PRODUCTIVITY ASSESSMENT OF STAGGERED PLANTED RAINFED MAIZE GENOTYPES: SIMULATION ON AGRONOMIC MANAGEMENT AND CLIMATE CHANGE SCENARIOS USING CSM-CERES-MAIZE MODEL

UMESH SHRESTHA

AUGUST 2014

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DEGREE OF

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(AGRONOMY)

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CERTIFICATE

This is to certify that the thesis entitled **"PRODUCTIVITY ASSESSMENT OF STAGGERED PLANTED RAINFED MAIZE GENOTYPES: SIMULATION ON AGRONOMIC MANAGEMENT AND CLIMATE CHANGE SCENARIOS USING CSM-CERES-MAIZE MODEL''** 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. UMESH SHRESTHA, Id No. R-2012-AGR-07 M** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

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

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The thesis attached hereto, entitled **"PRODUCTIVITY ASSESSMENT OF STAGGERED PLANTED RAINFED MAIZE GENOTYPES: SIMULATION ON AGRONOMIC MANAGEMENT AND CLIMATE CHANGE SCENARIOS USING CSM-CERES-MAIZE MODEL"** prepared and submitted by **Mr. UMESH SHRESTHA,** in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Agronomy),** is hereby accepted.

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Umesh Shrestha

TABLE OF CONTENTS

LIST OF TABLES

.

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

%	Percentage
@	At the Rate of
^{0}C	Degree Celsius
AGDM	Above Gross Dry Matter
AGDP	Agriculture Gross Domestic Product
ANOVA	Analysis of Variance
APP	Agriculture Perspective Plan
ASI	Anthesis and Silking Interval
CERES	Crop Estimation through Resource and Environment Synthesis
CGR	Crop growth rate
CH_4	Methane
CIMMYT	Centro International de Mejoramiento de Maizy Trigo
cm	Centimeter
Co_2	Carbon dioxide
CSM	Crop Simulation Model
CV	Coefficient of Variation
DAP	DI-Ammonium Phosphate
DAS	Days After Sowing
DAT	Days After Transplanting
DHM	Department of Hydrology and Meteorology
DLL	Drained lower limit
DMRT	Duncan's Multiple Range Test
DSSAT	Dicision Support System for Agrotechnology Transfer

DUL	Drained Upper Limit
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
HMG/N	His majesty the government of Nepal
IAAS	Institute of Agriculture and Animal Science
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
IPCC	Intergovernmental Panel on Climate Change
K_2O	Potassium Oxide
Kg	Kilo Gram
KN	Kernel Number
KW	Kernel Weight
LA	Leaf Area
LAD	Leaf Area Duration
LAI	Leaf Area Index
LSD	Least Significant Difference
m^{-2}	Meter Square
Max	Maximum
Min	Minimum
MoAD	Ministry of Agriculture and Development

MOP	Muriate of Potash
N	Nitrogen
N.S.	Non-significant
N_2O	Nitrous Oxide
NARC	Nepal Agricultural Research Council
NMRP	National Maize Research Programme
OPV	Open pollinated Varieties
P_2O_5	Phosphorous Oxide
PAR	Photo Synthetically Active Radiation
ppm	Parts per Million
PTI	Phenothermal Index
QPM	Quality Protein Maize
RCBD	Randomized Complete Block Design
RMSE	Root Mean Square Error
RUE	Radiation Use Efficiency
SEm	Standard Error of Mean
tha^{-1}	Ton per Hectare
VDC	Village Development Community

ABSTRACT

Name: Umesh Shrestha
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Major subject: Agronomy
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A field experiment and simulation modeling study in combination for different maize cultivars planted at different sowing dates were accomplished at Shiva mandir-2, Nawalparasi during spring season of 2013 to assess the productivity and best agronomic management options under changing climate scenarios using CSM-CERES-Maize model. Combined treatments of four cultivars {Local, Poshilo makai-1 (QPM), RML-4/17 (Hybrid) and Arun-2} and three sowing dates (7th April, 22nd April and 7th May) were assigned in field and each treatment was replicated thrice in a factorial RCB design. Result showed that RML-4/17 produced higher kernel rows ear^{-1}(13.77), kernels per row (30.42) and test weight (244.9). Significantly higher grain yield was also found for RML-4/17 (6.03 t ha^{-1}) compared to Poshilo makai-1 (4.73 t ha^{-1}), Arun-2 (3.55 t ha^{-1}) and Local (2.92 t ha^{-1}). Earlier sowing date (7th April) actually produced higher kernel row^{-1} (27.97), kernel rows ear^{-1} (12.89) and 1000 grain weight (232.0 g). Significantly higher grain yield (5.13 t ha^{-1}) was obtained in earlier sowing date (7th April). Although the mean ambient temperature during research period was increasing with delayed sowing, days to attain different phenological stages were decreased with late sowing. Though statistically similar GDD was recorded for different sowing dates the higher PTI values were noticed with delay in planting. Similarly, heat use efficiency (HUE) was found higher in early sowing date. Arun-2 had small reduction in HUE so that it can be considered stable and best cultivar among the tested cultivars. The CSM-CERES-Maize model was calibrated well and found well validated with days to anthesis (RMSE = 0.426 and D-index = 0.998), days to physiological maturity (RMSE = 0.674 day and D-index=0.999), number of grain m^{-2} at

maturity (RMSE= 85.287 grain m^{-2} and D-index =0.993), unit weight at maturity (RMSE =0.012 g $kernel^{-1}$ and D-index= 0.854) and grain yield (RMSE = 54.94 kg ha^{-1} and D-index = 1.00). The model was sensitive to sowing dates, under no water stress condition, cultivars, weather years and climate change parameters. Sensitivity analysis to sowing dates stated that 17th April was considered the best sowing date for Local and Arun-2, whereas for RML-4/17 and Poshilo makai-1, 12th April and 7th April were considered the best sowing dates, respectively. Under no water stress condition, model predicted yields of hybrid would have been increased more by 18.23% and this increment was higher than other cultivars. Among other cultivars under sensitivity analysis, Rampur Composite can be considered the best cultivar as it had the highest simulated yield (6493 kg ha^{-1}). Similarly, sensitivity analysis for weather years resulted 2006 was good for all maize cultivars followed by 2007 and yield seemed to be in decreasing order in rest of the weather years. The sensitivity for various climate change scenarios indicated that there was decreased trend in simulated spring maize yield with the increment of maximum and minimum temperature and decrease in solar radiation and Carbon-dioxide concentration. Even 2 ^{o}C rise in temperature can decrease around 15% yield of spring maize and this negative effect was even more pronounced in hybrid than other cultivars.

Asst. Prof. Lal Prasad Amgain, Ph.D.
Major advisor

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Author

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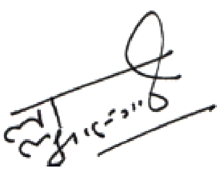

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1 INTRODUCTION

1.1 Background

Maize (*Zea mays* L.) is the second most important staple food crops both in-terms of area and production after rice in Nepal. It has the highest yield potential over other cereals and thus known as 'the queen of cereals' (Singh, 2002). It is grown in about 906253 ha land with 206772 metric tons total production and 2.23 mt ha^{-1} productivity (Agricultural Diary, 2069). Maize contributes 9.5% AGDP and 3.15% GDP (MoAD, 2012). Maize occupies about 28.32% of the total agricultural land cultivated, and shares about 23.89 % of the total cereal production in Nepal (MoAC, 2009/10). The overall demand for maize will be increased by 6-8% per annum largely for the next two decades as a result of increased demand for food in hills and feed in terai, inner terai and, this increased demand could only be met by increasing the productivity of maize per unit area of land (NMRP, 2009).

Rainfed farming means the cultivation of crops on relatively dry land that lacks easy access to irrigation and moisture requirement at any growth and development stages of crop. Rainfed farming area falls mainly in arid, semi-arid and dry sub-humid zones in the world but the Nepalese sub-tropical region is also rainfed. In Nepal, about 65% of the total arable land is under rainfed (Thapa, 1995). The variation in rainfall under rainfed zone especially during spring season feels long dry spell, early withdrawal and also increasing temperature caused stressful environment to plant growth, all of which strongly influence the productivity level of maize.

Climate change is another factor that is making stressful environment for maize production. Climate change refers to any change in climate over at least 30 years, 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. The change in climate is indicated by increase in temperature, change in rainfall pattern etc. The temperature of Nepal is increasing by 0.06 ^oC per year (Shrestha *et al.*, 1999). Climate dynamics, particularly the projected increase in the variability of rainfall regimes, suggest that Nepalese agriculture is facing with immense challenges as seasonal drought and heat stress is increasing.

Numerous technological (e.g. cropping patterns, choice of proper sowing date, and shifts to drought-resistant varieties, crop modeling) and socio-economic (e.g. ownership of assets, access to services, and infrastructural support) factors will come into play in enhancing the current capacity of rainfed farmers to cope with climate change.

Optimum planting date is a cost-less tool to improve the yield of maize. Spring maize is normally planted in mid of February. Maize planted in earlier spring season is facilitated by favorable temperature, availability of reserved soil moisture of long winter for vegetative growth, but drought problem during reproductive period creates stressful environment to the crop. When maize planting date is shifted to late spring, higher temperature stress during major crop period will hinder plant growth and development. However, there will be plenty of soil moisture during reproductive stage due to monsoon rainfall which also could not be favorable to C_4 maize. Even though, rainfall will occur in post flowering period but excessive high temperature decreases crop yield by shortening of growth duration and other physiological factors associated with poor grain filling. That is why, optimum sowing date for healthy crop growth is an important task to tackle changing climate during spring season.

The development of improved germplasm to meet the needs of future generations in light of climate change and population growth is of the upmost importance (Easterling *et al.,* 2007). Drought condition that often occurs in rainfed lower ecosystem seriously affects the growth and yield of maize. Most of the varieties released by National Agriculture Research Council are susceptible to drought. Even heat stress during summer season decreases crop yield with higher magnitude. To avoid high temperature and drought during post anthesis period, farmers like to cultivate short durational varieties. Farmer expects short durational variety to escape drought period and provide higher yield and net returns. However, they are still in dilemma, which varieties will provide greater yield under prevailing environment. So this research also focused on selection of proper variety for the particular location. Four varieties were chosen to determine the best one through research. Out of four varieties, Arun-2 and Local are short durational varieties. The major agro-climatic indices like temperature and solar radiation significantly affects the crop growth and development. The quantification of temperature and their application in predicting crop yield is a modern application in agricultural field. Environmental impact on agro-climatic indices such as heat use efficiencies and phenothermal index were studied to find there significant role in varietal selection. During both the winter and spring planting, 'Arun-2' has given more stable yield and heat use efficiency for the early and late (September 1 to November 1, and February 24 to March 4) plantings (Amgain, 2011). Remaining Poshilo Makai-1 and RML-4/17 are long durational but drought tolerant varieties. From several researches, it has also been reported that hybrids can give 20-50% more grain yield than the inbred variety (Gupta *et al.,* 2010). However, the hybrid and improved cultivars of any crops are more sensitive to the environment of climatic variability than the local genotypes, and yield reduction is more on them (Amgain, 2011, Lamsal and Amgain, 2010, Bhusal *et al.,* 2009).

With the advancement of the applied science, different types of the crop models have been evolved, among them; DSSAT ver. 4.5 is one which can help to investigate a range of issues from crop management (Jones *et al.*, 2003). Climate change simulation on growth and yield performance of various crop cultivars is other advantages provided in this crop simulation model. The CSM-CERES-Maize embedded in DSSAT model (version 4.0) has only been tested over a wide array of location except a very few locations in Nepal (Timsina, 1997, Sapkota et *al.*, 2008; Bhusal *et al.*, 2009) and found satisfactory, but not the version 4.5. Further testing of this version covers the sub-tropical climate of central Nepal and will be a highly valued scientific work as a climate resilient adaptive research for proper decision making especially with regards to spring season maize.

The present investigation was therefore designed to assess the productivity level of spring maize planted on staggered dates. Simultaneously, the simulation modeling was also done to assess the growth, phenology, yield of promising maize cultivars using CSM-CERES maize model with the following objectives.

1.2 Objectives

Broad objectives

- To increase the productivity of spring maize genotypes under rainfed upland condition of central-terai.

Specific objectives

- To find out the optimum planting dates for different maize genotypes grown under rainfed upland condition during spring.
- To estimate the effect of agro-climatic indices on various maize genotypes.
- To evaluate the CSM-CERES-Maize model for its ability to simulate agronomic management and climate change parameters on growth, phenology and yield of various maize genotypes.

2 LITERATURE REVIEWS

The materials/literatures reviewed from different sources have been placed in this heading.

2.1 Rainfed farming

Rainfed farming is a crop production in regions with annual rainfall more than 1150 mm, but excludes of irrigation from streams and underground sources. Sometimes it may include supplementary irrigation from dams or tanks fed from rainfall and associated runoff on particular landholdings. About 93% of farm land is rainfed in sub-Sahara Africa, 87% in Latin America, 67% in the Near East and North Africa, 65% in East Asia, and 58% in South Asia (FAO, 2002). Rainfed agriculture is practiced in 80% of the world's physical agricultural area and generates 62% of the world's staple food (FAOSTAT, 2005).

Nearly 20% of irrigated areas supply about 40 % of world's food demand. Irrigated areas are almost saturated with modern farming techniques. The gap between actual yield and potential yield of rainfed area is very high. In the future, rainfed areas are the only source to cope increasing demand of the increasing population. Historic trends show a growing yield gap between farmers' practices and farming systems that benefit from management advances (Wani *et al*., 2003).

2.2 Status of rainfed maize production in Nepal

In Nepal, about 65% of the total arable land is under rainfed (Thapa, 1995). The rainfed farming plays an important role in Nepalese economy. Rainfed agriculture has always been an important part of the agriculture sector. Nearly half of all food grains are grown under rainfed conditions and hundreds of millions of poor rural people depend on rainfed agriculture as the primary source of their livelihoods.

Maize is considered as important cereal of Nepal. It is cultivated in 871387 ha (MoAC, 2011-2012). Out of this spring maize occupies 14.2 % area (MoAD, 2011). In terai and inner terai regions of Nepal, spring maize is cultivated in low-land with sufficient soil moisture remained after rice cultivation. While, late spring maize is cultivated in upland rainfed condition because lowland often gets submersed during rainy season. Majority of western part of Nawalparasi lacks irrigation facilities so spring maize in this area is totally based on rainfall. In terai and inner terai, Rice-wheat-maize and Maize-mustard cropping patterns are much popular.

2.3 Climate change in Nepal

According to the Intergovernmental Panel on Climate Change (IPCC), the mean global surface temperature increased by 0.74 ^{o}C during the 20th century. Since 1971, rates of land surface temperature have been increasing at the alarming rate of between 0.23 and 0.28 ^{o}C per decade. This continuing trend coupled with changes in rainfall patterns and greater frequencies of extreme weather events are likely to have adverse effects on the global population.

Nepal is no exception: it is a vulnerable country because of its unique and fragile mountain ecosystem. Nepal has been ranked fourth in a new global ranking of the most vulnerable countries in the world in the concern of climate change. The observed trends of rising temperature in Nepal is challenging the IPCC projections, as it seems that land areas will warm more rapidly than the global average. Associated with temperature change, monsoon precipitation patterns have also undergone changes, with decreasing rainy days and increasing high-intensity rainfall-extreme events resulting in intense and frequent water- induced disasters such as landslides, debris flows, and floods (Adhikari, 2004).

2.3.1 Changing temperature

According to Synnott (2012), there is a general agreement that average temperatures in Nepal increased at an annual rate of 0.06 ^{o}C between 1977 and 2000, with a 0.04 ^{o}C increment in the terai and 0.08 ^{o}C increment in the Himalayas. Warming patterns have been most pronounced at higher altitudes and more so during the winter months as opposed to the monsoon season. Warming has also been greater in the western half of the country than in the eastern half. Baidya *et al* (2008) found a general increasing trend in the extreme temperature events with a consistent higher magnitude in the mountains than in the plains.

2.3.2 Changing precipitation pattern

While there is evidence that more intense precipitation events have been occurring, there are currently no definite trends in precipitation or reliable projections for the future. This is largely due to lack of data from few functioning meteorological and hydrological stations scattered across the country. According to IPCC (2007), despite this significant dearth of data, a few general observations have been made: 1) The western half of Nepal is considerably drier than the eastern half; 2) regions that receives less average rainfall have shown a higher degree of warming; 3) the timing of monsoon when Nepal receives 75-80 percent of its annual rainfall, has become increasingly unpredictable Although the effects of rainfall variation tend to be site-specific, delayed onset of monsoon had made planting date much unpredictable and typically has an adverse impact on crop yields.

2.4 Climate requirement of maize

Maize is a warm weather plant. It grows from sea level to 3000 metre altitude. It can be grown under diverse conditions. It is grown in many parts of the country throughout the year. Winter season is the main growing season in terai parts of Nepal. Spring maize is planted at any time from mid-February to April. Maize requires considerable moisture and warmth temperature from germination to flowering. The most suitable temperature for germination is 21°C and for growth 32°C. Extremely high temperature and low humidity during flowering damage the foliage, desiccate the pollen and interfere with proper pollination, resulting in poor grain formation. Fifty to seventy-five centimeter of well distributed rain is conducive to proper growth of maize. Maize is very sensitive to stagnant water, particularly during its early stages of growth.

2.5 Effect of heat stress in spring maize

Heat stress can be defined as temperatures above a threshold level that results in irreversible damage to crop growth and development and is a function of intensity, duration and the rate of increase in temperature. Furthermore, different plant tissues and organs, and different developmental stages are affected by heat stress in different ways, depending on the susceptibility of the dominant metabolic processes that are active at the time of stress (Larkindale *et al.,* 2005). Accumulated or acute high temperatures can cause an array of morphological, anatomical, physiological and biochemical changes within maize.

By the end of this century, growing season temperatures will exceed the most extreme seasonal temperatures recorded in the past century (Battisti and Naylor, 2009). Elevated temperature negatively affects the seedling and vegetative stages of crop. During the autotrophic phase of germination, plant energy is directly affected by soil temperature (Stone, 2001). High temperature reduces both seedling percentage and growth (Weaich *et al.,* 1996). In maize seedling growth is maximized at a soil temperature of 26 °C and above this temperature, root and shoot mass both decline by 10% for each degree increase until 35 °C when growth is severely retarded (Walker, 1969). Reduced seedling growth has been suggested to be associated with poor reserve mobilization, with reduced protein synthesis observed in seedlings grown under elevated temperatures (Riley, 1981).

Seedlings growing in high soil temperatures are likely to suffer further damage as the associated slower growth rate, delays canopy closure, consequently reducing soil shading. Above 35 °C, maize leaf elongation rate, leaf area, shoot biomass and photosynthetic CO_2 assimilation rate decreases (Watt, 1972). Elongation of the first internode and overall shoot growth of maize has been suggested as the most sensitive processes of the vegetative stage to high temperatures (Weaich *et al.*, 1996).

High temperature is also detrimental to reproductive organs. Successful grain set in maize requires the production of viable pollen, interception of the pollen by receptive silks, transmission of the male gamete to the egg cell, initiation and maintenance of the embryo and endosperm development (Schoper *et al.,* 1987). Pollen produced under high temperature has reduced viability. Pollen production and/or viability have been highlighted as major factors responsible for reduced fertilization under high temperatures. Additionally, high temperature is responsible for reduced water potential in pollen, quantity of the pollen shed and pollen tube germination.

Maize kernel weight is the product of the rate and duration of grain filling, both of which are affected by temperature. High temperature during this period is associated with a reduction in the duration of grain filling (Badu-Apraku *et al.,* 1983; Hunter *et al.,* 1977; Muchow, 1990).

Heat stress during grain filling reduces endosperm starch content, the primary constituent of kernels (Singletary *et al.*, 1994). Cheihk and Jones (1994) studied the effect of heat stress (35°C) on sink activity of maize kernels in vitro. Heat stress was not associated with reduced carbon supply to the kernel, suggesting that the effect of heat stress was related to changes in carbon utilization and partitioning. Thus, heat stress did not reduce sink activity by reducing kernel uptake of sugars but by adversely affecting the conversion of sugars to storage products. High temperature reduces the number and/or size of endosperm cells formed thereby reducing sink capacity (Jones *et al.*, 1984). During this stage heat stress affects cell division, sugar metabolism and starch biosynthesis, reducing subsequent dry matter accumulation within kernels (Commuri and Jones, 2001; Engelen-Eigles *et al.*, 2000; Monjardino *et al.*, 2005).

2.6 Effect of drought in spring maize

2.6.1 Drought effects during vegetative growth

Pre-anthesis stress reduces leaf and stem elongation through reduced cell expansion and extension (Kiziloglu *et al.*, 2009), decreasing plant height (Traore *et al.*, 2000) and LA (Cakir, 2004). Short internodes and reduced leaf area limit assimilate storage for grain filling causing decreased kernel weight (Moser *et al.*, 2006). Reduced leaf numbers have also been observed under severe drought occurring prior to tassel initiation (Kiziloglu *et al.*, 2009).

Under typical drought situations, the primary limitation to maize photosynthesis is reduced leaf internal CO_2 concentration which is caused by stomata closure as leaves attempt to minimize water loss through evaporation (Bruce *et al.*, 2002; Saccardy *et al.*, 1996; Wolfe *et al.*, 1988; Xianshi *et al.*, 1998), reducing photosynthesis due to lower interception and conversion of PAR into biomass (Moser *et al.*, 2006; Otegui *et al.*, 1995; Welcker *et al.*, 2007).

Pre-anthesis drought affects kernel number and kernel weight through canopy size reduction (Pandey *et al.*, 2000). In some situations, harvest index (HI) can increase with pre-anthesis stress (Lorens *et al.*, 1987; Moser *et al.*, 2006). Most of this could be due to reduced vegetative growth and shorter plants, followed by relatively normal ear growth.

2.6.2 Drought effect during flowering

Sensitivity of crops to drought is dependent on stage of development (Doorenbos and Kassam, 1979) and is the highest during and just after flowering (Banziger *et al*., 2000;

Grant *et al.*, 1989). Severe stress during flowering results in kernel abortion and significant reduction in kernel set, causing yield losses of 50-100% (Bolanos and Edmeades, 1993; Grant *et al.*, 1989; Pandey *et al.*, 2000). This supports findings by Doorenbos and Kassam (1979) who reported that maize was about 3-4 times more prone to drought if water stress occurred during anthesis rather than during vegetative growth or grain filling, with much less yield loss encounter if stress occurred during ripening stages. The most drought susceptible period is considered to be approximately 2 weeks either side of anthesis (Boomsma and Vyn, 2008; Shaw, 1974; Schussler and Westgate, 1995). Kernel number determination occurs during this period (Jamieson *et al.*, 1995). Cakir (2004) observed a 20% reduction in KN when water stress occurred at tasseling, vs 32- 35% if stress coincided with the tasseling to ear formation stage. Since maize grain yield is highly correlated with KN under drought stress (Bolanos and Edmeades, 1996), yield depression under severe stress at flowering is not surprising.

