94^{cd}	104
July 15+ Sukkha Dhan-3	53^{de}	66^{de}	75^{de}	76	85^{c}	95^{cd}	104
July 15+ Radha-4	56^{b}	72^{a}	82^{a}	87	92^{ab}	102^{a}	110
July 25+ Sukkha Dhan-1	53^{e}	68^{cd}	75^{d}	76	83^{cde}	96^{bc}	104
July 25+ Sukkha Dhan-2	50^{i}	63^{f}	72^{gh}	75	83^{cde}	95^{cd}	101
July 25+ Sukkha Dhan-3	54^{cd}	70^{b}	77^{c}	77	85^{cd}	98^{b}	103
July 25+ Radha-4	57^{a}	72^{a}	83^{a}	87	93^{a}	102^{a}	109
August 4+ Sukkha Dhan-1	49^{i}	64^{f}	72^{gh}	76	82^{ef}	96^{bc}	102
August 4+ Sukkha Dhan-2	51^{gh}	63^{f}	73^{gh}	76	82ef	93^{d}	101
August 4+ Sukkha Dhan-3	53^{ef}	68^{bc}	74^{ef}	76	83^{de}	95^{cd}	104
August 4+ Radha-4	55^{c}	70^{b}	80^{b}	85	91^{b}	103^{a}	107
August 14+ Sukkha Dhan-1	47^{k}	59^{g}	69^{i}	73	80^{g}	88^{e}	101
August 14+ Sukkha Dhan-2	48^{j}	60^{g}	71^{h}	74	80^{g}	90^{e}	100
August 14+ Sukkha Dhan-3	48^{j}	58^{g}	70^{i}	73	80^{fg}	89^{e}	99
August 14+ Radha-4	51^{h}	64_{ef}	78^{c}	79	84.33^{cd}	97^{bc}	105
LSD (0.05)	0.90	1.77	1.26	N.S	2.02	2.65	N.S
SEM (±)	0.31	0.61	0.43	0.84	0.69	0.91	1.15
CV (%)	1.03	1.61	1.00	1.87	1.42	1.64	1.92

DAS= Days After Sowing; N.S=Non Significant; PI= Panicle Initiation; Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Appendix 16. Interaction effect of transplanting dates and cultivars on growing degree days (GDD) at phonological stages of rice at Dhobadhi, Nawalparasi 2012

Treatments	GDD (^{0}C day)						
	PI	Booting	Heading	Flowering	Milking	Hard dough	Maturity
July 15+ Sukkha Dhan-1	1007^{fg}	1602^{ef}	1861^{fg}	1950.87	2179^{cd}	2556^{bc}	2822.63
July 15+ Sukkha Dhan-2	987.5^{g}	1611^{ef}	1833^{gh}	1971.03	2178^{cd}	2488^{cd}	2782.93
July 15+ Sukkha Dhan-3	1033de	1650^{ef}	1911de	1941.07	2216^{c}	2517^{cd}	2763.70
July 15+ Radha-4	1080^{b}	1823^{a}	2140^{a}	2263.77	2430^{ab}	2713^{a}	2951.97
July 25+ Sukkha Dhan-1	1027^{e}	1698^{cd}	1931^{d}	1950.90	2159^{cd}	2546^{bc}	2763.70
July 25+ Sukkha Dhan-2	967.5^{h}	1562^{f}	1841^{gh}	1931.23	2169^{cd}	2508^{cd}	2693.37
July 25+ Sukkha Dhan-3	1047^{cd}	1766^{b}	1971^{c}	1990.93	2207^{c}	2604^{b}	2753.20
July 25+ Radha-4	1100^{a}	1823^{a}	2159^{a}	2283.30	2460^{a}	2703^{a}	2908.33
August 4+ Sukkha Dhan-1	954.5^{hi}	1592^{f}	1833^{gh}	1941.30	2130de	2536^{bc}	2723.27
August 4+ Sukkha Dhan-2	995.0^{g}	1572^{f}	1851^{gh}	1941.07	2130de	2449^{d}	2693.03
August 4+ Sukkha Dhan-3	1020^{ef}	1717^{bc}	1891^{ef}	1960.73	2150^{cd}	2498^{cd}	2783.60
August 4+ Radha-4	1061^{c}	1766^{b}	2071^{b}	2207.10	2381^{b}	2754^{a}	2871.00
August 14+ Sukkha Dhan-1	906.2^{k}	1452^{g}	1746^{i}	1861.17	2061^{f}	2313^{e}	2683.67
August 14+ Sukkha Dhan-2	937.1^{ij}	1472^{g}	1814^{h}	1880.87	2061^{f}	2371^{e}	2643.27
August 14+ Sukkha Dhan-3	930.5^{j}	1422^{g}	1776^{i}	1852.40	2071^{ef}	2322^{e}	2633.83
August 14+ Radha-4	988.1^{g}	1601^{ef}	2001^{c}	2050.77	2198^{c}	2555^{bc}	2793.47
LSD (0.05)	18.10	51.39	36.83	N.S	58.68	76.79	N.S
SEM(±)	6.20	17.61	12.62	24.92	20.11	26.31	34.10
CV (%)	1.07	1.87	1.14	2.16	1.58	1.80	2.13