Water stress immediately prior to silking usually slows ear growth more rapidly than tasseling growth, thereby increasing anthesis to silking interval (Banziger *et al.*, 2000; Campos *et al.*,2004; Farre and Faci, 2006). Delays in silking emergence of up to 8 day under drought conditions have thus been documented (Hall *et al.*, 1981., 1981; Herrero and Johnson, 1981; Grant *et al.*, 1989). This significantly reduces chances of successful pollinations since pollen grains only have a limited lifespan (Bassetti and Westgate, 1994). Longer ASI is negatively correlated with grain yield (Bolanos and Edmeades., 1996) because of a reduction of kernel number caused by loss of silk receptivity, decline in fertilization and an increase in embryo abortion (Westgate, 1997;Banziger *et al.*, 2000;Bruce *et al.*, 2002). The delay in silking results in decreased male-female flowering synchrony or increased anthesis-silking interval (ASI). Early field experiments reported 82

% reduction in grain yield as ASI increased from 0 to 28 days (Du Plessis and Dijkhuis, 1967, Edmeades *et al.,* 1993).

2.6.3 Drought effect in grain filling stage

Drought negatively affects all stages of maize growth and production, the reproductive stage, particularly between tassel emergence and early grain-filling, is the most sensitive to drought stress. Drought stress during this period results in a significant reduction in grain yield, associated with a reduction in kernel size (Bolanos and Edmeades, 1993). Leaf growth, final size and orientation, and growing kernels are the main determinants of source and silk strengths through their respective relations with light interception and yield (Welcker *et al.,* 2007). Reduced photosynthetic rate during grain filling decreases source flux, thus minimizing assimilate flux to the developing ear.

During grain filling, water stress influences KW differently, depending on growth stage (Bajwa *et al.,* 1987; Roy and Tripathi., 1987). Stress within the first 3-4 weeks of grain filling leads to kernel abortion while stress in last 3-4 weeks leads to shriveled grain and accelerated leaf senescence (Edmeades *et al.,* 2000).

2.6.4 Effect of solar radiation

Provided all factors are non-limiting, accumulative IPAR is strongly related to total biomass accumulation (Edwards *et al.,* 2005) and grain yield (Wilson *et al.,* 1995). Both IPAR and RUE determine assimilate production rate, which is critical for growth, kernel set and grain filling (Bonhomme, 2000).

Tollenaar *et al.* (1992) found that newer maize hybrids with improved stress tolerance produced more kernels per plant and per unit area under stressful condition than the older counterparts. This was attributed to high crop growth rates (CGR) during silking improved partitioning of assimilate to the developing ear, and a greater tendency to prolificacy. Newer hybrids also have improved leaf-stay-green characteristics which increase cumulative IPAR during grain filling (Duvick, 1992; Rajcan and Tollenaar, 1999). The sunny condition that generates less LA per plant prolongs plant-stay-green ,extend crop duration and thus, reduced the degree of remobilization from the stem. The cool temperature slow development rate, consequently increasing photo-thermal quotient, which is the ratio of cumulative IPAR to cumulative TT. Higher PTQs are therefore associated with greater yields. Plants are also shorter in cool conditions, thus reducing lodging susceptibility.

Solar radiation provides the energy for the processes that drive photosynthesis, affecting carbohydrate partitioning and biomass growth of the individual plant components (Boote and Loomis, 1991).

Even though CGR is directly proportional to IPAR, grain filling rate is not greatly affected by day to day variation in photosynthesis (Cirilo and Andrade, 1996). Periodic variation in assimilate supply can be cushioned through remobilization of soluble carbohydrate from stalks (Daynard *et al.,* 1969). Remobilization should however be considered a short-term supplier of photosynthesis (Banziger *et al.,* 2000). Prolonged remobilization may exhaust stem reserves, shortening grain filling and inducing lodging (Cirilo and Andrade, 1996).

2.7 Spring maize in Nepal

Spring maize is the dominant crop in upland terai condition in the country, usually followed by pulse, or mustard. Summer, spring and winter maize occupies area of 73.9%, 14.2% and 11.9% respectively. (MoAD, 2011).Spring maize has been gaining momentum in the khet (low) and bari (up) land of central terai, inner-terai and in mid-hill as rice-maize and maize-mustard systems since the earlier time, respectively.

It is grown with onsets of moderately warm temperature during February- March and ends with hot and dry periods in May, which is also accompanied by occasional and erratic west monsoon at the beginning and some initial shores of East monsoon rains towards the end in May. The maximum temperature during the spring reaches in Nepal up to 40 ^{0}C in May (Carson, 1993; Thapa and Dangol, 1988). The drought, excess of monsoon rains (flood and water logging), soil erosion and landslide, soil fertility declining, plant pests (insects, weeds, diseases etc.) problems, limited the choice of crops grown, climatic misfortune (high temperature, speedy wind, hot dry wind, hail, frost etc.), low rate of inputs and poor input management, poor economy of farmers, etc are encountered in spring grown under rainfed condition of Nepal.

2.8 Effect of climate change in spring maize production

Maize production in rainfed area is based on climatic factors. For spring maize, rainfall is the pre-dominant factor that is governing its grain production. Maize is planted during February when soil moisture is favorable for germination of maize seed. However, there is high chance of post spring drought problem if rainfall doesn’t occur timely. It has even caused total crop failure and highly reducing spring maize production. But changing climate has brought unpredictable rainfall pattern. Traditional rainfall in Nepal during Jestha and Ashar (mid-July) has shifted in Shrawan and Bhadra (Pokharel, 2011). This rainfall exhibits high coefficient of variation particularly in dry-terai region. Skewed distribution has now become more common with reduction on number of rainy days. Aberrations in monsoon which include delay in onset, long dry spells and early withdrawal, all of which affect the crops, strongly influence the productivity levels (Lal, 2001). Higher temperatures, increased evapo-transpiration and decreased winter precipitation may bring about more droughts in Nepal (Alam and Regmi, 2004). Increasing extreme temperature and drought problems has highly reduced spring maize productivity and production level in rainfed areas.

2.9 Climate change adaptation in maize

As mentioned by IPCC's 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 maize production, there are some adoptive options like development and release of site specific heat tolerant cultivars, adjusting of sowing/ planting time and choice of cultivars with a growth duration allowing avoidance of peak stress periods are some of the adoptive measures against effect of global warming.

2.10 Adoption of crop management practices

Late spring maize production is very risky. Climate change has added even more risk, challenging the traditional maize production system. Lately planted spring maize is exposed to extreme heat. Heat stress is increasing even more as temperature is increasing due to global warming and shifting of rainfall pattern has added more droughts.

Of all the management aspects of growing a maize crop (cultivar selection, planting density, amount and timing of fertilizer etc.), planting date is probably the most subject to variation because of the great differences in weather at planting time between seasons and within range of climates (Otegui *et al*, 1995). Adjusting 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). Choice of correct planting dates helps to prevent sensitive stages of crop such as flowering against adverse situations such as intense rainfall, extreme temperatures and drought etc.

2.11 Effect of planting date on grain yield

Shepard *et al.* (1991) reported that early planting date could contribute significantly to higher maize yields. It also allows harvesting earlier in the season when conditions are usually better in field and losses can be minimized (Hicks *et al.*, 1993).

According to Aldrich *et al.* (1975) yield reduced in late plantings could be attributed to short growing duration, insect and disease pressure, heat and moisture stress during pollination. These results were in agreement with those by Otegui and Melon (1997), who reported that delayed planting are generally accompanied by increased temperatures during the growing season, which accelerate crop development and decrease accumulated solar radiation, resulting in less biomass production, kernel set and grain yield.

Khan *et al*. (2002) reported that grain yield of maize decreased with delay in sowing dates. Crops planted on 2nd May recorded maximum grain yield followed by crops planted on 9th May while minimum grain yield was observed in crops sown on 13th June. Maximum grain yield with early sowing might be due to prolonged growing period, more number of grains row^{-1} and high grain weight with early planting.

2.12 Effect of planting date on kernel number

Variation in planting date is commonly found to have an influence upon the number of grains ear^{-1} (Harris, 1984). Otegni and Melon (1997) reported that planting dates affects the kernel set and flower synchrony within ear of maize. Cirilo and Andrade (1994) suggested that kernel abortion rather than a morphogenetic process was the dominant factor determining the final kernel set.

Reduced kernels ear^{-1} are the most consistent, irreversible component of yield reduction under drought stress (Anderson *et al.*, 2004). The number of florets that may become kernels cannot exceed exposed silking number and declines from this potential as silks lose receptivity and senesce with age (Bassetti and Westgate, 1993). Hybrids with faster silk growth rates have more silks available for pollination at the beginning of flowering. However, when environmental conditions are below optimum kernel number may be limited by asynchrony (pollen is not shed when silks are exposed or receptive) (Anderson *et al.*, 2004), loss of silk receptivity (Silk is no longer functional to support pollen tube growth) (Bassetti and Westgate, 1993) or developmental failure of the ovary. Such limitations to Kernel number may have drastic impacts on grain or seed production profitability and may be influenced by silk characteristic for a given hybrid or inbred (Anderson *et al.*, 2004).

2.13 Effect of planting date on kernel mass

Higher temperature during crop growth period accelerates the development and phenological characters of maize. So, the crops maturing faster have lower dry mass at anthesis. This kind of tendency for later planted crops gives lighter grains. Thus in most findings, grain mass is either unaffected or reduced by later planting by upto 10 percent (Taylor and Blackett, 1982). Maddonni (2004) supports that the individual grain mass for a given cultivar is a relatively stable character. However, when delay in the start of grain filling by a few days coincides with a rapid deterioration in the environment, much larger effects can be anticipated. In conclusion, grain yield generally declines with delay in spring sowing, principally as a consequence of decreases in ear number, but also in some cases because of small decreases in individual grain mass. Maddonni *et al*. (2004) reported that kernel mass is conditioned by post-silking crop growth, with more dependence on reserve mobilization in hybrid with small kernels and large kernel number than in hybrids with fewer kernels of large size. Therefore reduction of solar radiation reduces final kernel mass through reductions in biomass production per kernel.

2.14 Effect of planting date on growth and dry matter yield

Variation in maize planting date modifies the radiation and thermal conditions which are supposed to be important requirement for crop growth and development. The amount of incident radiation and the proportion of this radiation that is intercepted by the crop directly determine crop growth rate (Cirilo and Andrade, 1994). Cirilo and Andrade (1994) reported that delays in planting date determined important reductions in the amount of incident radiation accumulated from emergence to silking, because it hastened development. Inversely, high temperature during early growth of late plantings hastened leaf area development as shown by their high early percentage photosynthetic active radiation (PAR) interception values. Hesketh and Warrington (1989) also reported similar temperature effects on leaf appearance rate and on leaf expansion in maize. Thus higher temperature retard crop growth and development.

2.15 Stress tolerant maize cultivars in Nepal

Gurung *et al* (2010) conducted an experiment at National Maize Research Program (NMRP) farm, Rampur, Chitwan during the summer season of 2010 to identify and select the heat tolerant maize genotypes from fourty four genotypes under investigation. Observations on days to tasseling and silking, plant height, ear height, ear length, ear diameter, plant aspect, ear aspect, unfilled ear, non grain ear, stem borer, wilt and grain yield were taken. Among the tested genotypes, Manakamana-4, Upahar, TLBRSSO7F16 and BGBY POP performed equally better in all tested locations and their grain yields were found higher, hence they were promising genotypes under heat stress growing conditions based on findings of this research.

Gurung *et al* (2011-2014) conducted a project entitled as “Development of high yielding and drought tolerant OPVs suitable for mid hills of Nepal” at National Maize Research Program, Rampur. They found genotypes namely, S99TLYQ-A, Synthetic-B, Rampur S03F08, Gaurav, TLBR07F16, Upahar, S00TLYQ-AB, OEHPW, RPOP-1, RPOP-4, Manakamana-4, RPOP-2, GLSYW, SOOTLYQ-B, Tereai Pool Yellow, Arun-2, OBATANPA, Khumal Yellow/Pool-17 and RPOP-3 respectively were found promising drought tolerant genotypes for hills.

The need for new alternatives for a sustainable agriculture (Khush, 1999), such as drought-tolerant plants, will provide a practical solution to alleviate the problem of water limitation. Most of the alternatives are based either on accelerating the selection of natural varieties or/ and inserting genes from plant varieties or species with capacity to provide drought tolerance.

2.16 Criteria for selection of suitable maize cultivar

The traits important for performance under drought and/or heat stress include enhanced root density and depth, transpiration efficiency, phenology and duration, rapid establishment, early vigor, lower stomatal conductance, slow wilting, leaf angle, leaf reflectance, delayed leaf senescence, accumulation and mobilization of carbohydrates and nitrogen from leaf and stem to grain, osmotic adjustment, and heat shock proteins and dehydrins.

Gurung *et al* (2011-2014) conducted a project entitled as “Development of high yielding and drought tolerant OPVs suitable for mid hills of Nepal” at National Maize Research Program, Rampur. They concluded grain yield, short anthesis and silking interval and stay-green are major indices for identification of drought tolerant genotypes.

Shorter-duration cultivars escape drought because they complete their life-cycle before the occurrence of drought, whereas long-duration cultivars have greater chances of being exposed to severe drought or heat stress, particularly, during the later stages of crop development. Since maize production in developing countries is extensively dependent on rainfed agriculture, vulnerability due to erratic rainfall and weather variability may be combated using extra-early hybrids (Oseni and Masarirambi, 2011). Early maturing varieties offer flexibility in planting dates which enables (1) multiple planting in a season to spread the risk of losing a single crop to mid season droughts (2) late planting during delayed onset of rainfall and (3) avoidance of known terminal drought during the cropping season (Pswarayi and Vivek, 2007).

One of the important components of tolerance to drought is enhanced soil moisture capture, which is possible by increased exploration of soil by the roots. Deeper roots will enable water absorption from greater depth. Cultivars with deeper root systems, when compared with shallow root systems are generally more tolerant to drought stress during critical stages of crop development. Extensive root growth and distribution of roots will help explore larger soil volumes and thus may provide plants greater access to water and nutrients under drought conditions. Plants will transpire more to keep the canopy cool; this cooling is only effective in the presence of water. Therefore, improved root systems will enable plants to transpire and keep the canopy cooler for longer periods of time during heat stress condition.

Drought studies have focused on the identification of the genetic basis of yield, yield components and secondary traits including increased flowering synchrony (ASI), root architecture, growth maintenance and stay-green (Ribaut *et al.*, 2009).

Stay-green genotypes retain chlorophyll in their leaves and maintain the ability to carry out photosynthesis longer than the senescent types, and are often shown to have a yield benefit (Borrell *et al.*, 2001; Jordan *et al.*, 2003). The stay-green trait and remobilization of stem carbohydrate reserves to grain have been explored under heat (Fokar *et al.*, 1998) and drought stress (Palta *et al.*, 1994; Yang *et al.*, 2000).

With respect to the importance of phenology to heat stress, Tewolde *et al.* (2006) identified and quantified the characteristics of wheat cultivars adapted to production systems with risks of heat stress during the post-heading period. They conclude that early-heading cultivars out-performed later-heading cultivars because of two distinct advantages: the early-heading cultivars had a longer post-heading period and, therefore, a longer grain-filling period than the later-heading cultivars. In addition, early-heading cultivars would have completed a greater fraction of the grain-filling duration earlier in the season when air temperatures were lower and generally more favorable. The advantage of earlier- heading cultivar was also manifested in the amount of green leaves retained to anthesis. Earlier-heading cultivars produced fewer total leaves per tiller but retained more green leaves and lost fewer leaves to senescence at anthesis than later-heading cultivars. The results suggest that early heading is an important and effective single trait defining wheat cultivars adapted to production systems prone to high temperature stress during post-flowering period (CIAT, 2001; CIMMYT, 2003).

2.17 Simulation modeling

Simulation models are designed for the purpose of imitating the behavior of a system. They are mechanistic and in the majority of cases they are deterministic. Since they are designed to mimic the system at short time intervals (daily time-step), the aspect of variability related to daily change in weather and soil conditions is integrated. The short simulation time-step demands that a large amount of input data (climate parameters, soil characteristics and crop parameters) be available for the model to run. These models usually offer the possibility of specifying management options and they can be used to investigate a wide range of management strategies at low costs.

Management decisions regarding cultural practices and inputs have a major impact on yield. Simulation models, that allow the specification of management options, offer a relatively inexpensive means of evaluating a large number of strategies that would rapidly become too expensive if the traditional experimentation approach were to be adopted.

Many publications are available describing the use of simulation models with respect to cultural management (planting and harvest date, irrigation, spacing, selection of variety type) and input application (water and fertilizer).

Crop simulation models are being more widely used over the past 20-30 years by scientists to hypothesize ways to improve agricultural production under seasonal and daily variability in weather. Model capture much of what we know about crop growth responses to factors of temperature, solar radiation, rainfall, soil traits and crop management (Boote *et al.*, 1998). Increased levels of CO_2 and other greenhouse gases are contributing to global warming with associated changes in rainfall pattern. Assessing the effects of these changes on crop yield is important at the producer as well as at the government level for planning purposes. Despite objections raised by Passioura (1996), the simulation approach remains the best tool for quantifying these effects. In Mauritius, the APSIM-Sugarcane model was used to assess the vulnerability of the sugar industry to climate change and to quantify the impact of a limited range of mitigation possibilities (e.g., irrigation adoption, variety type and harvest date) on cane and sucrose yields (Cheeroo-Nayamuth and Nayamuth, 2000). The CROPGRO, CERES and EPIC models, AUSCANE as well as many others have been used to quantify yield change resulting from global climate change.

2.18 Decision support system for agro-technology transfer (DSSAT 4.5) crop simulation model (CSM)

The Decision Support System for Agro technology Transfer (DSSAT) Version 4.5 is a software application program that simulates growth, development and yield as a function of the soil-plant-atmosphere dynamics. It is a computerized system to help resource planners and farmers make decisions as they seek solutions to specific agricultural problems. It comprises crop simulation models for over 28 crops. For DSSAT v4.5 to be functional it is supported by data base management programs for soil, weather, and crop management and experimental data, and by utilities and application programs. DSSAT v4.5 have been used for more than 20 years by researchers, educators, consultants, extension agents, growers, and policy and decision makers in over 100 countries worldwide. DASSAT was developed by IBSNAT. It was first released (v 2.1) in 1989; additional releases were made in 1994 (v 3.0) (Tsuji *et al.,* 1994), 1998 (v3.5) (Hoogenboom *et al.*, 1999) and 2002 (v 4.0).

These simulations are conducted at a daily step and, in some cases, at an hourly time step depending on the process and the crop model. At the end of the day the plant and soil water, nitrogen and carbon balances are updated, as well as the crop’s vegetative and reproductive development stage. DSSAT integrates the effects of soil, crop phenotype, weather and management options, and allows users to ask "what if" questions by conducting virtual simulation experiments on a desktop computer in minutes which would consume a significant part of an agronomist's career if conducted as real experiments. DSSAT v4.5 includes improved application programs for seasonal, spatial, sequence and crop rotation analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer and nutrient management, climate variability, climate change, soil carbon sequestration, and precision management.

DSSAT also provides for evaluation of crop model outputs with experimental data, thus allowing users to compare simulated outcomes with observed results. This is critical prior to any application of a crop model, especially if real-world decisions or recommendations are based on modeled results. Crop model evaluation is accomplished by inputting the user's minimum data, running the model, and comparing outputs with observed data. By simulating probable outcomes of crop management strategies, DSSAT offers users information with which to rapidly appraise new crops, products, and practices for adoption.

The following data set is required (Jones *et al.*, 1998) to run the model

- Weather: Latitude and longitude, daily solar radiation, Maximum and minimum air temperature and rainfall.
- Soil: Upper and lower horizon depths, texture, bulk density, organic carbon, pH and aluminum saturation.
- Management: Planting date, dates when soil conditions were measured prior to planting, planting density, row spacing, planting depth, crop variety, irrigation and fertilizer practices.

2.19 CERES-maize model

CERES- maize model is a process-based, comprehensive, deterministic simulation model, designed to simulate the effects of cultivar, planting density, weather, soil, water and in one of the version, nitrogen on crop growth, development and yield (Jones and Kiniry, 1986). This model is available as part of the DSSAT suite of the crop models designed to estimate production, resource use and risks associated with crop production practices (Tsuji *et al.*, 1994; Jones *et al.*, 1998).

2.19.1 Improvement of crop management practices

To raise yields and/or increase resource-use efficiency identification of low yields causing factors as well as improvement in crop management would be required. Crop models can be used strategically to evaluate management options and, in real time, to guide decision making. Locally validated CSMs have been used in numerous instances to develop improved crop management strategies for irrigation (Dogan et al., 2006; Hook, 1994), nitrogen management (Miao *et al.*, 2006; Thorp *et al.*, 2006), seedling dates (Carberry *et al.*, 1989; Saseendran *et al.*, 2005), and site-specific management (Fraisse *et al.*, 2001). Models have also been used to develop cultivar performance predictability when combined with geographic information systems (Loffler *et al.*, 2005).

2.19.2 Impact assessment of climatic variation

Schultze *et al.* (1996) used CERES-Maize to evaluate the impact of climate change in Africa. After employing different climate scenarios for the 21st centuary, they found that the CO_2 enrichment effect counteracted the relatively modest changes in temperature and precipitation. Studies concerned the effect of climate change and variability showed that the maize yields from CERES-Maize are sensitive to increased temperature and decreased precipitation eg. Maytin *et al* (1995) for Venezuela, Jinghua and Erda (1996) for China , Brown and Rosenberg (1997) for Central US. A negative correlation between maize yields and radiation over Europe was also reported by Wolf and Van Diepen (1995). Wolf (2002) considered a scenario with increased amounts of CO_2 and showed that yields increased in proportion to other variable changes such as solar radiation and temperature.

A.L, du Pisani used CERES-Maize as a drought prediction tool. The model is being used to assess drought impacts on maize at an early stage so that policy makers can have an objective measure to declare drought-stricken areas. To assess the impact of early season weather on crop yields, the model was run with actual weather data up to a given date. Historic data were used for the remainder of the growing season. Excellent correlations were found between yield predictions and actual yields.

3 MATERIALS AND METHOD

Materials and methods planned and executed during the study has been described in detail under different sub-headings are given below.

3.1 Description of the field experiment

3.1.1 Location and cropping history

A field experiment was conducted at Shivamandir VDC-2 of Nawalparasi district on maize (*Zea mays* L.) during late spring (April to August) season, 2013. The area is located at 27^{0} 66’ N latitude and 84^{0} 13’ E longitude with an elevation of 220 M above mean sea level. Millet- maize is the main cropping pattern in this area from last five years. However, maize is considered as suitable crop during spring.