N.S=Non significant; PI= Panicle Initiation; Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of confidence significance

Appendix 17. Interaction effect of transplanting dates and cultivars on plant height of rice at Dhobadhi, Nawalparasi 2012

Treatments	Plant height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
July 15+ Sukkha Dhan-1	55.72^{bc}	76.61^{c}	97.90^{b}	110.4^{b}	115.4^{c}
July 15+ Sukkha Dhan-2	57.34^{ab}	79.79^{b}	100.2^{ab}	113.9^{b}	119.4^{b}
July 15+ Sukkha Dhan-3	58.43^{a}	81.93^{a}	103.4^{a}	118.0^{a}	123.9^{a}
July 15+ Radha-4	51.26^{fg}	71.02^{ef}	88.77^{c}	99.29^{cd}	103.5^{ef}
July 25+ Sukkha Dhan-1	53.97^{de}	69.43^{fg}	83.35^{d}	95.24^{e}	100.4^{fg}
July 25+ Sukkha Dhan-2	54.89^{cd}	72.42^{de}	88.35^{c}	101.2^{c}	106.6^{de}
July 25+ Sukkha Dhan-3	56.47^{bc}	73.87^{d}	89.22^{c}	103.2^{c}	108.9^{d}
July 25+ Radha-4	48.01^{h}	59.55^{j}	69.75^{g}	79.51^{gh}	83.76^{jk}
August 4+ Sukkha Dhan-1	50.21^{g}	66.63^{h}	81.66^{d}	92.69^{e}	96.88^{g}
August 4+ Sukkha Dhan-2	51.15f^{g}	68.42^{gh}	84.43^{d}	96.43^{de}	100.8^{fg}
August 4+Sukkha Dhan-3	52.78^{ef}	71.10^{ef}	88.17^{c}	101.1^{c}	106.0^{de}
August 4+ Radha-4	47.90^{h}	62.87^{i}	76.39^{e}	84.96^{f}	88.97^{hi}
August 14+Sukkha Dhan-1	42.99^{j}	56.49^{k}	68.38^{g}	77.23^{h}	80.94^{k}
August 14+ Sukkha Dhan-2	43.92^{ij}	58.53^{j}	71.80^{fg}	82.27^{fg}	86.33^{ij}
August14+Sukkha Dhan-3	45.15^{i}	60.52^{j}	74.72^{ef}	86.20^{f}	90.50^{h}
August 14+ Radha-4	40.13^{k}	52.43^{l}	63.65^{h}	70.93^{i}	74.42^{l}
LSD (0.05)	1.61	1.96	3.67	3.83	3.95
SEM (±)	0.55	0.67	1.26	1.31	1.35
CV (%)	1.89	1.72	2.62	2.41	2.36

DAT= Days After Transplanting ,N.S=Non significant; Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Appendix 18. Interaction effect of transplanting dates and cultivars on number of tillers per square meter of rice at Dhobadhi, Nawalparasi, 2012