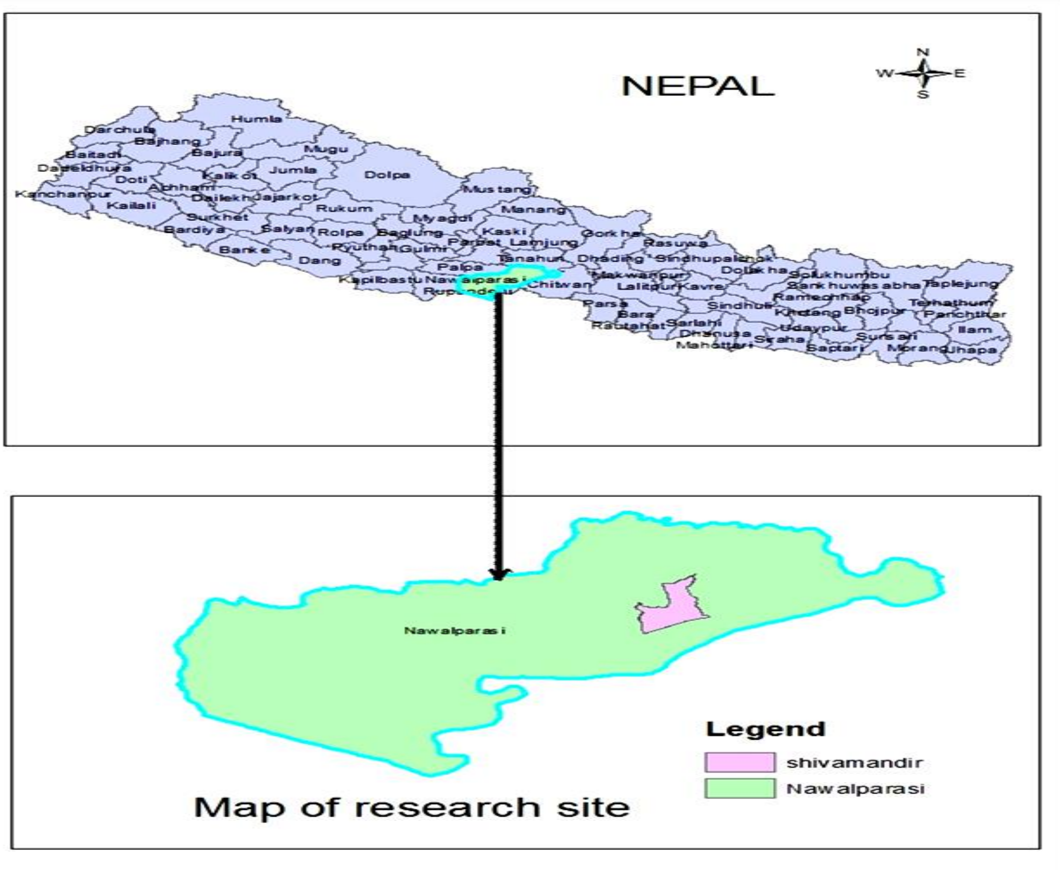

Figure 1. Map of Nawalparasi district showing research site (Shivamandir VDC)

3.1.2 Weather condition during experimental period

The experimental site lies in the sub-tropical humid climatic 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 to the east from research location.

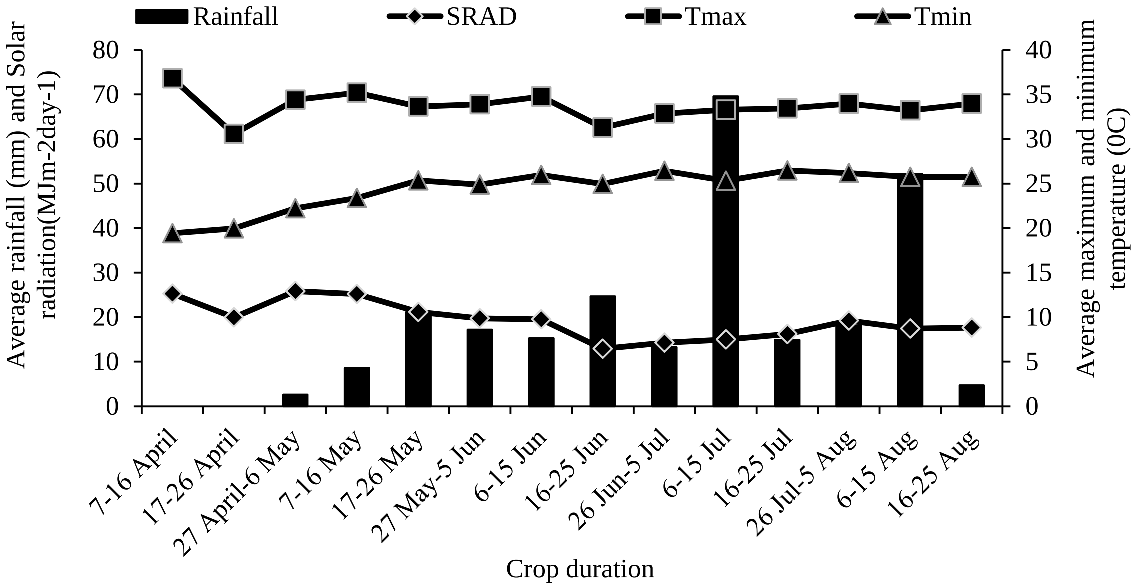

Figure 2. Average weather records during research period (10 days interval) at Shivamandir-2, Nawalparasi, 2013

The temperature during experimental period was hyper thermic. The highest maximum temperature was recorded during May (monthly average = 34.12 ^{0}C). After rainfall started from May, maximum temperature decreased slightly; however, minimum temperature was found increasing constantly and dropped slightly after July only. The highest minimum temperature was recorded during July (monthly average = 26.05 ^{0}C). Total rainfall received during research period (7th April to 27th August) was 2789.1 mm.

The brighter sunshine hour was recorded at the initial stages of maize planting during April-May, which drastically reduced in June-July due to initiation of monsoon.

3.1.3 Soil sampling and analysis

Soil of study site were collected from four different depth viz 0-20 cm, 20-40 cm, 40-60 cm and 60-80cm and their mechanical, physical and chemical properties were analyzed in soil laboratory of Soil Science Divisions of NARC, Khumaltar.

3.1.3.1 Mechanical analysis

The collected soil samples were analyzed by hydrometer method (Day, 1965) for soil texture. Sandy soil was found in all classified soil depths.

Table 1. Mechanical analysis of soil of experimental plot at Shivamandir-2, Nawalparasi during 2013

Soil depth (cm)	Clay (%)	Silt (%)	Textural type
0-20	6.1	4.9	Sandy soil
20-40	5.3	5.7	Sandy soil
40-60	5.8	5.1	Sandy soil
60-80	5.2	5	Sandy soil

3.1.3.2 Physical analysis

The highest and the lowest field measured water content of soil after it had been thoroughly wetted and allowed to drain until drainage become practically negligible is reflected by the drained upper limit and drained lower limit values. The value of soil moisture content at saturation, DUL and DLL was found decreasing with soil depth. The soil was found to be more compact under increasing soil depths and found the highest values of bulk densities at higher soil depth.

Table 2. Physical properties of soil of experimental plot at shivamandir-2, Nawalparasi during 2013

Soil depth (cm)	Drain upper limit (DUL) in bars	Drain lower limit (DLL) in bar	Soil moisture content at saturation in bar	Bulk density (g cm^{-3})
0-20	0.338	0.183	0.433	1.35
20-40	0.336	0.178	0.432	1.35
40-60	0.306	0.164	0.417	1.40
60-80	0.287	0.153	0.37	1.53

3.1.3.3 Chemical analysis

The soil of research site was found to be slightly acidic in nature. With the increment in the soil depth, the pH was found to be increased and last depth was found slightly basic. Likewise, the total nitrogen, available phosphorous and available potash in the experimental plot was found very high. Similarly, organic carbon (%) was found high to low and decreasing in order of soil depth. The chemical values of soil are presented in Table 3. Analysis of soil total nitrogen, phosphorous and potassium were done by using Kjeldhal distillation unit (Bremner, 1965), modified Olsen method (Watanabe and Olsen, 1965) and Neutral Ammonium Acetate method using Flame Photometer (Jackson, 1973), respectively. Similarly, soil pH and organic matter were analyzed through Blackman Glass Electrode pH meter (1:2.5 soil water suspension) (Wright, 1939) and Walkley and Blacks' titration method (1934) respectively.

Table 3. Chemical properties of soil of experimental plot during 2013 at Shivamandir-2, Nawalparasi

Soil depth	Soil pH	NH_4^+N (ppm)	NO_3^-N (ppm)	Total N (%)	Available P2O5 (Kgha^{-1})	Available k2O (Kgha^{-1})	Organic carbon (OC%)
0-20	6.2	8	15	3.5	58.0	132.5	3.1
20-40	6.3	6	18	3	48.0	123.5	1.4
40-60	6.6	5.7	19.5	2.7	46.0	120.0	1.5
60-80	7.4	5	21	2.5	40.0	117.0	0.4

3.2 Experimental details

3.2.1 Field layout for experiment

The experiment was conducted in two factorial Randomized Complete Block design (RCBD) consisting of 12 different treatments and each treatments was replicated thrice. Total area required for field to the layout was 799 m^2. It contained 36 plots. Plots were one meter apart. Each plot size was designed to maintain its 3 m width and 5 m length. Each plot contained 9 rows of maize in 3 m length. Crop geometry was 60 cm x 25 cm; row to row and plant to plant distance respectively. By this design, there were 12 plants per row, 108 plants per plot and 3888 plants in whole field. Out of 9 rows, two rows from outer periphery were considered as boarder rows, three rows for each net plot and destructive plot were allocated. Remaining one row from the middle, which separated destructive and net plot was selected as inter row.

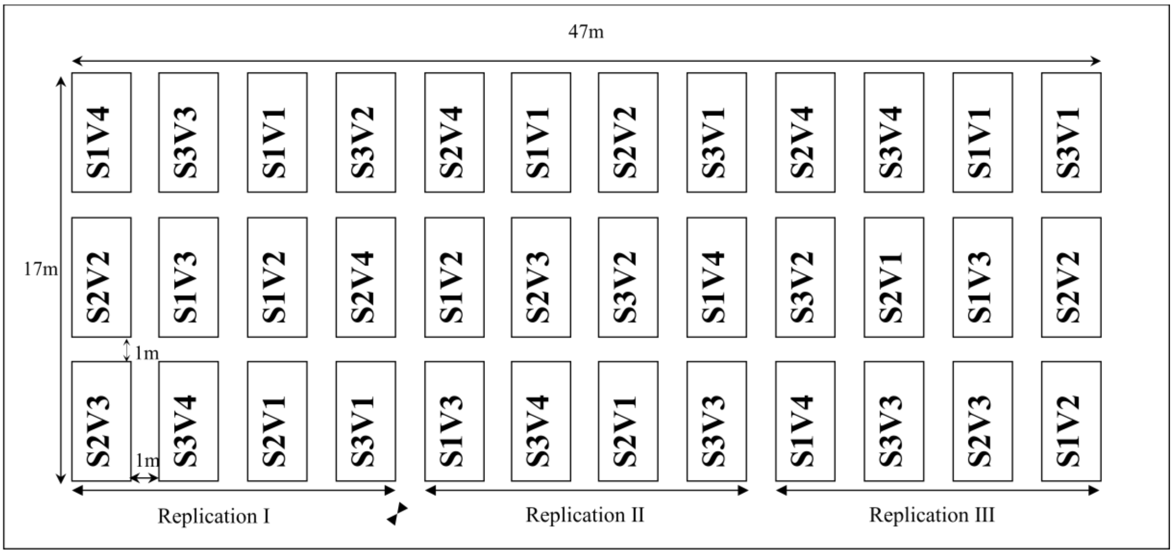

Figure 3. Layout of experimental field

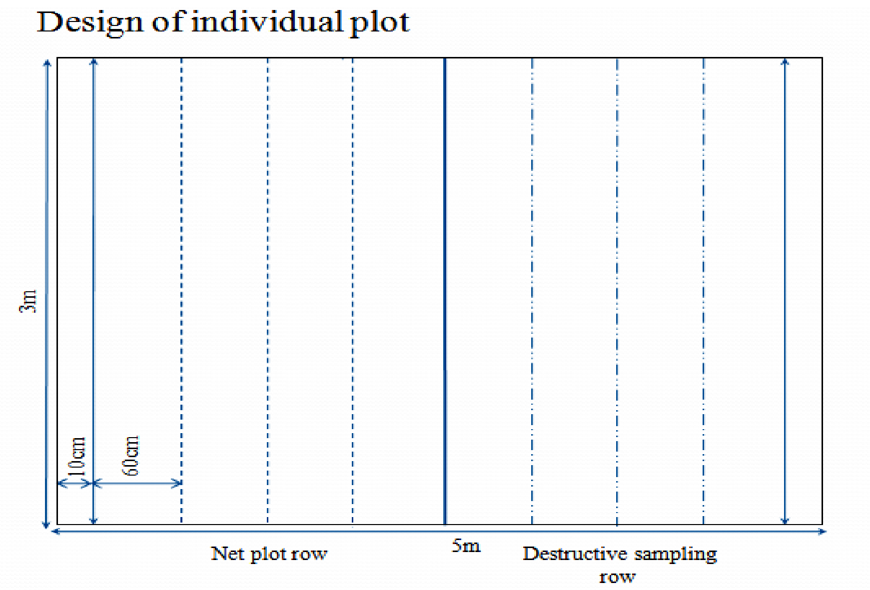

Figure 4. Layout of individual plot

3.2.2 Treatment details

Factor 1 (Sowing dates)

D_1 = 7th April

D_2 = 22nd April

D_3 = 7th May

Factor 2 (Varieties)

V_1= Local maize

V_2= Poshilo makai-1 (QPM)

V_3= RML-4/17 (Hybrid)

V_4= Arun-2

3.3 Description of tested maize cultivars

3.3.1 Local cultivar

This cultivar is also called Tharu makai by villagers in Shivamandir area. It is a dwarf and short durational variety. Yield potential was very low about 2.0 t ha^{-1}. It's kernel was pale yellow, small in size. Test weight was around 185 g and very susceptible to lodging.

3.3.2 Poshilo makai-1

It is normal season crop released in 2008 for the domain mid hill. The source of variety is CIMMYT (Mexico). Percentage includes S99 TLWQ-HG-“AB”. Variety is long durational with growth period of 140-145 days. Plant height is 210 cm. Yield potential of around 5.6 t ha^{-1}.This maize has white kernel which have doubled amount of Lysine and Tryptophan as compared to normal maize. The studies indicated that the QPM protein contains, in general, 55% more tryptophan, 30% more lysine and 38% less leucine than that of normal maize (Paes *et al.*, 1995). Several researchers later demonstrated the superior protein quality and its digestibility of QPM over normal maize (Bressani 1995, Graham *et al.*, 1980, Paes *et al.*, 1995).

3.3.3 RML-4/17

RML-4/17 is F1 of RML-4 and RML-17 cross. A coordinated varietal trail on hybrid was conducted at NMRP, Rampur in winter season of 2009/2010 to see their grain yield and other agronomic traits. At that time, plant height was recorded 208 cm. Ear height was 110 cm. Similarly, no of ears ha^{-1} was reported 48889. Grain yield of RML-4/17 was 7158 kg ha^{-1}.

3.3.4 Arun-2

Arun-2 introduced in 1976 was released in 1982 for low and mid-hill region as an early maturing variety. It was subsequently improved for earliness and uniform plant type through few cycles of mass and half-sib selection at Rampur (Mishra, 1982).It is derived from percentage Uncac 242 X Phil.DMr (Sub-tropical) = Amarilo 59 (temperate crop) and generally matures in 90 days. This variety is recommended for terai, inner terai and the hills (NMRP, 2000). Under monoculture conditions, short duration variety Arun-2 did better under high plant population (90 thousand ha^{-1}) with spacing of 50 X 25 cm^{-2} (Sen and Sthapit,1982). This genotype matured within 101 days during summer conditions even in the mid hills, Dailekh district (Koirala *et al.,* 2000). Arun-2 became very popular among farmers within a short span of time as it fits well into diverse type of cropping systems (Gauchan and Lal, 1990). The recommended package of practices for Arun-2 variety possess 46200 plant population ha^{-1}, 41100 numbers of ear ha^{-1} and 3.9 t ha^{-1} of yield during winter season under Rampur condition (Rijal *et al.,* 2000).

3.4 Cultural practices

3.4.1 Land preparation

Two to three cross ploughing of the millet harvested land was done before a week of planting with the help of tractor driven Mould Board Plough to make the soil loose and friable. After 4 days, the field was re-ploughed twice with tractor drawn harrow-spike to prepare fine seed-bed. However for second and third sowing dates, pre-planting manual weeding was done to make the plot weed free.

3.4.2 Fertilizer and manure application

The recommended dose of fertilizer was applied considering that there was no nutrient stress at any growth stages of maize. A total of 100:60:40 kg NPK ha^{-1} along with FYM @ 10 t ha^{-1} were applied. Half dose of N, and full dose of P_2O_5 and K_2O were used as basal before planting the seeds on (7th April, 22nd April and 7th May) and remaining half N was side dressed at knee height stage i.e. 42 days after sowing (DAS). The fertilizers used were Urea, Di-ammonium phosphate (DAP) and Muriate of Potash (MOP).

3.4.3 Seed rate and sowing

Bold, Bio-physically good and healthy seeds of local variety were selected while seed of other varieties were brought from NMRP. Two seeds per hill were dropped manually in the row line. The row to row distance and plant to plant distance were maintained 60 cm and 25 cm respectively. Sowing was done on 7th April, 22nd April and 7th May, 2013 as per treatment.

3.4.4 Gap filling and thinning

Gap filling was done on 15th DAS for all treatment to maintain desired level of plant population. By keeping one plant per hill, all other extra plants were removed maintaining required level of plant distances after 25 DAS.

3.4.5 Irrigation

Soil moisture during first sowing i.e. 7th April was critical for germination therefore, sprinkle irrigation was applied at the time of seed sowing that was 7th April and continued until proper germination upto 13th April for the first sowing.

3.5.6 Weed control

Comparatively, maize sown on 7th April was free of weeds, which was due to lack of rainfall. With the onset of rainfall, weeds emerged so that manual weeding was done at 22 DAS and 35 DAS.

3.4.7 Plant protection

Preventive measures of stem borer was done by the application of Carbofuran granules 3% CG @ 2-3 granules per plant was applied at knee height stage of crop for all sowing dates.

3.4.8 Harvesting and drying

Local, Poshilo makai-1, RML-4/17, and Arun-2 were harvested as per following schedule given in Table 4. Harvesting was done manually. Grain was dried under the roof of the house during day time till the grain moisture reached 15%.

Table 4. Date of harvesting of maize cultivars planted in different dates

Cultivars	Harvesting date of maize planted on different sowing dates		
	7th April	22nd April	7th May
Local	9th July	22nd July	5th August
Poshilo makai-1	29th July	13th August	27th August
RML-4/17	1st August	13th August	27th August
Arun-2	7th July	21th July	5th August

3.5 Observation recorded to estimate growth and yield attributes and grain response

3.5.1 Biometric observation

3.5.1.1 Leaf area index (LAI)

Leaf area of the plant was measured by taking 3 randomly selected plants from destructive sampling row of each plot at 30 DAS, 45 DAS, 60 DAS, 75 DAS, 90 DAS and 105 DAS by the use of leaf area meter at Central lab of IAAS. Leaves from the plants were detached and leaf area was measured, then after, leaf area index was calculated by dividing leaf area by ground area (Reddy and Reddi, 2005).

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

3.5.1.2 Leaf area duration (LAD)

The yield of dry matter is a function of leaf area and its duration, and the net assimilation rate. Assuming other management factors as constant, total assimilation is determined by the leaf area duration (LAD) i.e. the size of leaf area and the time periods through which it is retained. LAD of a crop is a measure of its ability to produce leaf area on unit area of land throughout its life. LAD is calculated by the formula:

$$\text{LAD (days)} = \frac{L_1+L_2}{2} \times (t_2-t_1)+\ldots\ldots\ldots+ \frac{L_{n-1}+L_n}{2} \times (t_n - t_{n-1})$$

Where, L_1 is leaf area index at the time t_1; L_2 is leaf area index at the time t_2; L_n= leaf area index at the time t_n and L_{n-1}= leaf area index at the time t_{n-1} (Reddy and Reddi, 2005).

3.5.1.3 Dry matter accumulation

After the measurement of leaf area, detached leaves were packed in the envelope and dried in hot oven for 48 hours at the temperature of 72 ^{o} C. The remaining portion i.e. stem of plant was vertically ruptured and then packed in the envelope and dried in hot oven for 48 hours at the temperature of 105^{o}C to get a constant weight for recording the periodic dry matter accumulation. Then, the dry weight of leaves and stem were taken in combination and expressed in t ha^{-1}.

3.5.1.4 Crop growth rate (CGR)

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

$$\text{Crop growth rate (CGR)} = \frac{W_2 - W_1}{SA\ (T_2 - T_1)}$$

Where, W_1 and W_2 are AGDM in gram at the time T_1 and T_2 respectively. SA is area occupied by the plant at each sampling.

3.5.2 Yield attributing characters

3.5.2.1 Number of harvested ears

Total numbers of ears harvested from net harvestable area were recorded as harvested ears plot^{-1} and it is converted in numbers ha^{-1}.

3.5.2.2 Number of ears plant^{-1}

The ears obtained from the net harvested plot were divided with the plant population of the individual plot to obtain total number of ears plant^{-1}.

3.5.2.3 Number of kernel rows ear^{-1}

Ten randomly selected ears from each plot were dehusked manually and all the kernel rows were counted and were reported as number of kernel rows ear^{-1}.

3.5.2.4 Number of kernels row^{-1}

Ten randomly selected ears from each plot were shelled manually and all the kernels were counted and were reported as number of kernels ear^{-1}.

3.5.2.5 Thousand grain weight (TGW)

One thousand shelled maize kernels from each plot were randomly taken, weighed and recorded as test weight and expressed in gram (g). The kernels used for test weight were corrected to 15% moisture content.

3.5.2.6 Grain moisture content (%)

Grain moisture content was taken after measuring the field ears weight. Ten ears were selected randomly. These ears were dried under roof of the house and central two kernel rows were shelled out. The moisture content was measured from bulked kernels taken from all ears. Multigrain moisture meter made by Farmex Company of USA was used to measure moisture.

3.5.2.7 Biological yield

The harvest produce from the sample row of individual plot was made the bundle and weight of bundle was considered as biological yield and expressed in t ha^{-1}.

3.5.2.8 Grain yield

After drying and shelling of the harvested produce of each sample row of individual plot, the grain yield was recorded. Grain yield was calculated on hectare basis by using following formulae:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{FEW x SP x (100- GMC)}}{\text{NHA x 85 x 10}}$$

Where,

FEW= Filled ears weight (kg)

SP= Shelling percentage (%)

GMC= Grain moisture at content harvest (%)

NHA=Net harvested area (m^2)

3.5.2.9 Stover yield

All maize stems with leaves was harvested from the base from the net harvested area and weighted immediately after harvesting. Husk was also included while taking stover yield. Stover yield was calculated on hectare basis in t ha^{-1}.

3.5.2.10 Harvest index

Harvest index (HI) was computed by dividing economic yield with the biological yield as per the following formula.

$$\text{HI} = \frac{\text{Economic yield or Grain yield (t/ha)}}{\text{Biological yield (t/ha)}}$$

3.6 Observation recorded to estimate agro-climatic indices

3.6.1 Days to phenological stages

3.6.1.1 Emergence

Seed emergence was recorded when about 50% of the seedling had emerged out of the soil.

3.6.1.2 Days to 75% tasseling

The date of tasseling was recorded from tassel emergence to 75 % of plant had tasseled in each plot .Ten plants from net plot rows were taken for each phenological observation.

3.6.1.3 Days to 75% silking

The date was recorded from the initiation of silk to 75% silking in each plot. The silk exposed 1cm from closed ear was considered as emerged silk. The same rows as that of tasseling records were taken for days of silking.

3.6.1.4 Days to 75% physiological maturity

The appearance of blank layer between ear surface and ear grains and occurrence of senescence of ear husks was considered as an indication to physiological maturity.

3.6.1.5 Heat units

The various measurements of accumulated heat units were calculated according to the following formulae of Rajput (1980).

3.6.1.5.1 Growing degree days: $\{(T_{max}-T_{min})/2\}-T_b$

Where: T_b =Base temperature= 10^{o}C

3.6.1.5.2 Phenothermal index (PTI) = GDD/Growth duration

3.6.1.5.3 Heat use efficiency = Grain yield (kg/ha)/ GDD

3.7 Statistical analysis

Analysis of variance (ANOVA) (Rangaswamy, 1995) for all recorded parameters was done using MS Excel and MSTAT-C computer based package. All the analyzed data were subjected to both Least Significant Difference (LSD) and Duncan’s significance was considered at 5% level for significance test.

3.8 Observation estimation for model testing

3.8.1 Simulation modeling

To assess growth, phenology and yields of maize and to see the impact of climate change, field data under varietal and sowing dates experimentation were inserted in various input file structures of CRRES-Maize model before its calibration, validation and evaluation.

3.8.2 Data requirements for model evaluation

Model requires a well-defined set of field data to simulate impact of climate in varietal performance of maize. For CERES-Maize model embedded in DSSAT 4.5 version, standard file formats have been developed where users can give input data in those formats for model calibration and evaluation (Tsuji et al 1994). For DSSAT-CSM-CERES-Maize, such input files are grouped into experimental details, soil, weather, species, ecotype, cultivar, and crop performance. Experimental details (i.e., agronomic management) were entered into FILEX, daily weather data into FILEW (with extension name WTH), and soil profile data into FILES, and cultivar (with extension name CUL) files. Performance files, FILEA and FILET were needed to enter the measured crop performance and soil conditions data. Description of Soil file, A file, T file, X file and weather file prepared for maize experiments have been given in appendices 14, 15, 16, 17 and 18 respectively.

3.8.3 Model calibration

Calibration consists of making adjustments to model parameters to give the best fit between simulated results and results obtained from measurements on the real system.

The data collected from the best treatment for each cultivar was used for calibrating the model, which was a process of adopting some model parameters to the local conditions by adjusting their values. Calibration was done as suggested by Tsuji *et al.* (1994). The calibration process involved of selecting an existing cultivar in the International

Benchmark Sites Network for Agrotechnology Transfer (IBSNAT, 1993) genetics data file similar to the one to be calibrated and its genetic coefficients were used.

To estimate the genetic coefficients, information from the four maize varieties (Local, Poshilo makai-1, Hybrid-4/17 and Arun-2) planted each on 7th April were used. An ecotype coefficient of IB0001 was used for all the four maize cultivars. A series of runs were made to calibrate the genetic coefficients were then used for validation and evaluation of model. To estimate the genetic coefficients associated with plant development (P1, P2 and P5), the information collected from the field experimentation on average thermal requirements to reach the anthesis and physiological maturity were used The two genetic coefficients controlling the rate of leaf appearance (PHINT) was adjusting until the predicted and measured final number of leaves matched.

3.8.4 Model validation and evaluation

The remaining data set, not used previously in model calibration was now used for validation and evaluation of model. The four varieties sown on 22nd April and 7th May was used for validation of the model. The parameters used for validation of the model are days to anthesis, days to physiological maturity, grain yield, no of kernel at maturity (no per m^2) and unit weight of kernel at maturity {g (dm)/ha}.

The model was evaluated using the root mean square error (RMSE) and index of agreement (D-Stat) statistics (Willmott, 1982). The d-stat of a good model should approach to unity and RMSE approach to zero. The RMSE is considered the best overall measure of model performance as it summarizes the mean difference in the units of observed and predicted values (Toit and Toit, 2003).

3.8.5 Sensitivity analysis

The sensitivity analysis was carried out as follows:

- The model used 7th April planting for all maize cultivars as a base to sensitivity of CERES-Maize to various parameters. Any kind of modification in the parameter would bring the change in out-put.
- The sensitivity of the model was tested for a wide range of variables (cultivars, sowing dates, weather years and different climate change scenarios) that influence yields of maize cultivars. Each variable to be tested for its sensitivity was altered once at a time and the model was re-run each time.
- Sensitivity to climate change parameters was done by altering minimum and maximum temperature by $\pm$ 2 ^{0}C, solar radiation by ± 1 $MJm^{-2}day^{-1}$ and CO_2 concentration increasing by 20 ppm.

4 RESULTS

This section deals about results obtained during the investigation, and shown with the help of tables as well as figures wherever suitable. Basically, it consists of three features a) results obtained from effect of sowing dates and maize cultivars on growth attributes, grain yield and yield attributes as analyzed statistically. b) effect of agro-climatic indices like growing degree days, phenothermal index and heat use efficiency of various maize genotypes and c) evaluate the CSM-CERES-Maize model for its ability to simulate agronomic management and climate change parameters viz. phenology and yield of various maize genotypes.

4.1 Statistical analysis

4.1.1 Growth attributes of maize

4.1.1.1 Above ground dry matter (AGDM)

The differences between the dry matter means of maize planted on various sowing dates were significantly ($p<0.05$) different at all DAS except at 45 DAS (Table 5). At 30 DAS, dry matter accumulation was the highest for maize planted on 7th May (0.474 t/ha), followed by dry matter (0.289 t/ha) of sowing date 22nd April and the lowest (0.207 t/ha) of sowing date 7th April. The mean dry matter accumulation observed for 7th April planting were 5.762 t/ha, 8.532 t/ha and 10.12 t/ha during 60, 75 and 90 DAS, respectively, which were significantly higher than 22nd April sowing (5.064, 7.493 and 9.077 t/ha at 60, 75 and 90 DAS, respectively). Among the sowing dates the lowest dry matter accumulation was recorded for 7th May planting (4.866, 6.629 and 8.082 t/ha at 60, 75 and 90 DAS, respectively).

So far the dry matter production with respect to varieties was concerned; dry matter production was non-significant among the varieties at 30 DAS. At 45 DAS, dry matter accumulated by RML-4/17 (2.660 t/ha) was the highest and rest of the varieties had statistically similar dry matter accumulation whose mean values were 2.246 t/ha, 1.925 t/ha and 2.142 t/ha for Poshilo makai-1, Arun-2 and Local, respectively. At 60 DAS, dry matter accumulations were 6.297 t/ha, 5.289 t/ha, 4.727 t/ha and 4.610 t/ha ranking from the highest to the lowest for RML-4/17, Poshilo makai-1, Arun-2 and Local, respectively. Similarly at 75 DAS, RML-4/17 had 8.956 t/ha dry matter accumulation which was the highest among the varieties and rest of the varieties had statistically similar dry matter accumulation. In addition to this, at 90 DAS, dry matter accumulation were 11.60 t/ha, 8.778 t/ha, 8.015 t/ha and 7.971 t/ha ranging from the highest to lowest for RML-4/17, Poshilo makai-1, Local and Arun-2 respectively. Here also dry matter accumulation was statistically at par for Local and Arun-2.

At all growth stages, interaction effect of sowing dates and varieties were found non-significant ($p<0.05$) except at 75 DAS for dry matter accumulation. RML-4/17 planted on 7th April had the highest while Local planted on 7th May had the lowest dry matter accumulation among the treatments. Arun-2 and Local both planted on 7th April had higher dry matter production than RML-4/17 planted on 7th May. Similarly, Local cultivar planted on 22nd April had higher dry matter production than Poshilo makai-1 planted on 7th May.

Table 5. Effect of sowing dates and varieties on dry matter accumulation of maize at different growth stages during spring, 2013 at Shivamandir-2, Nawalparasi

Factors	Dry matter accumulation (t/ha)				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Sowing dates					
7th April	0.207c	2.273	5.762a	8.532a	10.120a
22nd April	0.289b	2.206	5.064b	7.493b	9.077b
7th May	0.473a	2.251	4.866b	6.629c	8.082c
SEm$\pm$	0.027	0.108	0.160	0.137	0.187
LSD (0.05)	0.080	NS	0.469	0.402	0.548
Varieties					
Local	0.339	2.142b	4.610c	6.938b	8.015c
Poshilo makai-1	0.298	2.246b	5.289b	7.396b	8.778b
RML-4/17	0.264	2.660a	6.297a	8.956a	11.600a
Arun-2	0.390	1.925b	4.727bc	6.916b	7.971c
SEm$\pm$	0.034	0.133	0.196	0.168	0.229
LSD (0.05)	NS	0.389	0.575	0.492	0.671
CV%	30.01%	16.72%	10.59%	6.29%	7.12%

Mean followed by common letter (s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant

4.1.1.2 Leaf area index

The sowing dates exhibited mean LAI significantly ($p<0.05$) different at all DAS (Table 6). At 30 DAS, LAI of maize planted on 22nd April was the highest and at par with maize planted on 7th May but the lowest for maize planted on 7th April whose values were 0.860, 0.823 and 0.319 respectively. At 45 DAS, LAI was the highest for maize planted on 7th April (2.750) followed by 22nd April (2.483) and the lowest on 7th May (2.004). At 60 DAS, LAI were 3.288, 3.111 and 2.770 for maize planted on 7th April, 22nd April and 7th May respectively. Statistically similar LAI of maize was observed between 7th April and 22nd April plantation at 60 DAS, it was higher than maize planted on 7th May for LAI values. The same trend of result of LAI at 45 DAS and at 75 DAS was overlooked and the values for mean LAI at 75 DAS were 3.007, 2.548 and 1.773 for 7th April, 22nd April and 7th May plantation, respectively.

The significant ($p<0.05$) difference on LAI due to varieties at various DAS was seen. At 30 DAS, mean LAI for RML-4/17, Poshilo makai-1, Arun-2 and Local were 0.820, 0.649, 0.621 and 0.579, respectively in order of the highest to the lowest values. RML-4/17 had the highest LAI than rest of the varieties had statistically similar LAI. At 45 DAS, RML-4/17 had highest LAI (2.898) followed by Poshilo makai-1 (2.535). While, Arun-2 and Local had statistically similar but the lowest LAI whose values were 2.148 and 2.068, respectively. At 60 DAS, mean LAI for RML-4/17, Poshilo makai-1, Arun-2 and Local were 3.818, 3.314, 2.779 and 2.315, respectively. RML-4/17 was the holding highest LAI followed by Poshilo makai-1, while Arun-2 had the highest LAI among short durational varieties, but lower than long durational varieties. At 75 DAS, LAI for RML-4/17, Poshilo makai-1, Arun-2 and Local were 3.044, 2.728, 2.255 and 1.744, respectively. Here, RML-4/17 and Poshilo makai-1 had statistically similar and higher LAI than Arun-2 and Local while, Local had the lowest LAI among the tested varieties.

Interaction effect of sowing dates and varieties on LAI was found significantly ($p<0.05$) difference at 30 DAS only. The LAI of RML-4/17 planted on 7th April was found lowest among the treatments, while same cultivar when planted on 22nd April and 7th May was found the highest in LAI among the treatments. Similarly Poshilo makai-1 planted on 7th April was the second lowest LAI producer among the treatments which was also statistically similar to RML-4/17 planted on 7th April. While, Poshilo makai-1 planted on 22nd April produced higher leaf area index among the treatments after RML-4/17 planted on 22nd April and 7th May.

4.1.1.3 Leaf area duration

The leaf area duration exhibited significant result due to sowing dates (Table 6). LAD for 7th April, 22nd April and 7th May were 170.1, 142.1 and 101.7, respectively. LAD for maize planted on 7th April was the highest followed by 22nd April and the lowest for maize planted on 7th May. Similarly varieties also showed significant result. RML-4/17 had the highest LAD (183.7) followed by Poshilo makai-1 (155.5) then Arun-2 (114.2) and local (98.30).

Table 6. Effect of sowing dates and varieties on leaf area indices (LAI) and leaf area duration (LAD) at different growth stages of maize during spring, 2013 at Shivamandir-2, Nawalparasi

Factors	Leaf area index				Leaf area duration
	30 DAS	45 DAS	60 DAS	75 DAS	
Sowing dates					
7th April	0.319^{b}	2.750^{a}	3.288^{a}	3.007^{a}	170.1^{a}
22nd April	0.860^{a}	2.483^{b}	3.111^{a}	2.548^{b}	142.1^{b}
7th May	0.823^{a}	2.004^{c}	2.770^{b}	1.773^{c}	101.7^{c}
SEm$\pm$	0.047	0.061	0.074	0.103	3.390
LSD (0.05)	0.137	0.178	0.216	0.301	9.943
Varieties					
Local	0.579^{b}	2.068^{c}	2.315^{d}	1.744^{c}	98.30^{d}
Poshilo makai-1	0.649^{b}	2.535^{b}	3.314^{b}	2.728^{a}	155.5^{b}
RML-4/17	0.820^{a}	2.898^{a}	3.818^{a}	3.044^{a}	183.7^{a}
Arun-2	0.621^{b}	2.148^{c}	2.779^{c}	2.255^{b}	114.2^{c}
SEm$\pm$	0.054	0.070	0.085	0.126	3.915
LSD (0.05)	0.158	0.205	0.249	0.368	11.48
CV%	24.04%	8.71%	8.34%	14.52%	8.51%

Mean followed by common letter(s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant

4.1.2 Yield attributing characters and yield

4.1.2.1 Grain and stover yields

Grain and stover yields were significant ($p<0.05$) different for sowing dates (Table 7). Maize planted on 7th April had the highest grain yield (5.13 t/ha) and stover yield (14.35 t/ha) followed by maize planted on 22nd April in both grain (4.10 t/ha) and stover (14.26 t/ha) yields, but stover yield of maize sown on 7th April and 22nd April were found to be at par. Maize planted on 7th May had the lowest grain (3.692) t/ha yield and stover (12.58 t/ha) yield.

In addition to this, both grain and stover yields were found to be statistically ($p<0.05$) different due to varieties but the result for both parameters were similar. Grain and stover yields were the highest for RML-4/17 followed by Poshilo makai-1 then Arun-2 and the lowest for Local. Mean grain yield at 15% moisture were 6.03 t/ha, 4.73 t/ha, 3.55 t/ha and 2.92 t/ha for RML-4/17, Poshilo makai-1, Arun-2 and Local, respectively. Similarly, mean stover yields were 17.18 t/ha, 14.47 t/ha, 12.62 t/ha and 10.64 t/ha for RML-4/17, Poshilo makai-1, Arun-2 and Local, respectively.

Interaction effects of sowing dates and varieties on grain and stover yields were significantly different. RML-4/17 planted on 7th April had recorded the highest grain yield followed by Poshilo makai-1 planted on 7th April. For rest of the treatments, RML-4/17 (planted on 22nd April and 7th May) had higher grain yield than Poshilo makai-1 (planted on 22nd April and 7th May), followed by Arun-2 (planted on 7th April, 22nd April and 7th May). The least grain yield was recorded for Local planted on 7th April, 22nd April and 7th May.

Similarly, RML-4/17 planted on 7th April and 22nd April had statistically similar and the highest stover yield among the treatments. Poshilo makai-1 planted on 7th April and 22nd April were statistically similar had higher stover yield after RML-4/17 planted on

7^{th} and 22^{nd} April but higher than RML-4/17 planted on 7^{th} May. Arun-2 planted on 22^{nd} April had the highest stover yield than Poshilo makai-1 planted on 7^{th} May and Arun-2 planted (7^{th} April and 7^{th} May). Local maize planted on 7^{th} May had higher stover yield followed by those planted on 22^{nd} April and 7^{th} April.

4.1.2.2 Harvest index

Harvest index showed significant ($p<0.05$) different due to sowing dates (Table 7). Maize planted on 7^{th} April had the highest HI while, lower and statistically similar HI was observed for maize planted on 22^{nd} April and 7^{th} May. The mean HI for maize planted at 7^{th} April, 22^{nd} April and 7^{th} May were 0.3474, 0.2893 and 0.2903, respectively.

As similar to sowing dates, HI was found to be significant ($p<0.05$) due to varieties. Long durational varieties had higher HI than short durational varieties. HI for Local, Poshilo makai-1, RML-4/17 and Arun-2 were 0.278, 0.326, 0.351 and 0.282, respectively.

Interaction effects of sowing dates and varieties on HI were found to be significant ($p<0.05$). RML-4/17 planted on 7^{th} April had the highest HI among the treatments. Poshilo makai-1 planted on 7^{th} April had highest HI than RML-4/17 planted 22^{nd} April and 7^{th} May. There was no statistically difference between Poshilo makai-1 planted on 22^{nd} April and 7^{th} May, Local (planted on 7^{th} and 22^{nd} April), Arun-2 planted on 7^{th} April and RML-4/17 planted on 22^{nd} April in their respective HI. Similarly, Arun-2 planted on 22^{nd} April and 7^{th} May had no statistical difference with Local planted on 7^{th} May however these values were lowest among the treatments.

Table 7. Effect of sowing dates and varieties on grain yields (t ha^{-1}), Stovar yield (t ha^{-1}) and harvest index of maize during spring, 2013 at Shivamandir-2, Nawalparasi

Factors	Grain yield at 15% MC (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
Sowing dates			
7th April	5.126^{a}	14.35^{a}	0.347^{a}
22nd April	4.104^{b}	14.26^{a}	0.289^{b}
7th May	3.692^{c}	12.58^{b}	0.290^{b}
SEm±	0.078	0.289	0.009
LSD (0.05)	0.227	0.849	0.027
Varieties			
Local	2.920^{d}	10.64^{d}	0.278^{b}
Poshilo makai-1	4.725^{b}	14.47^{b}	0.326^{a}
RML-4/17	6.030^{a}	17.18^{a}	0.351^{a}
Arun-2	3.554^{c}	12.62^{c}	0.282^{b}
SEm±	0.089	0.334	0.011
LSD (0.05)	0.262	0.980	0.033
CV%	6.23%	7.30%	9.15%

Means followed by common letter (s) with in each column are statistically similar at LSD 0.05

4.1.2.3 The yield components

Four key components of maize yields are number of ears ha^{-1}, number of kernel rows ear^{-1}, number of kernel row^{-1} and 1000 kernel weight. Both sowing dates and varieties had insignificant ($p<0.05$) difference for number of ears ha^{-1}.

The mean number of kernel rows ear^{-1} and kernels row^{-1} were found significantly ($p<0.05$) different due to sowing dates. The kernel rows ear^{-1} were 12.89, 12.47 and 12.22 and kernels row^{-1} were 27.97, 24.47 and 22.73 for maize planted on 7th April, 22nd April and 7th May, respectively. Maize planted on 7th April had the highest kernel rows ear^{-1} and kernels row^{-1} while that planted on 7th May had the lowest kernel rows ear^{-1} and kernels row^{-1} and 22nd April planting had intermediate. In addition to this, kernel rows ear^{-1} and kernels row^{-1} were found significantly different due to varieties. The kernel rows ear^{-1} were 13.77, 13.17, 11.86, 11.31 and kernels row^{-1} were 30.42, 26.13, 22.58 and 21.10 for RML-4/17, Poshilo makai-1, Arun-2 and Local, respectively. RML-4/17 had the highest kernel rows ear^{-1} and kernels row^{-1}. Poshilo makai-1 had the second highest value followed by Arun-2 and Local had the lowest values.

Interaction effect of sowing dates and varieties on kernel rows ear^{-1} was significantly ($p<0.05$) different. Poshilo makai-1 planted on 7th April had highest kernel rows ear^{-1} followed by RML-4/17 planted on 7th April, 22nd April and 7th May. However, statistically similar kernel rows ear^{-1} was found between RML-4/17 planted on 22nd April and 7th May. Then after, Poshilo makai-1 planted on 22nd April and 7th May had higher kernel rows ear^{-1}. From the result it was seen that, long duration varieties had higher number of kernel rows ear^{-1} than short durational varieties in all sowing dates. Among short durational varieties also, Arun-2 planted on 7th April and 22nd April had statistically similar and higher number of kernel rows ear^{-1} followed by Arun-2 planted on 7th May.

Similarly, interaction effect of sowing dates and varieties on kernel row^{-1} was significantly ($p<0.05$) different. Among the treatments, RML-4/17 planted on 7th April had the highest kernels row^{-1} while Local planted on 7th May had the lowest kernels ear^{-1}. Poshilo makai-1 planted on 7th April had the second highest kernel row^{-1} which was even higher than RML-4/17 planted on 22nd April and 7th May, which were statistically similar. Poshilo makai-1 when planted on 22nd April had higher kernels ear^{-1} than Arun-2 planted on 22nd April and 7th April, but when Poshilo makai-1 was planted on 7th May, kernels row^{-1} decreased and value was even lower than Arun-2 planted on (7th April and 22nd April) and also those values were statistically similar with Local planted on 7th April and 22nd April. Local cultivar planted on 7th May had lowest kernels row^{-1} among the treatments.

The test weight varied significantly ($p<0.05$) among sowing dates. Maize planted on 7th April and 22nd April had statistically similar 1000 grain weight, whose mean values were 232 g and 231.3 g, respectively while maize planted on 7th May had the lowest test weight (224.3 g). Test weight also varied significantly on the basis of maize varieties, RML-4/17 and Poshilo makai-1 had the highest test weight; 244.9 g and 241.2 g, respectively though they were statistically similar. Among short durational varieties, Arun-2 had the highest test weight (226.3 g) but its test weight was found significantly lower than long durational varieties. Local had small grain size and the lowest test weight of 204.4 g.

Table 8. Effect of sowing dates and varieties on yield attributing characters of maize during spring, 2013 at Shivamandir-2, Nawalparasi

Factors	Number of Ears ha^{-1}	Kernel rows ear^{-1}	Kernels row^{-1}	1000 grain weight (g)
Sowing dates				
7th April	59070	12.89^{a}	27.97^{a}	232.0^{a}
22nd April	57590	12.47^{b}	24.47^{b}	231.3^{a}
7th May	58150	12.22^{c}	22.73^{c}	224.3^{b}
SEm$\pm$	800.7	0.075	0.301	1.686
LSD (0.05)	NS	0.219	0.883	4.946
Varieties				
Local	59750	11.31^{d}	21.10^{d}	204.4^{c}
Poshilo makai-1	56540	13.17^{b}	26.13^{b}	241.2^{a}
RML-4/17	58270	13.77^{a}	30.42^{a}	244.9^{a}
Arun-2	58520	11.86^{c}	22.58^{c}	226.3^{b}
SEm$\pm$	980.7	0.092	0.369	2.065
LSD (0.05)	NS	0.268	1.082	6.058
CV%	4.76%	2.07%	4.16%	2.55%

Mean followed by common letter (s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant

4.1.2.4 Correlation regression studies

To assess relationship between yield attributing traits and grain yield, simple correlation coefficients were worked out. The highly significant positive ($p<0.01$) correlation were seen between grain yield and yield attributing traits like kernel rows ear^{-1} (0.906**), kernels row^{-1} (0.984**) and 1000 grain weight (0.786**).