Treatments	Number of tillers m^{-2}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
July 15+ Sukkha Dhan-1	180.7^{ab}	254.7^{bc}	233.7^{fg}	225.6^{bcd}	215.57
July 15+ Sukkha Dhan-2	172.7^{bc}	224.4^{e}	232.9^{fg}	228.5^{bcd}	217.28
July 15+ Sukkha Dhan-3	155.9^{de}	260.9^{b}	275.8^{ab}	244.8^{bc}	211.08
July 15+ Radha-4	134.9^{g}	206.3^{f}	272.4^{bc}	250.8^{ab}	213.57
July 25+ Sukkha Dhan-1	190.7^{a}	242.5^{D}	227.1^{gh}	220.3^{cde}	214.32
July 25+ Sukkha Dhan-2	157.4^{de}	251.0^{bcd}	241.9^{efg}	229.3^{bcd}	215.97
July 25+ Sukkha Dhan-3	159.4^{de}	272.9^{a}	243.3^{ef}	235.2^{bc}	208.37
July 25+ Radha-4	134.0^{g}	273.4^{a}	288.1^{a}	276.3^{a}	211.51
August 4+ Sukkha Dhan-1	188.3^{a}	245.5^{cd}	243.4^{ef}	244.6^{bc}	209.77
August 4+ Sukkha Dhan-2	147.5^{ef}	180.8^{h}	252.0^{de}	246.3^{bc}	213.59
August 4+ Sukkha Dhan-3	161.9^{cd}	200.4^{fg}	233.5^{fg}	220.1^{cde}	192.36
August 4+ Radha-4	136.7^{fg}	216.9^{e}	259.7^{cd}	218.9^{cde}	208.43
August 14+Sukkha Dhan-1	132.1^{g}	201.1^{fg}	208.6^{i}	202.9^{de}	194.09
August 14+ Sukkha Dhan-2	130.6^{g}	199.9^{fg}	210.9^{i}	201.6^{de}	196.67
August 14+Sukkha Dhan-3	130.3^{g}	201.5^{fg}	213.3^{hi}	203.0^{de}	189.29
August 14+ Radha-4	123.8^{g}	191.8^{g}	200.2^{i}	193.0^{e}	189.50
LSD (0.05)	11.40	10.21	14.30	26.30	N.S
SEM (±)	3.91	3.50	4.90	9.01	2.71
CV (%)	4.44	2.67	3.54	6.86	2.28

DAT= Days After Transplanting; N.S=Non significant; Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Appendix 19. Interaction effect of transplanting dates and cultivars on above ground dry matter of rice at Dhobadi, Nawalparasi, Nepal, 2012

Treatments	Above ground dry matter (g m^{-2})			
	30 DAT	45 DAT	60 DAT	75 DAT
July 15+ Sukkha Dhan-1	91.68	233.4^{bc}	426.6^{ab}	587.4^{a}
July 15+ Sukkha Dhan-2	89.02	234.4^{abc}	445.9^{a}	569.7^{a}
July 15+ Sukkha Dhan-3	96.04	245.0^{a}	461.7^{a}	584.7^{a}
July 15+ Radha-4	87.55	237.3^{abc}	434.5^{ab}	584.6^{a}
July 25+ Sukkha Dhan-1	70.16	217.2^{def}	355.8^{d}	411.1^{e}
July 25+ Sukkha Dhan-2	71.47	220.9^{de}	427.5^{ab}	534.2^{b}
July 25+ Sukkha Dhan-3	69.81	218.8^{def}	438.2^{ab}	469.6^{d}
July 25+ Radha-4	73.71	232.8^{bc}	378.7^{cd}	469.0^{d}
August 4+ Sukkha Dhan-1	94.55	233.1^{bc}	403.6^{bc}	500.8^{c}
August 4+ Sukkha Dhan-2	91.44	227.1^{cd}	292.9^{e}	403.0^{e}
August 4+ Sukkha Dhan-3	88.84	243.8^{ab}	313.1^{e}	355.3^{f}
August 4+ Radha-4	93.71	221.4^{de}	449.0^{a}	503.4^{c}
August 14+ Sukkha Dhan-1	78.27	208.1^{f}	283.2^{e}	314.6^{g}
August 14+ Sukkha Dhan-2	76.25	214.3^{ef}	311.1^{e}	327.9^{g}
August 14+ Sukkha Dhan-3	75.66	211.4^{ef}	281.9^{e}	314.7^{g}
August 14+ Radha-4	83.40	221.8^{de}	299.0^{e}	326.8^{g}
LSD (0.05)	N.S	9.85	36.62	24.26
SEM (±)	2.70	3.38	12.55	8.31
CV (%)	5.62	2.58	5.79	3.17

DAT= Days After Transplanting; N.S=Non Significant; Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Appendix 20. Interaction effect of transplanting dates and cultivars on crop growth rate of rice at Dhobadi, Nawalparasi, 2012