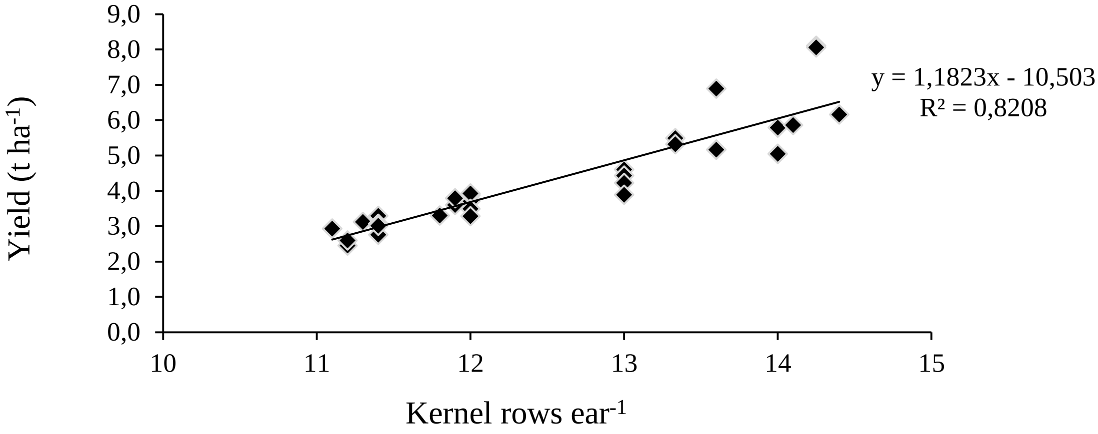

Figure 5. Relationship between grain yield and number of kernel rows ear^{-1} at shivamandir-2, Nawalparasi, 2013

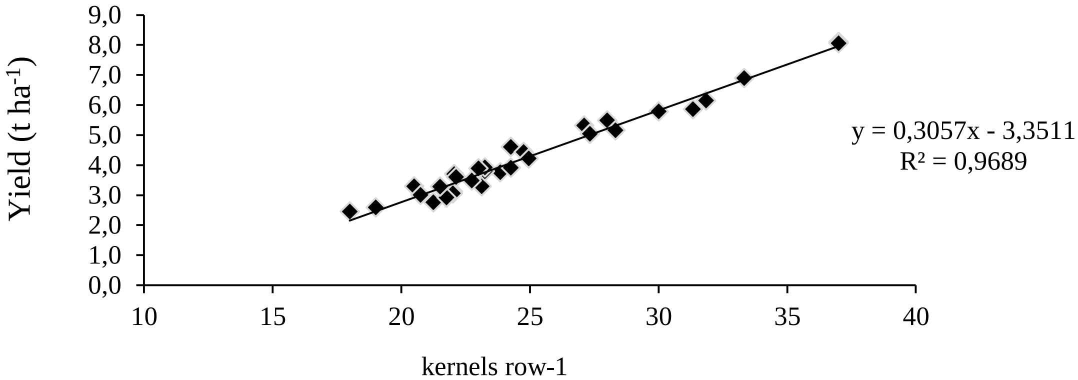

Figure 6. Relationship between grain yield and no of kernels per row at Shivamandir-2, Nawalparasi, 2013

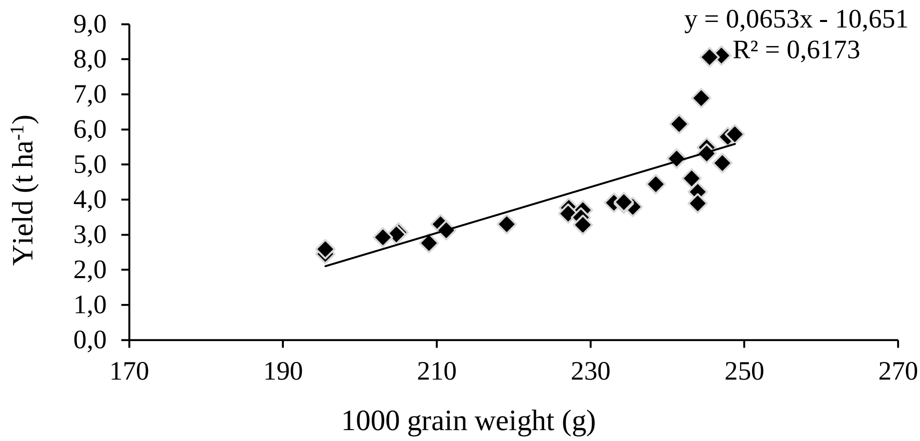

Figure 7. Relationship between grain yield and 1000 grain weight (g) at Shivamandir-2, Nawalparasi, 2013

The kernel rows ear^{-1} contributes approximately 82% (R^2= 0.82) on grain yield, hereas the remaining 18% increase in grain yield might be due to variables other than kernel rows ear^{-1}. Similarly, approximately 96.8% (R=0.968) contribution of kernels row^{-1} on grain yield. And the remaining 3.2% increase in grain yield was due to other variables except kernels ear^{-1}. The 1000 kernel weight contributed about 61.7% (R=0.617) towards grain yield. The remaining 38.3% contribution for increasing yield was given by the variables other than 1000 grain weight.

4.2 Effect of agro-climatic indices

4.2.1 Days to phenological stages

Sowing dates had shown significant ($p< 0.05$) difference on days to phenological stages (Table 9). Maize planted on 7th April, 22nd April and 7th May consumed 31.42, 28.08 and 28 mean days to attain knee height stage, respectively. Similarly to attain anthesis, it took 53.75, 52.42 and 52 mean days, respectively from earlier sowing to late sowing dates. To attain silking, it took 58.08, 56.25 and 55.75 mean days for 7th April, 22nd April and 7th May sowing dates respectively. No of days to attain knee height, anthesis and silking stages between 22nd April and 7th May plantings were found to be statistically at par but, maize planted on 7th April had consumed higher days to reach knee height, anthesis and silking stages. In addition to this, maize planted on 7th April consumed highest mean days (51.25 days) to accomplish seed filling followed by maize planted on 22nd April (50.83 days) and 7th May planting took least days (49.92 days).

Varietal performance had also shown statistically significant ($p < 0.05$) difference on days to phenological stages. At knee height stage, Poshilo makai-1 consumed highest mean days (31 days), while that of RML-4/17, Local and Arun-2 consumed 29, 28.33 and 28.33 days, respectively which were found statistically at par. At anthesis, Poshilo makai-1, RML-4/17, Arun-2 and Local consumed 60.33 days, 54 days, 48.22 days and 48.33 days, respectively. Similarly the days recorded for silking were 64 days, 57.78 days, 52.56 days and 52.44 days, respectively. Poshilo makai-1 took the highest days to reach anthesis and silking followed by RML-4/17, but Arun-2 and Local recorded the lowest days to attain those stages. RML-4/17 took the highest seed fill duration (60.67 days) followed by Poshilo makai-1 (53.67 days), Arun-2(43.67 days) and Local took (44.67 days).

The interaction effect of sowing dates and varieties on days to phenological stages was found non-significant ($p < 0.05$) at all the stages except at knee height stage. The interaction result revealed that hybrid-4/17 planted on 7th April recorded the highest days to attain knee height among the 12 treatments, while same hybrid planted on 22nd April and 7th May took lowest days to reach knee height stage. Poshilo makai-1, when planted on 7th April took higher days to attain knee height stage than Arun-2 and Poshilo makai-1 planted on 7th April and 22nd April, respectively. Local cultivar planted on all three sowing dates consumed statistically higher days to attain knee height stage than Arun-2 planted on 22nd April and 7th May.

Table 9. Effect of sowing dates and varieties on days to phenological stages of maize during spring season, 2013 at Shivamandir-2, Nawalparasi

Factors	Days to phenological stages (DAS)			
	Knee height stage	Anthesis	Silking	Seed fill duration
Sowing dates				
7th April	31.42[a]	53.75[a]	58.08[a]	51.25[a]
22nd April	28.08[b]	52.42[b]	56.25[b]	50.83[ab]
7th May	28.00[b]	52.00[b]	55.75[b]	49.92[b]
SEm$\pm$	0.439	0.431	0.459	0.423
LSD (0.05)	1.287	1.263	1.346	1.240
Varieties				
Local	28.33[b]	48.33[c]	52.44[c]	44.67[c]
Poshilo makai-1	31.00[a]	60.33[a]	64.00[a]	53.67[b]
RML-4/17	29.00[b]	54.00[b]	57.78[b]	60.67[a]
Arun-2	28.33[b]	48.22[c]	52.56[c]	43.67[c]
SEm$\pm$	0.538	0.527	0.562	0.518
LSD (0.05)	1.576	1.547	1.649	1.518
CV%	5.21%	2.83%	2.80%	2.89%

Mean followed by common letter (s) within each column are significantly similar

4.2.2 Growing degree days (GDD)

Sowing date exhibited significant different ($p<0.05$) GDD accumulation at different growth stages (Table 10). At knee height stage, GDD accumulation of maize planted on 7th April (545.4) and 7th May (540.3) were statistically at par but higher than 22nd April (514.4). At anthesis stage, maize planted on 7th May had accumulated the highest GDD (1007) followed by 22nd April (989.1) and the lowest by maize planted on 7th April (976.3). Sowing date for GDD accumulations at silking and seed fill duration was found to be non-significant.

Maize varieties also exhibited significant ($p< 0.05$) different for GDD accumulation at different growth stages. At knee height stage, Poshilo makai-1 accumulated the highest

(569.5) GDD while RML-4/17, Local and Arun-2 accumulated 530.3, 517.3 and 516.5 GDD, respectively. However, those values were statistically at par. At anthesis stage, Poshilo makai-1, RML-4/17, Arun-2 and Local accumulated 1138, 1016, 903.4 and 905.4 GDD, respectively. Poshilo makai-1, RML-4/17, Arun-2 and local accumulated 1210, 1081, 989 and 987.1 GDD, respectively at silking. At both anthesis and silking stages, Poshilo makai-1 accumlated highest GDD followed by RML-4/17 while GDD accumulated by Arun-2 and Local cultivar were statistically at par and were lowest among the varieties. At seed fill period, it was found that, RML-4/17 had accumulated the highest (1190) GDD, followed by Poshilo makai-1 (1054), lowest by Arun-2 (851.7) and local (870.8) which were statistically at par.

Interaction effect of sowing dates and varieties on GDD accumulation at different growth stages was found to be significant ($p<0.05$) at knee height stage only. Among the 12 treatments, RML-4/17 planted on 7th April had the highest (596.2) GDD accumulation, while same variety RML-4/17 planted on 22nd April (481.4) had the lowest GDD accumulation at knee height stage. After RML-4/17 planted on 7th April, Poshilo makai-1 had led in GDD accumulation. Arun-2 planted on 7th April, Local planted on 22nd April and RML-4/17 planted on 7th May had statistically at par.

Table 10. Effect of sowing dates and varieties on growing degree days accumulated at different phenological stages of maize during spring season, 2013 at Shivamandir-2, Nawalparasi

Factors	Growing degree days, °C day			
	Knee height stage	Anthesis	Silking	Seed fill duration
Sowing dates				
7th April	545.4[a]	976.3[b]	1062	998.8
22nd April	514.4[b]	989.1[ab]	1066	991.1
7th May	540.3[a]	1007[a]	1072	985.5
SEm±	8.677	8.592	8.227	8.401
LSD (0.05)	25.45	25.20	NS	NS
Varieties				
Local	517.3[b]	905.4[c]	987.1[c]	870.8[c]
Poshilo makai-1	569.5[a]	1138[a]	1210[a]	1054[b]
RML-4/17	530.3[b]	1016[b]	1081[b]	1190[a]
Arun-2	516.5[b]	903.4[c]	989.0[c]	851.7[c]
SEm±	10.63	10.52	10.08	10.29
LSD (0.05)	31.17	30.86	29.55	30.18
CV%	5.64%	3.00%	2.67%	2.93%

Mean followed by common letter(s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant

4.2.3 Phenothermal index (PTI)

The sowing dates showed significant ($p< 0.05$) different phenothermal index at different growth stages (Table 11). Phenothermal index were 19.29, 18.31 and 17.35 at knee height stage; 19.36, 18.86 and 18.15 at anthesis stage; 19.24, 18.96 and 18.27 at siking stage and 19.74, 19.49 and 19.48 at seed fill period for 7th May, 22nd April and 7th April respectively. Maize planted on 7th May had highest PTI value while that of 22nd April and 7th April had intermediate and lowest PTI respectively at all growth stages. Statistically at par but the lowest PTI at seed fill period was recorded between maize planted on 7th April and 22nd April.

Effect of varietal performance on PTI at different growth stages was significantly ($p<0.05$) different at all growth stages except at silking stage. Poshilo makai-1 and RML-4/17 had statistically similar and higher PTI, while that of Arun-2 and Local had statistically similar but the lowest value of PTI at knee height, anthesis and seed fill period.

Interaction effect of sowing dates and varieties on phenothermal index was found to be significant at knee height stage, anthesis and seed fill duration. At knee height stage, Poshilo makai-1 planted on 7th May was exposed to higher GDD in short duration so it's PTI at this stage was higher than any other treatments. Just opposite to this, Local planted on 7th April had the lowest PTI. Local planted on 7th May had the second highest PTI value followed by Arun-2 and RML-4/17 planted on 7th May, which had statistically similar PTI value. It was seen that varieties maize planted late on 7th May had higher PTI values than planted on other sowing dates. All maize varieties planted on 22nd April had intermediate PTI values between first and third sowing dates. Among third sowing date also, long duration varieties had higher PTI values than short durational varieties.

At anthesis, maize varieties planted on 7th May had statistically similar and higher PTI values than rest of the treatments. Among the remaining treatments, RML-4/17 planted on 22nd April had higher PTI followed by other three varieties planted on same date, and also these varieties were statistically similar for their PTI values. At 7th April also, Poshilo makia-1 had higher PTI value, while other three varieties had statistically similar and the lowest PTI values.

At seed fill period, treatments planted on 7th May had higher PTI values among the treatments. RML-4/17 planted on 7th May had the highest PTI value followed by Poshilo makai-1 planted on same date. Both short durational varieties planted on 7th April and 22nd April had statistically similar but the lowest PTI values among the treatments.

Table 11. Effect of sowing dates and varieties on Phenothermal index at different phenological stages of maize during spring season, 2013 at Shivamandir-2, Nawalparasi

Factors	Phenothermal index			
	Knee height stage	Anthesis	Silking	Seed fill duration
Sowing dates				
7th April	17.35[c]	18.15[c]	18.27[c]	19.48[b]
22nd April	18.31[b]	18.86[b]	18.96[b]	19.49[b]
7th May	19.29[a]	19.36[a]	19.24[a]	19.74[a]
SEm±	0.022	0.013	0.066	0.009
LSD (0.05)	0.066	0.038	0.195	0.027
Varieties				
Local	18.26[b]	18.74[b]	18.83	19.50[b]
Poshilo makai-1	18.40[a]	18.87[a]	18.90	19.64 [a]
RML-4/17	18.35[a]	18.83[a]	18.73	19.62[a]
Arun-2	18.26[b]	18.74[b]	18.83	19.51[b]
SEm±	0.027	0.016	0.081	0.011
LSD (0.05)	0.080	0.046	NS	0.033
CV%	0.44%	0.23%	1.22%	0.16%

Mean followed by common letter (s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant

4.2.4 Heat use efficiency of maize

From the result (Table 12), it was observed that all the cultivars were more efficient at early planting condition than the late growing condition. RML-4/17 had markedly higher HUE (3.502) followed by Poshilo makai-1 (2.757), Arun-2 (2.190) and the lowest with Local cultivar (1.777) under 7th April planting condition. Under late planting condtions, all maize cultivars had reduced HUE at various magnitude in comparison to early planting condition by following same trend with little bit different between Arun-2 and Poshilo makai-1.At later planting dates, Arun-2 was second heat use efficient cultivar followed by Poshilo makai. The reductions in HUE for long durational maize cultivars were higher for 7th April vs 22nd April planting and for short durational cultivars HUE reduction was higher for 22nd April vs 7th May. The decrease in HUE due to late sowing depended on varieties and found to be higher in Poshilo makai-1 (36.742%) in between 7th April vs 7th May planting followed by RML-4/17 (31.296%) between 7th April vs 22nd April and Local cultivar (19.457%) between 22nd April vs 7th May planting.Arun-2 had less reduction in HUE amongst the planting time and therefore it can be concluded that it is the best cultivar for both early and late spring planting.

Table 12. Heat use efficiency (HUE) of different maize cultivars as affected by planting dates

Cultivars	Heat use efficiency (HUE)			Reduction (%) due to late sowing		
	April 7	April 22	May 7	April 7 vs April 22	April 22 vs May 7	April 7 vs May 7
Local maize	1.777	1.729	1.478	2.701	19.457	16.826
Poshilo makai-1	2.757	2.032	1.744	26.297	14.173	36.742
RML-4/17	3.502	2.406	2.36	31.296	1.912	32.609
Arun-2	2.190	2.147	1.803	1.963	16.022	17.671

4.3 CSM-CERES-MAIZE model

4.3.1 Model calibration

Model calibration or parameterization is the adjustment of parameters so that simulated values compare well with observed values. Using statistically analyzed data, various genetic coefficients of the maize cultivars under study were adjusted by using CSM-CERES-Maize model embedded under DSSAT v4.5. The meanings of the various genetic coefficients for maize cultivars are presented below:

P1: Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above a base temperature of 8^{o}C) during which the plant is not responsive to changes in photoperiod.

P2: Extent to which development (expressed as days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours).

P5: Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8^{o}C).

G2: Maximum possible number of kernels per plant.

G3: Kernel filling rate during the linear grain filling stage and under optimum conditions (mg/day).

PHINT: Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.

4.3.1.1 Calibrated genetic coefficients of tested cultivars

The genetic coefficient of maize cultivars were adjusted by running the model for 15 times with various possible changes in the genetic coefficients till the simulated values for parameters such as days to anthesis, physiological maturity day, grain yield matches with observed values for those observations. The value such as 230 (P1), 0520 (P2), 940 (P5), 360 (G2), 9.28 (G3) and 38.90 (PHINT) were adjusted for local; 400 (P1), 0.600 (P2), 1130 (P5), 590.9 (G2), 8.38 (G3) and 18.90 (PHINT) were adjusted for Poshilo makai-1; 380.0 (P1), 0.260 (P2), 1290 (P5), 816.9 (G2), 7.36 (G3) and 8.90 (PHINT) were for RML-4/17 and 230.0 (P1), 0.520 (P2), 910.0 (P5), 440.0 (G2), 9.88 (G3) and 38.90 (PHINT) for Arun-2.

Table 13. Genetic coefficients of maize cultivars during spring, 2013 at Shivamandir-2, Nawalparasi

Coefficients	Local cultivars	Poshilo makai-1	RML-4/17	Arun-2
P1	230	400	380	230
P2	0.520	0.600	0.260	0.520
P5	940	1130	1290	910
G2	360	590.9	816.9	440
G3	9.28	8.38	7.36	9.88
PHINT	38.90	18.90	8.9	38.90
Simulated				
Anthesis	49	61	56	49
Physiological maturity	94	114	116	92
Grain yield	3121	5933	7684	3765
Observed				
Anthesis	49	61	56	49
Physiological maturity	94	114	116	92
Grain yield	3124	5931	7685	3768

4.3.2 Model validation

Genetic coefficient of four varieties determined during calibration of the model was used for validation of the model. Model validation was done by comparing model performance against data collected on days to anthesis and physiological maturity, unit number of grain, unit grain weight and grain yield for all eight treatments (April 22 and May 7 planted varieties).

Model evaluation for development, yield and time-course of growth was performed using RMSE and index of agreement (D-index) as suggested by Willmott (1982) and Willmott *et al.* (1985). For all eight treatments model fairly predicted days to anthesis, days to physiological maturity, number at maturity (no m^{-2}), unit weight at maturity (g[dm]/unit area) and grain yield. Days to anthesis was well simulated with RMSE of 0.426 days and D-index of 0.998. Similarly, days to physiological maturity was simulated with RMSE of 0.674 days and D-index of 0.999. Agreement between simulated and observed grain number at maturity with RMSE of 85.287 grain per m^2 and D-index of 0.993 was found satisfactory. In addition to this, a good agreement between observed and predicted unit weight at maturity with RMSE of 0.012 g $kernel^{-1}$ and D-index of 0.854 was found. The grain yield was simulated with RMSE of 54.94 kg per ha and D-index of 1.0 against observed values of grain yield for all eight treatments. Overall performance of CSM-CERES-Maize embedded in DSSAT 4.5 was found satisfactory at Shivamandir-2, Nawalparasi.