Treatments	Crop growth rate (g $m^{-2}day^{-1}$)		
	30-45 DAT	45-60DAT	60-75DAT
July 15+ Sukkha Dhan-1	9.45^{bcd}	12.88^{ab}	10.71^{a}
July 15+ Sukkha Dhan-2	9.69^{abc}	14.10^{a}	8.26^{b}
July 15+ Sukkha Dhan-3	9.93^{abc}	14.45^{a}	8.19^{b}
July 15+ Radha-4	9.99^{abc}	13.14^{ab}	10.01^{a}
July 25+ Sukkha Dhan-1	9.80^{abc}	9.24^{c}	3.68^{d}
July 25+ Sukkha Dhan-2	9.96^{abc}	13.77^{ab}	7.12^{bc}
July 25+ Sukkha Dhan-3	9.94^{abc}	14.62^{a}	2.09^{de}
July 25+ Radha-4	10.61^{a}	9.73^{c}	6.02^{c}
August 4+ Sukkha Dhan-1	9.24^{cd}	11.36^{bc}	6.48^{c}
August 4+ Sukkha Dhan-2	9.04^{cd}	4.390^{d}	7.34^{bc}
August 4+ Sukkha Dhan-3	10.33^{ab}	4.62^{d}	2.82^{de}
August 4+ Radha-4	8.52^{d}	15.17^{a}	3.63^{d}
August 14+ Sukkha Dhan-1	8.65^{d}	5.01^{d}	2.09^{de}
August 14+ Sukkha Dhan-2	9.21^{cd}	6.45^{d}	1.12^{e}
August 14+ Sukkha Dhan-3	9.05^{cd}	4.70^{d}	2.19^{de}
August 14+ Radha-4	9.23^{cd}	5.14^{d}	1.86^{e}
LSD (0.05)	0.89	2.456	1.58
SEM (±)	0.30	0.8414	0.54
CV (%)	5.55	14.69	17.88

DAT = Days After Transplanting; Treatments mean followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance

Appendix 21. Grain yield of rice as influenced by the combined effect of transplanting dates and cultivars at Dhobadi, Nawalparasi, 2012

Transplanting dates	Grain yield (t ha^{-1})			
	Sukkha Dhan-1	Sukkha Dhan-2	Sukkha Dhan-3	Radha-4
July 15	2.17	2.63	2.49	2.54
July 25	2.19	3.05	1.82	1.53
August 4	2.05	1.75	1.28	1.95
August 14	0.27	0.34	0.31	0.29

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

Appendix 22. Correlation coefficient among growth parameters, yield attributing traits and yield of rice at Dhobadi, Nawalparasi, 2012

	TN@90	LAI@60	AGDM@75	ET	FG_pan	SP	TGW	Gyld	Syld	HI
PLH@90	.405**	.455**	759**	.265	.347*	-.490**	.303*	.632**	.490**	.574**
TN@90		.380**	.465**	.459**	.068	-.314*	.301*	.401**	.425**	.300*
LAI@60			.471**	.128	.077	-.116	.020	.335*	.407**	.286*
AGDM@75				.359*	.290*	-.548**	.307*	.667**	.462**	.646**
ET					.300*	-.572**	.473**	.516**	.452**	.520**
FG_pan						-.753**	.030	.391**	.177	.483**
SP							-.231	-.648**	-.403**	-.701**
TGW								.374**	.202	.406**
Gyld									.663**	.878**
Syld										.315*

*Significant at the 0.05 level; **Significant at the 0.01 level; PLH@90= plant height at 90 DAT; TN@90= number of tillers m^{-2} at 90 DAT; LAI@60=Leaf area index at 60 DAT; AGDM@75= Above ground at 75 DAT; ET= Effective tillers m^{-2}; FG_pan= Filled grains per panicle; SP= Sterility percentage; TGW= Thousand grains weight; Gyld= Grain yield; Syld= Straw yield; HI=Harvest index

BIOGRAPHICAL SKETCH

Mr. Dinesh Bahadur Karki, was born on 9th December, 1987 in Bhotewodar-08, Lamjung as eldest son of Mrs. Krishna Kumari Karki and Mr. Krishna Bahadur Karki. He has received his School Leaving Certificate from Adarsha Bal Higher Secondary school, Baretar, Lamjung in 2002 A.D. He has passed his Intermediate level from Chitwan Science College, Bharatpur-09, Chitwan, in 2005 A.D. After that he joined in the Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan and completed the Bachelor degree with major in Horticulture in 2010 A.D. Just After his graduation, he was enrolled on post graduate programme in the same Institute to pursue his Master's degree in Agronomy in 2011 A.D.

At present he is living happily with his family and friends.

Author