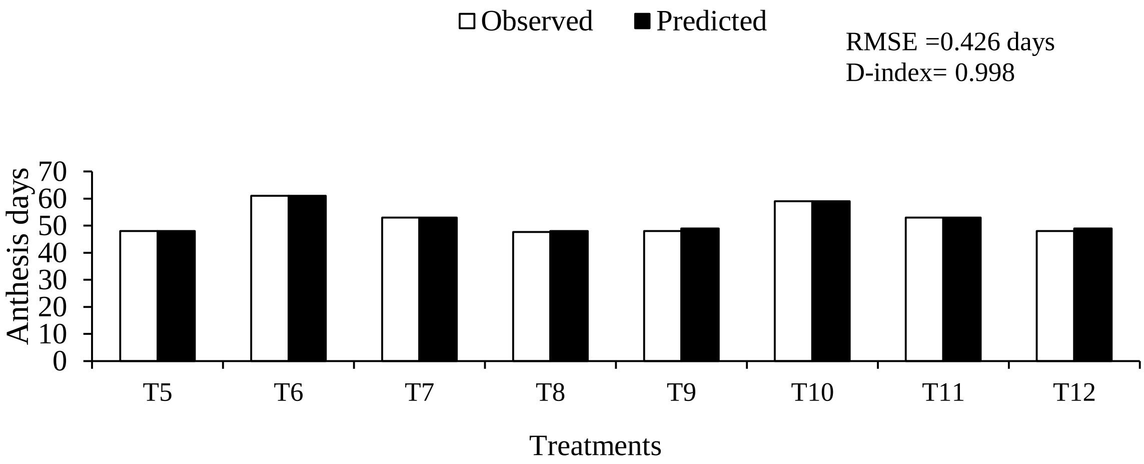

Figure 8. Simulated and observed anthesis days of treatments

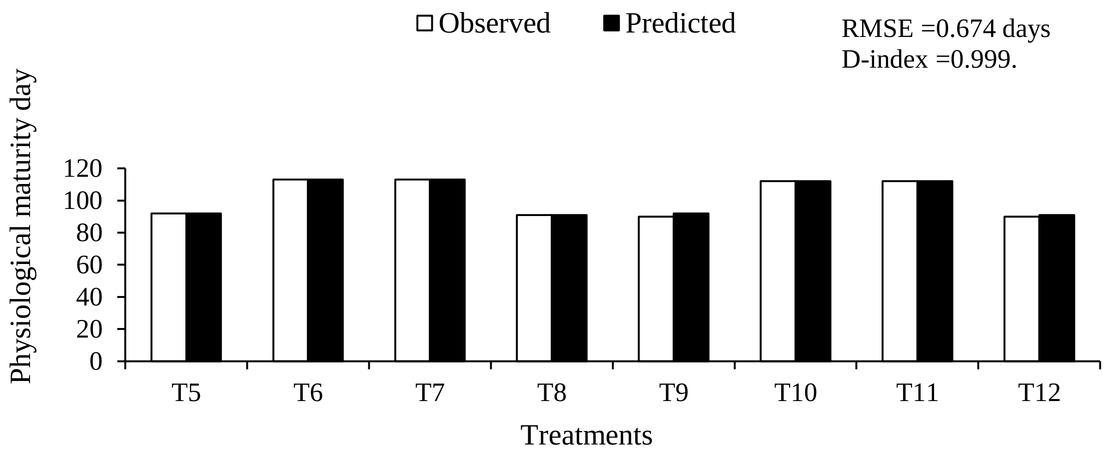

Figure 9. Simulated and observed physiological maturity days of treatments

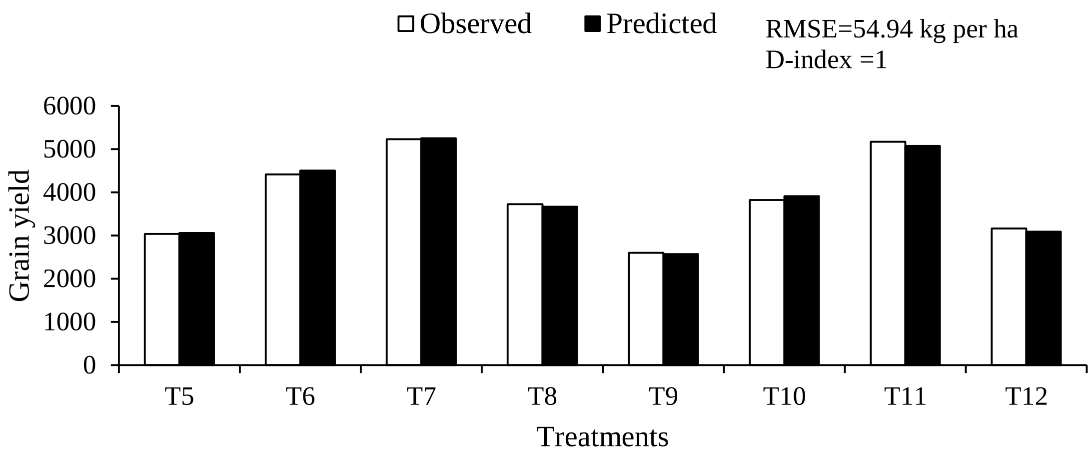

Figure 10. Simulated and observed grain yield of treatments

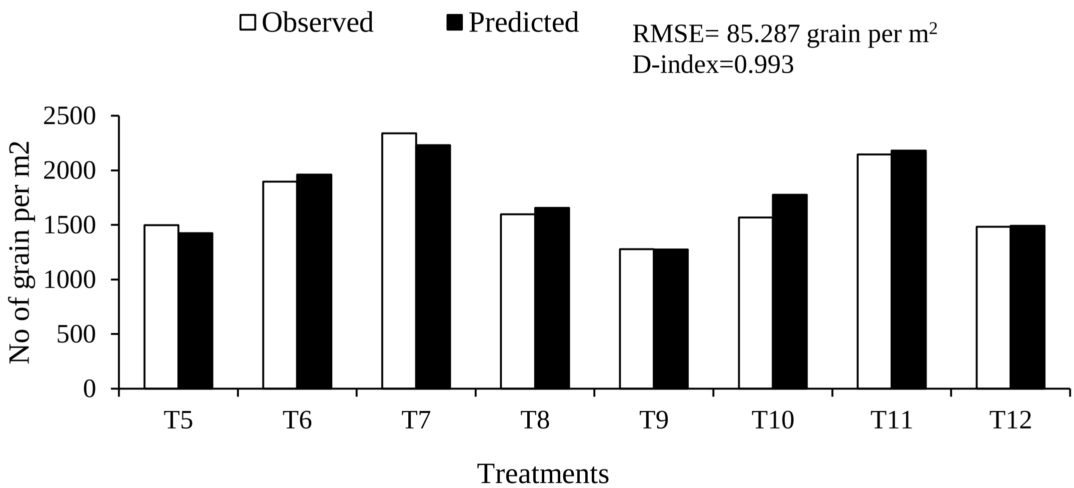

Figure 11. Simulated and observed no of grain per m^2 of treatments

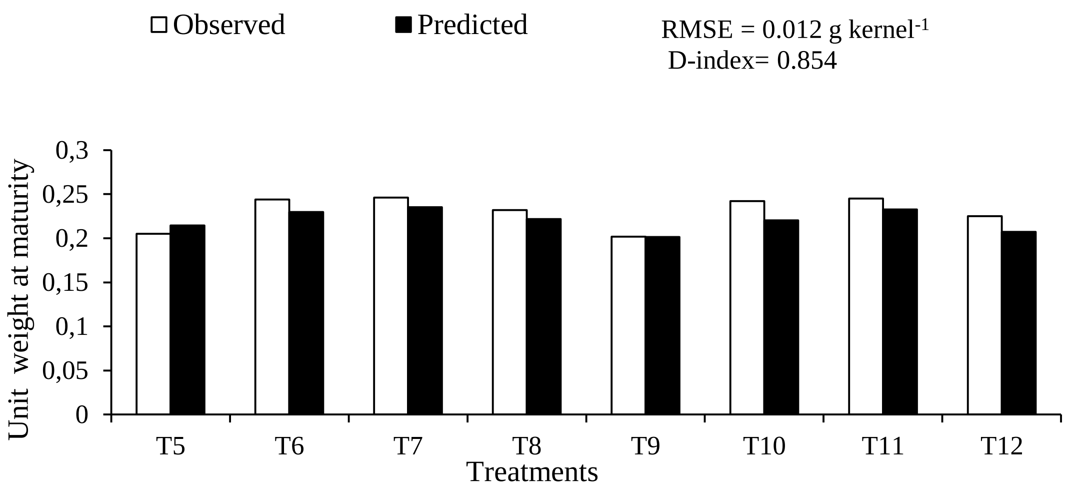

Figure 12. Simulated and observed unit weight at maturity for different treatments

4.3.3 Sensitivity analysis

4.3.3.1 Sensitivity analysis for sowing dates

Four sowing dates were used to study the sensitivity of simulated yield by using CERES-Maize model. The response of maize cultivars to sowing dates was different for each cultivar. Short durational varieties had positive effect on yield with increment of yield of Local cultivar by 11.78% and 16.61% and Arun-2 by 12.71 % and 18.81% when sensitivity analyses were done for 12th April and 17th April, respectively. Simulation for 27th April showed decreased in yield by 16.87% in Local and 15.84% in Arun-2 and it was decreased by 18.28% in Local and 18.13 % in Arun-2, when simulation was done for 2nd May plantation.

Similarly, the effect of sowing dates seems to be negative on yield of longer durational varieties too. The yield of Poshilo makai-1 decreased by 31.33%, 35.12%, 23.84% and 25.88% when sensitivity analysis was done for 12th April, 17th April , 27th April and 7th May, respectively. In case of RML-4/17, yield increased slightly by 2.51% when sensitivity was done for 12th April but it's yield also decreased by 28.11%, 20.01% and 23.84 % when sensitivity analysis was done for 17th April, 27th April and 2nd May, respectively.

For all varieties, postponing sowing date had shortening effect on growth period of all varieties.

Table 14. Sensitivity of simulated yields of maize cultivars to sowing dates

Sowing dates	Varieties	Simulated grain yield (kgha^{-1})	% yield change	Anthesis days	Maturity days
7th April*	Local	3124	100	49	94
	Poshilo makai-1	5931	100	61	114
	RML-4/17	7685	100	56	116
	Arun-2	3768	100	49	92
12th April	Local	3492	+11.78	49	93
	Poshilo makai-1	4073	-31.33	63	116
	RML-4/17	7878	+2.51	56	116
	Arun-2	4247	+12.71	49	92
17th April	Local	3643	+16.61	49	93
	Poshilo makai-1	3848	-35.12	61	114
	RML-4/17	5525	-28.11	56	116
	Arun-2	4477	+18.82	49	92
27th April	Local	2597	-16.87	46	90
	Poshilo makai-1	4517	-23.84	61	113
	RML-4/17	6147	-20.01	55	114
	Arun-2	3171	-15.84	46	89
2nd May	Local	2553	-18.28	47	90
	Poshilo makai-1	4396	-25.88	59	111
	RML-4/17	5853	-23.84	54	114
	Arun-2	3085	-18.13	47	89

* denotes standard treatment

4.3.3.2 Sensitivity analysis for no water stress condition

Maize planted on 7th April faced pre-vegetative drought stress so a simulation study on grain yield of maize cultivars under no water stress condition was done for their possible yield outcome. Under no water stress condition, model predicted yields of Local, Poshilo makai-1, RML-4/17 and Arun-2 would have been increased by 6.183%, 11.951%, 18.230% and 6.634% respectively.

Table 15. Sensitivity of simulated yields of maize cultivars to no water stress condition

Water management options	Varieties	Simulated grain yield (Kgha^{-1})	% yield Change
Rainfed condtion*	Local	3121	100
	Poshilo makai-1	5931	100
	RML-4/17	7685	100
	Arun-2	3768	100
No water stress condition	Local	3314	106.183
	Poshilo makai-1	6639	111.951
	RML-4/17	9086	118.230
	Arun-2	4018	106.634

* denotes standard treatment

4.3.3.3 Sensitivity to variety

The sensitivity analyses of varieties were done on the basis of their known genetic coefficient (Bhusal, 2008 and Sapkota, 2006). Four maize cultivars; Deuti, Upahar, Rampur Composite and Arun-4 with planting date 2013/4/7 were used for sensitivity analysis. These genetic coefficient values were used to simulate their yield, anthesis day and Physiological maturity day.

Among these varieties, Rampur Composite gave the highest yield (6493 kg ha^{-1}) whereas yield of Upahar was 6079 kg ha^{-1}, although both of them had similar simulated anthesis day (57 days) and physiological maturity day (98 days). Deuti and Arun-4 produced approximately similar simulated yield of 4234 kg ha^{-1} and 4221 kg ha^{-1}, respectively. However, physiological maturity day of Deuti was higher (97 days) than Arun-4 (89 days). But both of these varieties had approximately similar seed fill duration.

Table 16. Sensitivity on simulated yields of maize to various cultivars

Varieties	Antheis days	Physiological maturity days	Grain yield (kg ha^{-1})
Deuti(ZM-621)	59	97	4234
Rampur composite	57	98	6493
Upahar	57	98	6079
Arun-4	52	89	4221

4.3.3.4 Simulation to weather years

CERES-Maize model was run using five years weather data including weather year of 2013 as a standard (Table 17). Variation in climatic data in each year showed different simulated yields in respective years. Maize varieties responded differently with change in weather years. Maize production was seen very favorable in 2006 as yield of short durational varieties (Local and Arun-2) had increased by 125.064% and 124.682%, respectively whereas long durational varieties (Poshilo makai-1 and RML-4/17) had increased only by 34.092% and 58.439%, respectively. Similar trend of result was noticed in 2007. The yield of Local and Arun-2 had increased by 85.179% and 83.413% whereas Poshilo makai-1 and RML-4/17 had 18.901% and 39.831% increment in yield, respectively. There was simultaneous decreased in yield by 82.49%, 53.073% in Local; by 83.757%, 57.325% in Arun-2; by 82.532%, 59.0% in Poshilo makai-1 and by 83.10%, 49.50% in RML-4/17, when simulation was done for weather years 2008 and 2011, respectively. We can notice both growth duration as well as yield of maize had declined down recently so we can verify that changing climate had negative impact in spring maize production.

Table 17. Sensitivity of simulated yields of maize cultivars to weather years

Weather Years	Varieties	Simulated grain yield (Kg ha^{-1})	% yield change (days)	Anthesis (days)	Growth Duration
2013/4/7	Local	3124	100	49	94
	Poshilo makai-1	5931	100	61	114
	RML-4/17	7685	100	56	116
	Arun-2	3768	100	49	92
2011/4/7	Local	1466	46.927	45	87
	Poshilo makai-1	2432	41.005	55	106
	RML-4/17	3881	50.501	52	111
	Arun-2	1608	42.675	45	86
2008/4/7	Local	547	17.51	44	85
	Poshilo makai-1	1036	17.468	53	104
	RML-4/17	1299	16.903	51	109
	Arun-2	612	16.243	44	83
2007/4/7	Local	5785	185.179	69	133
	Poshilo makai-1	7052	118.901	-	146
	RML-4/17	10746	139.831	-	146
	Arun-2	6911	183.413	69	131
2006/4/7	Local	7031	225.064	70	135
	Poshilo makai-1	7953	134.092	89	169
	RML-4/17	12176	158.439	81	172
	Arun-2	8466	224.682	70	133

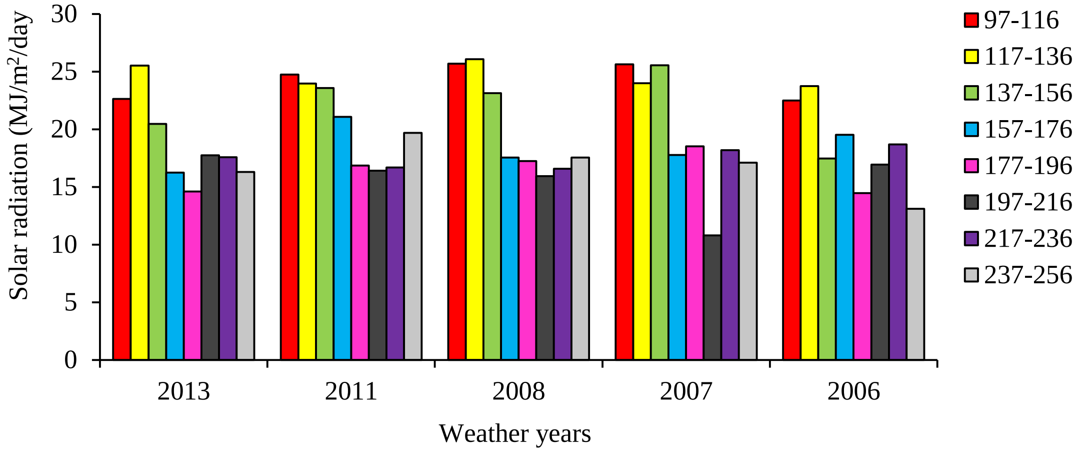

Figure 13. Average solar radiation pattern of every 20 days from 97 to 256 days period of years

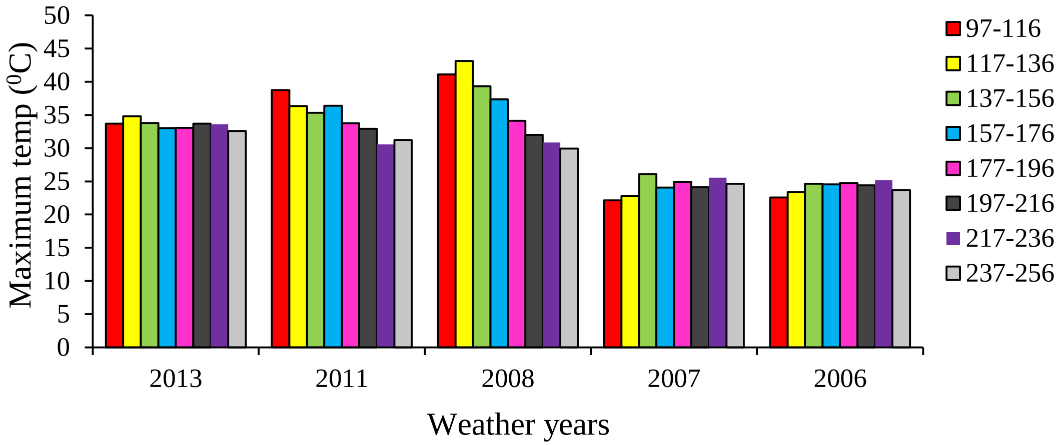

Figure 14. Average maximum temperature pattern of every 20 days from 97 to 256 days period of years

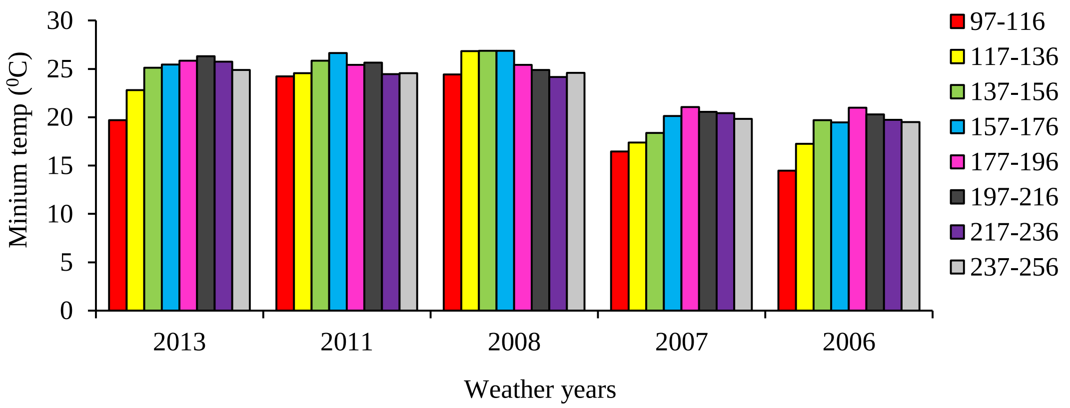

Figure 15. Average minimum temperature pattern of every 20 days from 97 to 256 days period of years

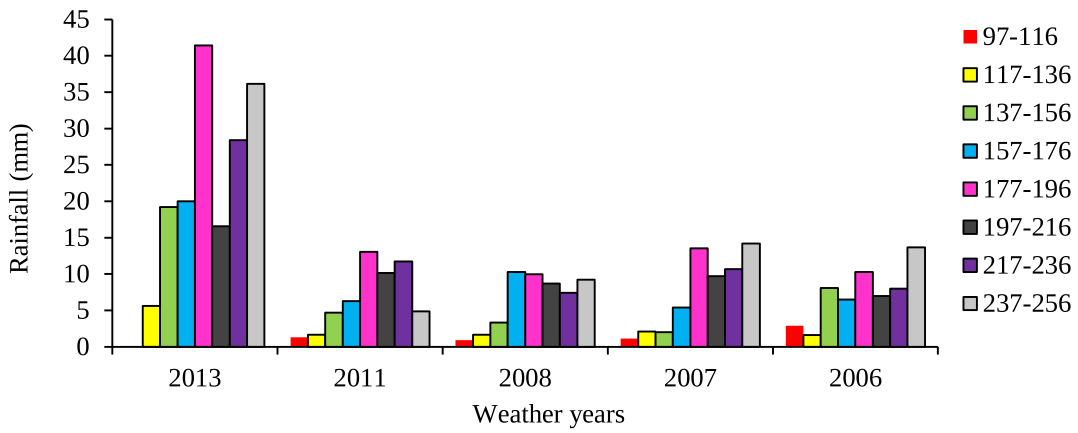

Figure 16. Average rainfall pattern of every 20 days from 97 to 256 days period of years.

4.3.3.5 Simulation to climate change parameters

Various scenarios of temperature, carbon dioxide concentration and solar radiation were selected for running sensitivity analysis of yields simulated by CERES-Maize for maize cultivars (Table 18). Compared to simulated yield of standard treatment, the increase in yield was 12.07%, 7.92%, 20.01% and 11.74% for Local, Poshilo makai-1, RML-4/17 and Arun-2, respectively when temperature (both max and min temperatures) were decreased by 2 ^{0}C and CO_2 concentration maintained constant at 380 ppm with no change in solar radiation. But, when temperature was increased by 2 ^{o}C yield of Local, Poshilo makai-1,RML-4/17 and Arun-2 decreased by 8.07%, 3.92%, 16.01% and 7.74%, respectively. Elevated CO_2 by 20 ppm along with raise in temperature by 2 ^{0}C had resulted in decrease of yield by 10.9%, 6.2%, 18.31% and 10.5% for Local, Poshilo makai-1, RML-4/17 and Arun-2, respectively. Under same configuration of climatic variables except the maximum and minimum temperature decreased by 2 ^{0}C, there was increased in yield of Local, Poshilo makai-1, RML-4/17 and Arun-2 by 10.21%, 18.35%, 22.36% and 15.48%, respectively. Positive impact of increased solar radiation was noticed in simulated yield. When solar radiation was increased by 1MJm^{-2}day^{-1} with increased in temperature by 2^{0}C and CO_2 concentration by 20 ppm, yield of Local, Poshilo makai-1, RML-4/17 and Arun-2 decreased by 8.98%, 4.94%, 16.54% and 8.47%, respectively. When above configuration of climate parameters maintained constant with change in Solar radiation by -1 $MJm^{-2}day^{-1}$, there was even more decreased in yield of Local, Poshilo makai-1, RML-4/17 and Arun-2 by 12.73%, 8.51%, 20.11% and 12.44%, respectively. There was increased in yield of Local, Poshilo makai-1, RML-4/17 and Arun-2 by 17.05%, 21.27%, 28.59% and 19.03%, respectively when temperature decreased by 2 ^0C and increased solar radiation by 1 $MJm^{-2}day^{-1}$ with 20 ppm increased in CO_2 concentration. But, when temperature decreased by 2 ^0C and decreased solar radiation by 1 $MJm^{-2}day^{-1}$ with 20 ppm increased in CO_2, there was increased in yield by 7.54%, 13.03%, 15.27% and 8.93% for Local, Poshilo makai-1, RML-4/17 and Arun-2, respectively however yield was said to be less increased when solar radiation increased by 1 $MJm^{-2}day^{-1}$.Increase of temperature caused shortening of growth duration and yield loss in spring maize, which can be noticed from the Table 17.

Table 18. Sensitivity analysis of maize cultivars with changes in temperature, solar radiation and CO_2 concentration

Max Temp(^{0}C)	Min Temp (^{0}C)	CO_2 Conc (ppm)	Solar Radiation (MJm^{-2} day^{-1})	Varieties	Simulated Grain yield	% yield change (Kg ha^{-1})	Growth duration (days)
+0	+0	380	+0	Local	3068	100	94
				Poshilo makai-1	5902	100	114
				RML-4/17	7459	100	116
				Arun-2	3710	100	92
+2	+2	380	+0	Local	2697.69	87.93	88
				Poshilo makai-1	5434.56	92.08	106
				RML-4/17	5966.45	79.99	108
				Arun-2	3274.45	88.26	87
-2	-2	380	+0	Local	3289.20	107.21	101
				Poshilo makai-1	6810.32	115.39	123
				RML-4/17	8977.65	120.36	126
				Arun-2	4181.17	112.70	99
+2	+2	+20	+0	Local	2733.59	89.1	88
				Poshilo makai-1	5536.08	93.8	106
				RML-4/17	6093.26	81.69	108
				Arun-2	3320.45	89.5	87
-2	-2	+20	+0	Local	3381.24	110.21	101
				Poshilo makai-1	6985.02	118.35	123
				RML-4/17	9126.83	122.36	126
				Arun-2	4284.31	115.48	99
+2	+2	+20	+1	Local	2792.49	91.02	88
				Poshilo makai-1	5610.44	95.06	106
				RML-4/17	6225.28	83.46	108
				Arun-2	3395.76	91.53	87
+2	+2	+20	-1	Local	2677.44	87.27	88
				Poshilo makai-1	5399.74	91.49	106
				RML-4/17	5958.99	79.89	108
				Arun-2	3248.48	87.56	87
-2	-2	+20	+1	Local	3591.09	117.05	101
				Poshilo makai-1	7157.36	121.27	123
				RML-4/17	9591.53	128.59	126
				Arun-2	4416.01	119.03	99
-2	-2	+20	-1	Local	3299.32	107.54	101
				Poshilo makai-1	6671.03	113.03	123
				RML-4/17	8597.99	115.27	126
				Arun-2	4041.30	108.93	99

5 DISCUSSION

5.1 Dry matter production

Maize planted on earlier sowing date i.e. on 7th April had higher dry matter production (Table 5). Production of dry matter declined with shifting of sowing dates to late spring in all DAS except at 30 DAS and 45 DAS. At 45 DAS, dry matter production seemed to be insignificant different ($p < 0.05$) to sowing dates. While at 30 DAS, dry matter production was higher for maize planted on later sowing dates. Maize planted on 7th April faced drought during early vegetative stage as a result dry matter production was very low at 30 DAS. This event was in agreement with Cakir (2004) who reported water stress caused dry matter reduction during the pre-flowering period. At the initial stage of early planted maize, level of deficiency was high so life saving irrigation was provided to seedlings. However, mild water stress was also faced by 22nd April planted maize but level was not as critical as on 7th April as there was few rainfall during those period. Consequences of water deficiency can be noticed in their dry matter production. Plant growth is the function of cell division and elongation. Water is essential to maintain cell turgidity and elongation, which further leads to plant growth and dry matter accumulation. At remaining growth stages; 60 DAS, 75 DAS and 90 DAS, maize planted on earlier date had led in dry matter production as lately planted maize were exposed to higher temperature. Planting maize in the spring season is supposed to be most critical for maize growth. Moreover, postponing planting date to late spring added even more critical environmental factors which hindered crop growth rate and their dry matter accumulation. Rate of plant growth is also negatively affected by high temperature (Ritchie and NeSmith, 1991). As suggested by research, maize planted late in the spring faced higher heat stress than planted earlier. The raising temperature had negative impact in biomass production during both vegetative and reproductive stages. High temperature reduces growth (Weaich *et al.,* 1996). In maize, seedling growth is maximized at a soil temperature of 26 °C and above this temperature, root and shoot mass both decline by 10 % for each degree increase until 35 °C (Walker, 1969). Reduced seedling growth had been suggested to be associated with poor reserve mobilization, with reduced protein synthesis observed in seedlings grown under elevated temperatures (Riley, 1981). Elongation of the first internode and overall shoot growth of maize had been suggested as the most sensitive processes of the vegetative stage to high temperatures (Weaich *et al.*, 1996).

The significant difference among varieties for dry matter production was noticed (Table 5). At early vegetative stages, short durational varieties were seen to be competitive on Poshilo makai-1, which was a long durational variety. Many authors had noted that short durational varieties tend to grow faster as they have short growth period and they need to develop all the structures within short period of time. That is why, they tend to grow faster. The growth of long durational varieties was often slow but in long run long durational varieties produced higher biomass at harvest. Genetic variability among hybrids, open pollinated varieties and inbred lines, its impacts on morphological characteristics and plant vigor, and distinct differences in their field performance is well known. However, except at 30 DAS, long durational maize namely RML-4/17 had the highest dry matter production throughout the growth period among varieties. RML-4/17 is a hybrid variety. Characteristically, RML-4/17 had broad leaf, long time stay green ability and high chlorophyll content as marked by their deep green leaf colour. This hybrid cultivar had strong and thick stem with good root coverage. One of the most important factor for higher dry matter production by hybrid is it’s good source and sink relationship. Due to high LAI all round the growth period, its photosynthetic efficiency was also higher and also had higher LAD, which supported this cultivar for higher dry matter.

5.2 Leaf area index and duration

As rainfall occurred on 6^{th} May then continuously rained, maize planted on 7^{th} April, faced water deficit problem for first 30 days after sowing and 14 days for maize planted on 22^{nd} April. However, life saving irrigation rescued plant. Although life had been saved, but maize planted on 7^{th} April had to compromise with its leaf area development as we noticed that leaf area index was the highest for maize planted on 22^{nd} April and 7^{th} May than on 7^{th} April at 30 DAS. But, both cell division and cell expansion were able to recover fully when stress occurred at early phases of leaf development, but in leaves at the final phase of either cell division or cell expansion, these processes did not resume long enough to generate full size leaves (Alves and Setter, 2004). In rest of the growth period i.e. 45 DAS, 60 DAS and 75 DAS, maize planted on 7^{th} April had the highest leaf area index followed by 22^{nd} April and the least for 7^{th} May. Although, for rest of the growth period, water had not been problematic as there was plenty of rainfall. But, raising temperature was much conducive for early senescence of leaf and low leaf area index for lately planted maize. The daily average temperature for 7^{th} May planted crop was 0.5 ^{0}C higher than daily average temperature for 7^{th} April planted maize. Similarly, daily average temperature for 22^{nd} April planted maize was 0.2 ^{0}C higher than daily average temperature for 7^{th} April planting. The weather of post-spring and summer season was very hazardous to plant growth. Number of leaves and leaf appearance rate has also been reported as important traits by many researchers for high temperature stress. High temperature reduced leaf number in maize (Hunter *et al.*, 1974). At higher temperature, cell respiration was high so early senescence of late planted maize was not matter of wonder. For lately planted maize (7^{th} May), there were plenty of rainy days, so fertilizer management was very difficult. Split dose was placed at 42 DAS which was 17^{th} June. During those periods rainfall was so continuous that urea might had leached away. For 22^{nd} April and 7^{th} April planted maize, day for split dose urea placement fall on 2nd June and 18th May, respectively, when there was no rainfall. Nitrogen is one of the important constituent of chloroplast. By leaching of urea, their might had been nitrogen deficiency, which was indicated by pale green leaf. Both higher temperature and leaching of nitrogenous fertilizer might had caused early senescence of leaf and poor leaf growth and development.

Both short durational varieties had competitive LAI with long durational variety i.e. Poshilo makai-1 at early seedling stage (Table 6). Short durational variety have short or no lag vegetative periods and require less growth degree units to meet growth potential so they had higher LAI at initial growth stage (Sharma and Adhikari, 1998). Leaf growth in long durational variety was slow. These varieties attained maximum leaf area index lately, but they maintain their green leaf for longer period of time. However, RML-417 had maintained its higher LAI at all growth period. Its leaf area was broad and green leaf color was persistent for long duration that is why its leaf area duration was high. Hybrid are higher yielder so they need to develop higher LAI as leaves are kitchen of plant body, from where supplements are transported for other structural formation. Arun-2 and Local are short duration varieties that was why these varieties had lower leaf area duration among the tested varieties.

5.3 Grain yield

When maize was planted on 22nd April and late on 7th May, grain yield reduced by 19.94% and 27.98% respectively than grain yield obtained when planted earlier on 7th April (Table 7). Maize grain yield can be described as a function of the rate and duration of dry matter accumulation by the individual kernels multiplied by the number of kernels per plant (Westgate *et al.,* 1997). Anything that affects these yield attributing factors will significantly affect the final yield (Hatfield *et al.,* 1984). Maize was grown in extreme weather condition when temperature normally crosses 32 ^{0}C during day time. The temperature was even higher for lately planted maize. Maize planted earlier developed better and had higher yield potential because the vegetative period of its development occurred in the relatively cooler part of the season (Aldrich *et al.,* 1986).Maize yield was negatively correlated with accumulated degrees of daily maximum temperatures above 32 °C during the grain filling period (Dale, 1983).Yield decreases would be higher if higher temperatures was prevailed during the period when the maize ears swell (Southworth *et al.* 2000). Although there was plenty of rainfall but raising temperature harmful for plant growth which was main drawback for lately planted maize. Lobell and Burke (2010) suggested that increased in temperature of 2 °C would result in a greater reduction in maize yields within sub-Saharan Africa than decreased in precipitation by 20 %. Under high temperature, the number of ovules that were fertilized and developed into grain decreased (Schoper *et al.,* 1987). High temperature during the early stages of kernel development had a detrimental effect on kernel development and final kernel mass due to a reduction in the number and/or size of endosperm cells formed thereby reducing sink capacity (Jones *et al.,* 1984). Heat stress during this stage affected cell division, sugar metabolism and starch biosynthesis, reducing subsequent dry matter accumulation within kernels (Monjardino *et al.,* 2005). Maize kernel weight is the product of the rate and duration of grain filling, both of which are affected by temperature. High temperature during this period is associated with a reduction in the duration of grain filling (Muchow, 1990). Earlier studies showed temperature to increase the growth rate of kernel development (Muchow, 1990); however, this increase was unable to compensate for the reduction in growth duration and this resulted in kernels with less weight (Singletary *et al.,* 1994). High temperature had adverse effect on the growth and development of plants (Noohi *et al.,* 2009) and the yield may be reduced by 101 kg ha^{-1} day-1 when the temperature reaches up to 35 ^{0}C during pollination and grain filling stage (Smith, 1996). Because of this reason, number of kernels per row and 1000 grain weight of seed drastically reduced for 22nd April and 7th May planted maize which consequently reduced yield. This finding was in agreement with Otegui and Melon (1997), who also reported that delayed plantings are generally accompanied by increased temperatures during the growing season, which accelerate crop development and decrease accumulated solar radiation, resulting in less biomass production, kernel set and grain yield. The most significant factors associated with maize yield reduction include shortened life cycle, reduced light interception and increased sterility (Stone, 2001).

Grain yield of maize was also significantly affected due to varieties. RML-4/17 produced higher yield among all varieties followed by Poshilo makai-1. RML-4/17 yielded 5.1 t/ha during winter season (Annual Report of NMRP, 2011-2012), while Arun-2 produced higher grain yield among short durational varieties. Higher yield variation was found in Arun-2. The yield of Arun-2 was 4502 kg ha^{-1} in Dailekh, while at Lumle yield was 4096 kg/ha (Annual Report of NMRP, 2011-2012). There is no confusion that if there is no any yield penalties, long durational varieties will yield higher than short durational varieties. Leaf area duration, seed fill duration, along with crop duration and biomass production capacity of longer maize duration varieties were higher. These factors were determinant for higher yield in long durational varieties. Local maize was poor in genetic potential. Improved varieties, which had been tested many time in research trial and released with full confident would certainly yield higher than Local maize.

5.4 Stover yield

Stover yield is the fresh total biomass yield at field during harvest. The stover yield decreased by 0.627% and 12.33% when planted on 22nd April and 7th May than on 7th April planted maize (Table 7). Weaich *et al.* (1996) also observed reduction in the rate of growth of first internode of plants due to high day temperature, thereby reducing the overall shoot growth. Heat stress often decreases root growth, and it had been seen that root growth had a very narrow optimum temperature range when compared with other growth processes (Porter and Gawith, 1999). Heat stress reduced root number as well as root length and root diameter. Root growth was also decreased, when heat stress occurred during reproductive development, mainly because of decreased carbon partitioning to roots (Batts *et al.*, 1998). Due to poor root growth, there had been poor assimilate supply, thus poor stover yield of plant.

5.5 Harvest index

Harvest index indicates transfer of photosynthetic matters from vegetative organs (source) to seed (silk). Harvest index was found significantly ($p < 0.05$) different among sowing dates. Early planting date had the highest harvest index. This finding was in agreement with Jasemi *et al.* (2013) who found harvest index was higher for plant sown on 22nd May than 13th July.

5.6 Kernel rows

Kernel rows ear^{-1} was found significantly different according to sowing dates (Table 8). Maize, which was planted on 7th April produced the highest kernel row per ear and row number decreased in late planting dates. Khan et al (2002) suggested that kernel rows is genetically controlled and have high resistant to environmental control, however Vafa (2013) found that sowing dates have significant ($p < 1\%$) influence in number of kernel rows ear^{-1} and this finding is in agreement with finding of this research too.

5.7 Kernel numbers row^{-1}

There was a significant effect of sowing dates in kernel number per row (Table 8). The kernel number was higher for early planting. Mhike *et al.* (2012) reported great variation among genotypes for each trait depends on the intensity and severity of stress. A number of factors could be responsible for reduction in number of kernels per row under heat stress, such as reduced pollen viability and receptivity of silk, increased frequency of kernel abortion, decreased cell division in endosperm, reduced sink capacity of developing kernels, reduced starch grain number and overall starch synthesis, increased soluble sugar accumulation, duration of grain filling, kernel development and enzyme activities (Duke and Doehlert, 1996). Heat stressed plants had no detectable levels of cytokinin, leading to seed abortion. (i.e., cessation of dry matter accumulation before initiation of rapid starch deposition in the endosperm) or cease starch deposition prematurely (Cheikh and Jones, 1994).

Kernel number variation was also found according to cultivars. Kernel number ear^{-1} was the highest for Hybrid (RML-4/17). The reason for best performance for most of the traits for hybrid might be due to added traits, i.e. heterosis, compared to inbred lines under stress.

5.8 Kernel weight

Kernel weight differed significantly with sowing dates (Table 8). Test weight decreased, when maize planting date postponed to 7th May. Suwa *et al.* (2010) reported depression in source-sink activity under high temperatures. Any severe stress that occurs during the grain fill period will cause premature kernel black layer formation and is related to the reduction in or termination of sucrose (photosynthate) availability to the developing kernels (Afuakwa *et al.,* 1984). High night temperatures result in loss of more sugars for respiration and reduce the availability for kernel filling, thereby lowering potential grain yield (Thomison, 2010). Heat stress (Hellewell *et al.,* 1996; Prasad *et al.,* 2006) decreased the seed-filling duration. There may be a slight increase in seed-filling rate but a large decrease in seed-filling duration under heat stress. The increased in seed-filling rate does not compensate for loss of duration, thus resulting in smaller seed size (Shipler and Blum, 1986; Tashiro and Wardlaw, 1989). Our finding is in agreement with Killi and Altanbay (2005), who observed that seed weight was significantly affected by the planting dates.

Lower solar radiation was experienced by later planted maize i.e. 7th May as days were cloudy. As solar radiation is a part of photosynthesis, its rate decreased over late planting resulted in less test weight for lately planted maize.

Test weight of maize was significantly different due to varieties.Arun-2 and Local variety had comparatively lower test weight, as these varieties were short durational varieties. These varieties had short seed fill duration and mature faster so test weight was lower. Local maize was genetically small seeded variety. Among the long durational varieties, RML-4/17 was hybrid, while Poshilo makai-1 is synthetic variety. Both of these long durational varieties posses higher test weight among the cultivar. These varieties are genetically improved. Hybrid contained hybrid vigor. Hybrid had longer crop duration, high seed fill duration, longer leaf stay green character, higher leaf area index, thick stem and strong root system. This all attributes helped it to maintain high test weight among the varieties.

5.9 Days to phenological stages

The result suggested that the days for attainment of different phenological stages differed significantly from one planting date to another (Table 9). At early planting condition (7th April), more lengthy days were attained to get the respective pheno-phages like emergence, anthesis, silking and seed fill duration, than when planting was done on 22nd April and 7th May because of relatively less hot environmental condition during earlier planting. Development is mostly described as a function of temperature, suggesting it to be a major driving force and intensity and duration of heat stress not only influenced the transition of one developmental stage to other but also the duration of the developmental stage. Both developmental rate of individual organs such as leaves and the progress of the entire plant through various ontogenetic stages were quantitatively dependent on temperatures (Sinclair, 1994). The higher the temperature the faster is the development and thus the shorter is the duration of the growth phase. Every crop has certain thermal requirement before reaching phenological stage. At high temperature maize could gain required growing degree days earlier due to which the days required to attain different phenological stages got shorter. The higher temperature increased rate of growing degree days (GDD) accumulation at night (higher respiration rates at night utilized sugars produced during the day, so plants needed to increase photosynthesis to maintain yield). This increased hasten maturity, which reduced the length of the grain-fill period for 7th May planted maize as compared to April planted maize.

Another reason for early senescence of leaves during grain filling period during late planting (7th May) might be leaching of urea along with higher temperature and more rainfall. When there was no uptake of nitrogen from soil then remobilization of nitrogen occurred from leaves to grain. Thus, early senescence of leaf occurred. Frederick and Camberato (1995) also had reported similar finding.

The days to attain different phenological stages significantly differed from varieties to varieties. Days to reach phenological stages is their genetic character. However, occurrence of these phenological characters is driven by environmental factors like temperature, rainfall etc too. The extent of environmental affected on them differed according to varieties. Poshilo makai-1 took higher days to attain knee height stage, anthesis, silking stages followed by RML-4/17, while Local and Arun-2 had similar behavior to days for attainment of phenological stages but they took least days among the varieties compared because these varieties were genetically short durational varieties. Poshilo makai-1 had lower growth duration than RML-4/17, so the seed fill duration was higher for RML-4/17 than Poshilo makai-1.

5.10 Growing degree days

Growing degree days accumulated at knee height and anthesis stage were significantly different while it was non-significant for silking and seed fill duration due to planting dates (Table 10). The difference of GDD acquired at knee height and anthesis stages were very close. The principle of GDD concept is that, temperature controls the developmental rate of plant. Plants require a certain amount of heat to develop from one point in their life cycles to another. The phenological stages of the crop can be predicted using GDD concept. From result, it was clear that, maize tended to accumulate a certain required GDD at particular stages.

5.11 Phenothermal index

The pheno-thermal index for various pheno-phages was significantly different among the sowing dates. Phenolthermal index gradually increased from one pheno-stage to another (Table 11). The pheno-thermal index was high at seed fill duration and gradually decreased in early stages. Likewise, the maize planted lately on 7th May received required growing degree days to attain certain pheno-phase in shorter period than maize planted in early date that was why phenothermal index was higher when planting date was postponed to 7th May and gradually decreased when shifted to early date. This finding is similar to Navaprakaash *et al.* 2007, who reported pheno-phases were attained earlier in summer season and also relatively higher GDD values within short period influenced higher PTI values.

5.12 Heat use efficiency

Heat use efficiency of maize cultivars was found higher in early planting (Table 12). Grain yield of maize cultivars were higher in early planted dates but more or less similar GDD accumulation upto physiological maturity among planting dates caused higher HUE for early planted maize. Arun-2 had less reduction in HUE amongst the planting time and therefore it can be concluded that it is the best cultivar for both early and late spring planting. The results are in accordance with spring and winter maize as noted by Amgain (2011).

5.13 Model calibration and validation

The model was calibrated comparing the simulated and observed values of days to anthesis, days to physiological maturity and grain yield of all maize varieties planted on 7th April. Calibration was continued until the values compared matches exactly. The adjusted genetic coefficients were used without changing any values for Local, Poshilo makia-1, RML-4/17 and Arun-2 for validation of the model. The model simulated day to anthesis approximately with RMSE of 0.426 days and D-index of 0.998. Similarly RMSE of 0.674 days and D-index of 0.999 for day to physiological maturity was noticed. Model was seen with an agreement of RMSE of 85.287 grain per m^2 and D-index of 0.993 with observed values for number at maturity (grain/ m^2). In addition to this, a good agreement between observed and predicted unit weight at maturity with RMSE of 0.012 g kernel^{-1} and D-index of 0.854 were found. Simulated yield simulated by model was much similar with observed yield. RMSE and D-index values of grain yield were 54.94 kg per ha and 1.0 respectively.

5.14 Sensitivity analysis

5.14.1 Sensitivity to sowing dates

Varieties responded differently with sowing dates (Table 14). 17th April was seen as a best sowing date for both short durational varieties, further late planting decreased the yield. However for long durational varieties 7th April was the best sowing date for Poshilo makai-1 and 12th April for RML-4/17. Even increasing 10 days from 7th April there was increased in yield of both short durational varieties it might be because of their short growth period which made it escaped possible damage due to higher temperature and shifting sowing date made nearer to rainfall period. However, for long durational varieties, delay planting added even more severe high temperature. Delayed planting was generally accompanied by increased temperature during the growing season, which accelerated crop development and decreased temperature and solar radiation accumulation, resulting in less biomass production, kernel set and grain yield (Otegui and Melon, 1997).

5.14.2 Simulation to weather years

Sensitivity of maize to five different weather years; 2006, 2007, 2008, 2011 (downloaded from www.power.larc.nasa.gov) and 2013 were carried out using CERES Maize model (Table 17). Model predicted yield of maize was decreasing in recent years. The model predicted yield of maize was very high during 2006 and 2007 for all varieties. As during these years, weather condition was very moderate and favorable for maize growth and development. From the result, it can be noticed maximum temperature during those days barely exceed 25 ^{0}C, while minimum temperature was around 20 ^{0}C, which was very favorable temperature without stressful environment for crop growth. Yield of maize during rest of the years i.e. 2008, 2011 and 2013 had severely decreased because of adverse weather. During these years, temperature records crossed 35 ^{0}C and even reached 45 ^{0}C and minimum temperature above 25 ^{0}C and even reached 30 ^{0}C during hot summer which was found adverse for pollen survival .Under this kind of circumstances maize growth and development had been severely affected, which was reflected in their crop phenology and yield parameter as simulated by crop model.

5.14.3 Simulation to climate change parameters

Maize production and productivity are prone to rapid and constant changes due to global warming related environmental changes (Porter 2005; Wahid *et al.*, 2007). Under increased temperature condition (along with elevated CO_2 and increased or decreased solar radiation), the growth duration of maize cultivars was decreased and consequently decreased in grain yield. In contrast, with decrease in minimum and maximum temperature by 2 ^{0}C there was increased in growth duration, thereby increased grain yield. Temperature is a major determinant factor in crop growth and development. In tropics, high temperature decreased the duration of growth and grain yield, despite high levels of radiation (Muchow *et al.,* 1990). Higher temperatures generally speeds up development of a plant so that it matures sooner (thus reducing the period available for yield production); they often also exacerbate stress on water resources that are essential for crop growth. Temperature affects the duration of crop growth, through its effect on enzymatic reactions in the plant (Gardner *et al.,* 1985). Amgain *et al.* (2006) found decreased in simulated yield of both rice by 34% and wheat by 4% with increments in both maximum and minimum temperature as compared to base scenario. They also reported decreased in yield of rice and wheat by 33% and 3% respectively while increasing 4^{O}C for both maximum and minimum temperature along with an increase in CO_2 concentration by 20 ppm from standard CO_2 concentration of 335 ppm.

Higher CO_2 level in the atmosphere, increase growth and yield, mainly through their effect on the photosynthesis processes of crop which is called CO_2 fertilization (Hendrey and Kimball, 1994).From the table 18, it was clear that CO_2 along increased yield. Free-air carbon enrichment experiment confirm that CO_2 enrichment responses under field conditions consistently increase biomass and yields in the range of 5-15% with CO_2 concentration elevated to 550 ppm (Ainsworth and Long, 2005). The increased CO_2 concentrations and decreased temperature increased growth duration and yield, while increased temperature shortened growth duration and reduced leaf area, biomass and yield (Timsina *et al.,* 1997; Rao and Sinha, 1994; Qureshi and Iglesias, 1994). At elevated CO_2, light intensity positively affects photosynthesis and increased temperature, that promoted both photosynthesis and leaf area (Imai and Murata, 1979).

Increase in solar radiation increased grain yield and vise-versa. Provided all factors are non-limiting, cumulative IPAR is strongly related to total biomass accumulation (Edwards *et al.,* 2005) and grain yield. Assimilate production and dry matter accumulation in the plant is positively related to solar radiation interception (Gardner *et al.,* 1985). Both IPAR and Radiation use efficiency determine assimilate production rate, which is critical for growth, kernel set and grain filling (Bonhomme, 2000).

6 SUMMARY AND CONCLUSION

6.1 Summary

A field experiment was conducted during spring season of 2013 at Shivamandir-2, Nawalparasi with an objective to evaluate best agronomic management options by using agro-climatic indices and CSM-CERES-Maize ver. 4.5 for its pertinent use in simulating the growth and yield of maize cultivars under varying sowing dates of various promising maize cultivars. The experiment was conducted using a two factorial Randomized Complete Block Design (RCBD) where treatments were the combination of three sowing dates (7th April, 22nd April and 7th May) and four maize cultivars (Local, Poshilo makai-1, RML-4/17 and Arun-2), making 12 treatments which were replicated thrice. The parameters studied were LAI, LAD, DM accumulation, number of ears ha^{-1}, kernel rows per ear, kernel number per row, thousand grain weight, grain yield, stover yield, harvest index, days to phenological stages, GDD, PTI and HUE. The data were analyzed with suitable ANOVA and model evaluation was also done simultaneously.

Dry matter accumulation was found higher for cultivars planted on 7th April and decreased on later sowing dates at all DAS except at 30 and 45 DAS. At 30 DAS, dry matter accumulated was higher for lately planted maize and at 45 DAS there was no statistically difference between sowing dates for dry matter production. At earlier vegetative stage, 7th April and 22nd April planted maize faced severe drought which was reflected in their dry matter production. However, for other DAS, lately planted maize faced higher temperature which caused lower dry matter production in comparison to earlier sowing dates. Similarly, drought problem had caused lower leaf area during early vegetative stage for maize planted on 7th April. However later on plant resumed their leaf area development and had led on LAI and LAD as plants were facilitated by lower temperature in comparison to 22nd April and 7th May. Likewise, significantly higher dry matter production, leaf area index and leaf area duration were recorded in RML-4/17. However, at 30 DAS, dry matter production was lower for long duration varieties as short durational varieties tended to grow faster as they have short growth period and they need to develop all the structures within short period of time. Poshilo makai-1 had the second highest rank in dry matter production, LAI and LAD followed by Arun-2 and the lowest for Local cultivars.

Maize planted on 7th April was found superior in yield attributing characters except plant population which was non-significant due to sowing dates. Yield attributes were in decreasing order when sowing dates shifted late to 22nd April and 7th May. Similarly, maize cultivars were found statistically similar in plant population. However, higher yield attributing characters like kernel rows per ear and kernel numbers per row was found higher in RML-4/17 followed by Poshilo makai-1 then Arun-2 and lowest for local cultivar. Statistically, similar and higher weight was found in RML-4/17 and Poshilo makai-1, followed by Arun-2 and the lowest on local cultivar.

As the yield attributing characters were found higher for maize planted on 7th April, grain yield was also high for maize planted on 7th April followed by 22nd April and the lowest for 7th May. In addition to this, statistically similar stover yield was found between maize planted on 7th April and 22nd April while the lowest stover yield was found in maize planted on 7th May. In case of harvest index, maize planted on 7th April had higher harvest index, while remaining two sowing dates had statistically similar harvest index. Grain and stover yields were higher for RML-4/17 followed by Poshilo makai-1 then Arun-2 and Local had lowest values for grain and stover yields. Harvest index was statistically higher and similar for long durational varieties and similar but lower for short durational varieties.

Effect of sowing dates and varieties was found significantly different on days to phenological stages of maize. Maize planted on 7th April had significantly higher days to attain knee height, anthesis, silking and seed fill period, while maize planted on 22nd April and 7th May had statistically similar, but lower days reached to attain phenological stages. However, PTI values were statistically higher for 7th May planted maize as crops were exposed to almost similar GDD at shorter crop duration. From the result it was seen that maize cultivars tended to accumulate required GDD to reach different phenological stages. Likewise, cultivars also had significantly different days to attain phenological stages, GDD accumulation, PTI values. Poshilo makai-1 had the highest calendar days, GDD accumulation at knee height stage, anthesis and silking stages followed by RML-4/17 while both of these short duration varieties had statistically similar but the lowest days attained and GDD accumulation at all stages. However at seed fill period, RML-4/17 had led among the varieties followed by Poshilo makai-1 and both short duration varieties had lowest days attained and GDD accumulation at seed fill duration. PTI values were higher for long durational varieties than short durational varieties. Statistically similar values were found among long durational and among short durational varieties. In addition to this, HUE was higher at earlier planting date. Stable HUE over different planting dates was found in Arun-2 so it can be considered as the best cultivar among the tested cultivars.

DSSAT v4.5 crop model was used to evaluate CSM-CERES-Maize under Shivamandir 2, Nawalparasi. The model calibration was performed for four maize varieties planted on 7th April. Observed anthesis days, physiological maturity and grain yield were used to determine genetic coefficient of all four maize cultivars. The genetic coefficient adjusted were 230 (P1), 0.520 (P2), 940 (P5), 360 (G2), 9.28 (G3) and 38.90 (PHINT) for local maize; 400 (P1), 0.600 (P2), 1130 (P5), 590.9 (G2), 8.38 (G3) and 18.90 (PHINT) for Poshilo makai-1; 380.0 (P1), 0.260 (P2), 1290 (P5), 816.9 (G2), 7.36 (G3) and 8.90

(PHINT) for RML-4/17; 230.0 (P1), 0.520 (P2), 910.0 (P5), 440.0 (G2), 9.88 (G3) and 38.90 (PHINT) for Arun-2.

Model validation was accomplished using eight treatments (varieties planted on 22nd April and 7th May). Days to anthesis was well simulated with RMSE of 0.426 and D-index of 0.998. Similarly, days to physiological maturity was simulated with RMSE of 0.674 days and D-index of 0.999. Agreement between simulated and observed number of grain m^{-2} at maturity with RMSE of 85.287 grains per m^2 and D-index of 0.993 was found satisfactory. In addition to this, a good agreement between observed and predicted unit weight at maturity with RMSE of 0.012 g $kernel^{-1}$ and D-index of 0.854 was found. The grain yield was simulated with RMSE of 54.94 kg per ha and D-index of 1.0 against observed values of grain yield for all eight treatments.

The model was found sensitive to sowing dates, no water stress condition, cultivars, weather years and climate change parameter as determined by sensitivity analysis. Suitable sowing dates of 17th April, 7th April, 12th April and 17th April for Local cultivar, Poshilo makai-1, RML-4/17 and Arun-2 respectively were determined on the basis of their respective simulated yield.

Yield simulation of tested maize cultivars was done to know how much yield reduction had there been due to early vegetative drought stress. Due to early vegetative drought stress there had been 5.824%, 10.664%, 15.419% and 6.222% yield reduction in Local, Poshilo makai-1, RML-4/17 and Arun-2 respectively as predicted by the model.

The genetic Coefficient values were 250 (P1), 0.70 (P2), 800(P5), 400.0 (G2), 12.5 (G3) and 70.0 (PHINT) for Deuti; 283.7(P1), 0.50 (P2), 869.5 (P5), 776.2 (G2), 8.71 (G3) and 45.0 (PHINT) for Rampur Composite; 300.0(P1), 0.50 (P2), 880.0 (P5), 718.3 (G2), 8.75 (G3) and 45.0 (PHINT) for Upahar and 232.0 (P1), 0.50 (P2), 785.0 (P5), 678.2 (G2), 8.93 (G3) and 48.0 (PHINT) for Arun-4 were used from previous thesis. Among these varieties, Rampur composite gave the highest yield (6493 kg ha^{-1}) whereas Upahar had the second highest yield of 6079 kg ha^{-1}. While Deuti and Arun-4 had approximately similar, but comparatively lower simulated yield of 4234 kg ha^{-1} and 4221 kg ha^{-1} respectively.

The simulated grain yield of maize was found higher during early weather years i.e., 2006 and 2007. But yield, days to anthesis and physiological maturity had decreased in 2008 and 2011.

The model was also sensitive to change in temperature, solar radiation and CO_2 concentration. It was also noticed that decrease in temperature, increase in solar radiation and CO_2 concentration, any one of this can increase the yield of maize and vice-versa.

6.2 Conclusion

Maize cultivation in late spring season is very risky. However, maize planted on 7th April had higher growth rate, higher yield and it's attributing characters as it was facilitated by relatively favorable temperature. Although, there was lower reduction in yield of short durational varieties due to late planting but, because of its lower yield, farmer can be suggested to grow longer durational varieties as these varieties were genetically high yielder even in post-planting dates. Specially, Hybrid (RML-4/17) produced higher yield among the tested cultivars, so that farmers ranked them highly preferred.

Although temperature during research period was increasing with progress of day, days to attain different phenological stages decreased with delay in sowing dates. At all sowing dates, maize tried to accumulated statistically similar GDD. Due to statistically similar GDD but decreasing days to attain different phenological stages under delayed planting, higher PTI value was noticed with delay in planting. Similarly HUE was found higher in early sowing date. Arun-2 had lower reduction in HUE so it can be considered stable and best cultivar among the tested varieties.

Due to changing climate, there has been great negative impact of increasing temperature in spring maize. Temperature during post spring season seems to be beyond optimum threshold level. Even 2^0C rise in temperature than present condition, model predicted higher yield decline in maize. To tackle with changing climatic situation, model had been used to find suitable sowing dates for cultivars under different agro-climatic situation.

Many works can be done in the field of climate change using simulation modeling. For this extensive and repetitive field work and quality data sets should be generated to make model work properly and accurately.

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APPENDICES

Appendix 1. Means for leaf area indices (LAI) and leaf area duration (LAD) at different growth stages as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	LAD(days)
Local					
7th April	0.389	2.377	2.396	2.368	120.819
22nd April	0.690	2.085	2.359	1.869	102.699
7th May	0.660	1.743	2.189	0.995	71.389
Poshilo makai-1					
7th April	0.263	2.959	3.629	3.157	192.065
22nd April	0.890	2.591	3.482	2.928	160.443
7th May	0.795	2.055	2.83	2.098	113.978
RML-4/17					
7th April	0.240	3.265	4.131	3.774	228.475
22nd April	1.116	3.124	3.805	2.967	185.917
7th May	1.104	2.305	3.516	2.389	136.856
Arun-2					
7th April	0.385	2.399	2.995	2.730	138.915
22nd April	0.744	2.133	2.798	2.427	119.254
7th May	0.733	1.911	2.545	1.607	84.397
SEm±	0.093	0.121	0.147	0.205	6.780
LSD (0.05%)	0.273	NS	NS	NS	NS
CV%	24.04%	8.71%	8.34%	14.52%	8.51%

Appendix 2. Means above ground dry matter production at different growth stages as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Local					
7th April	0.282	2.271	4.885	7.794	8.946
22nd April	0.29	2.110	4.53	7.19	8.305
7th May	0.446	2.044	4.416	5.831	6.795
Poshilo makai-1					
7th April	0.149	2.145	5.568	8.15	9.219
22nd April	0.238	2.166	5.232	7.409	8.943
7th May	0.508	2.426	5.066	6.63	8.172
RML-4/17					
7th April	0.18	2.835	7.321	10.59	13.49
22nd April	0.266	2.635	6.051	8.71	11.28
7th May	0.346	2.511	5.519	7.569	10.04
Arun-2					
7th April	0.217	1.839	5.276	7.597	8.809
22nd April	0.362	1.913	4.444	6.665	7.782
7th May	0.592	2.022	4.461	6.485	7.321
SEm±	0.055	0.2168	0.3199	0.2739	0.3737
LSD(0.05%)	NS	NS	NS	0.8032	NS
CV%	30.01%	16.72%	10.59%	6.29%	7.12%

NS=Non significant

Appendix 3. Means days at different phenological stages as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	Knee height	Anthesis	Silking	Seed fill period
Local				
7th April	28.67	49	53.33	46
22nd April	28.33	48	52	45
7th May	28	48	52	43
Poshilo makai-1				
7th April	32.67	61	64.67	54
22nd April	30.33	61	64.33	53
7th May	30	59	63	54
RML-4/17				
7th April	34	56	60.67	61
22nd April	26.33	53	56.67	61
7th May	26.67	53	56	60
Arun-2				
7th April	30.33	49	53.67	44
22nd April	27.33	47.67	52	44.33
7th May	27.33	48	52	42.67
SEm±	0.878	0.861	0.918	0.845
LSD(0.05%)	2.574	NS	NS	NS
CV%	5.21%	2.83%	2.80%	2.89%

NS=Non significant

Appendix 4. Means growth degree days at different phenological stages as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	Knee height	Anthesis	Silking	Seed fill period
Local				
7th April	492.6	885.4	968.4	891.5
22nd April	519	902	986.9	873.5
7th May	540.3	928.8	1006	847.5
Poshilo makai-1				
7th April	569.3	1118	1192	1054
22nd April	557.4	1151	1216	1042
7th May	581.8	1145	1221	1067
RML-4/17				
7th April	596.2	1016	1111	1196
22nd April	481.4	1007	1075	1188
7th May	513.1	1025	1057	1187
Arun-2				
7th April	523.7	885.4	974.8	853.9
22nd April	499.8	895.9	1005	860.7
7th May	526	928.8	986.9	840.6
SEm±	17.35	17.18	16.45	16.8
LSD(0.05%)	50.9	NS	NS	NS
CV%	5.64%	3.00%	2.67%	2.93%

NS=Non significant

Appendix 5. Means phenothermal index at different phenological stages as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	Knee height	Anthesis	Silking	Seed fill period
Local				
7th April	17.18	18.07	18.16	19.38
22nd April	18.32	18.79	18.98	19.41
7th May	19.29	19.35	19.35	19.71
Poshilo makai-1				
7th April	17.42	18.33	18.44	19.52
22nd April	18.37			
7th May	19.39			
RML-4/17				
7th April	17.53	18.14	18.32	19.6
22nd April	18.28	19	18.98	19.47
7th May	19.24	19.35	18.89	19.78
Arun-2				
7th April	17.26	18.07	18.16	19.41
22nd April	18.28	18.8	18.98	19.41
7th May	19.25	19.35	19.34	19.7
SEm±	0.0447	0.02582	0.1329	0.01826
LSD(0.05%)	0.1312	0.07573	NS	0.05355
CV%	0.44%	0.23%	1.22%	0.16%

NS=Non significant

Appendix 6. Means for different yield attributes of maize as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	Ear no ha^{-1} ('000)	Kernel rows ear^{-1}	Kernels row^{-1}	1000 grain weight (g)
Local				
7th April	60000	11.4	21.96	206.8
22nd April	60000	11.27	21.92	206.4
7th May	59260	11.27	19.42	200
Poshilo makai-1				
7th April	54810	14.17	31.06	246.1
22nd April	57040	13	24.65	241.9
7th May	57780	12.33	22.68	235.8
RML-4/17				
7th April	62220	14.03	35.78	245.6
22nd April	56300	13.64	27.89	244.5
7th May	56300	13.64	27.59	244.5
Arun-2				
7th April	59260	11.97	23.08	229.5
22nd April	57040	11.97	23.41	232.4
7th May	59260	11.63	21.25	217
SEm±	1601	0.1494	0.6022	3.373
LSD(0.05%)	NS	0.4383	1.766	NS
CV%	4.76%	2.07%	4.16%	2.55%

NS=Non significant

Appendix 7. Means for grain yield (t ha^{-1}), stover yield (t ha^{-1}) and harvest index of maize as affected by three sowing dates and four different cultivars in maize during spring, 2013 at Shivamandir-2, Nawalparasi

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
Local			
7^{th} April	3.121	10.54	0.2967
22^{nd} April	3.036	10.63	0.2917
7^{th} May	2.601	10.76	0.2453
Poshilo makai-1			
7^{th} April	5.933	15.61	0.38
22^{nd} April	4.418	15.27	0.291
7^{th} May	3.825	12.54	0.3063
RML-4/17			
7^{th} April	7.684	18.81	0.41
22^{nd} April	5.232	17.96	0.2913
7^{th} May	5.173	14.79	0.3507
Arun-2			
7^{th} April	3.765	12.44	0.303
22^{nd} April	3.73	13.16	0.2833
7^{th} May	3.168	12.24	0.259
SEm$\pm$	0.1549	0.5788	0.01826
LSD(0.05%)	0.4544	1.698	0.05355
CV%	6.23%	7.30%	9.15%

NS=Non significant

Appendix 8. Summary of probability values for DM from analysis of variation

Source of variation		DM accumulation				
		ANOVA probability values				
	Df	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Rep	2	*	0.1873	*	*	**
Sowing dates	2	**	…..	**	**	**
Varieties	3	0.0608	**	**	**	**
S X V	6	0.3110	……..	0.4231	*	0.0604

Appendix 9. Summary of probability values for LAI and LAD from analysis of variance

Source of variation		LAI				
		ANOVA probability values				
	df	30 DAS	45 DAS	60 DAS	75 DAS	LAD
Rep	2	0.1453	*	…….	0.3498	….
Sowing dates	2	**	**	**	**	**
Varieties	3	*	**	**	**	**
S X V	6	*	0.2448	…….	……	0.0844

Appendix 10. Summary of probability values for yield and yield attributing character from analysis of variance

Source of variation	df	EN	KRN	KN	TW	GY	SY	HI
ANOVA probability values								
Rep	2	0.2202	*	…	…	….	0.1715	0.1502
Sowing dates	2	……	**	**	**	**	**	**
Varieties	3	0.1370	**	**	**	**	**	**
S X V	6	0.1505	**	**	0.4094	**	*	*

Appendix 11. Summary of probability values for days to phonological stage from analysis of variance

Source of variation		Days to phenology			
		ANOVA probability values			
	df	Knee height stage	Anthesis	Silking	Seed fill period
Rep	2	…….	…..	…….	……
Sowing dates	2	**	*	**	0.0966
Varieties	3	**	**	**	**
S X V	6	**	……	0.4266	……

Appendix 12. Summary of probability values for growth degree days to phenological stages from analysis of variance

Source of variation		Growth degree days			
		ANOVA probability values			
	df	Knee height stage	Anthesis	Silking	Seed fill period
Rep	2	…….	…..	…….	……
Sowing dates	2	*	0.0597	…….	…….
Varieties	3	**	**	**	**
S X V	6	*	……	0.1413	……

Appendix 13. Summary of probability values for phenothermal index at different phenological stages from analysis of variance

Source of variation		Phenothermal index			
		ANOVA probability values			
	df	Knee height stage	Anthesis	Silking	Seed fill period
Rep	2	…….	…..	0.3838	0.3596
Sowing dates	2	**	**	**	**
Varieties	3	**	**	……	**
S X V	6	**	**	0.1765	**

Appendix 14. 'Soil file' used in spring maize experiment for running 01NP1301.MZX experiment file

```
       Atthis bigha
@SITE              COUNTRY       LAT      ``LONG     SCS   FAMILY
 Shiva-mandir-2      Nepal        27.66574   84.1309
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
     Y  0.09   6.0  0.25  81.0  1.00  1.00 IB001 IB001 IB001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    20   -99 0.183 0.338 0.433 1.000  0.68  0.98   3.1   6.1   4.9   -99 3.500   6.2   -99  -99   -99
    40   -99 0.178 0.336 0.432 0.559  0.65  1.17   1.4   5.7   5.7   -99 3.000   6.3   -99  -99   -99
    60   -99 0.164 0.306 0.417 0.368  0.64  1.14   1.5   5.1   5.1   -99 2.700   6.6   -99  -99   -99
    80   -99 0.153 0.287 0.370 0.247  0.60  1.25    .4     5     5   -99 7.400   8.4   -99  -99   -99
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    20  96.0 210.0 187.0  0.27  2.30  2.30   -99   -99   -99   -99  0.08  0.13  0.00 13.30   -99  0.27
    40  56.0 183.0 155.0  0.12  2.01  2.30   -99   -99   -99   -99  0.03  0.05  0.00 15.30   -99  0.12
    60  40.0 150.3 100.0  0.11  1.25  2.30   -99   -99   -99   -99  0.03  0.04  0.00 14.10   -99  0.11
    80  32.1 134.2  96.1  0.09  1.09  2.09   -99   -99   -99   -99  0.09  0.09  0.00 12.10   -99  0.09
```

Appendix 15. 'A file' used in spring maize experiment for running 01NP1301.MZX experiment file

@TRNO	PDAT	EDAT	ADAP	MDAP	HWUM	HWAM	SDAT	H#AM	-99
1	13097	13102	49	94	0.206	3121	13097	1501	-99
2	13097	13101	61	114	0.246	5933	13097	2411	-99
3	13097	13102	56	116	0.245	7684	13097	3123	-99
4	13097	13101	49	92	0.229	3765	13097	1635	-99
5	13112	13117	48	92	0.205	3037	13112	1499	-99
6	13112	13117	61	113	0.244	4418	13112	1898	-99
7	13112	13117	53	113	0.246	5233	13112	2339	-99
8	13112	13116	47.67	91	0.232	3730	13112	1597	-99
9	13127	13132	48	90	0.202	2601	13127	1279	-99
10	13127	13132	59	112	0.242	3825	13127	1567	-99
11	13127	13132	53	112	0.245	5174	13127	2146	-99
12	13127	13131	48	90	0.225	3168	13127	1483	-99

Appendix 16. 'T file' used in spring maize experiment for running 01NP1301. MZX experiment file

@TRNO	DATE	LLAID	CGRD
1	13126	0.389	0.157
1	13141	3.377	2.207
1	13156	2.396	2.900
1	13171	2.368	3.236
1	13186	0.648	1.283
2	13126	0.263	0.091
2	13141	2.959	2.418
2	13156	3.630	4.167
2	13171	3.157	3.144
2	13186	2.508	1.883
3	13126	0.240	0.097
3	13141	3.265	2.844
3	13156	4.131	4.807
3	13171	3.774	3.5
3	13186	3.451	3.111
4	13126	0.385	0.122
4	13141	2.399	1.823
4	13156	2.995	3.867
4	13171	2.730	2.616
4	13186	0.568	1.360
5	13141	0.696	0.161
5	13156	2.085	2.022
5	13171	2.359	2.689
5	13186	1.869	2.956
5	13201	0.375	1.239
6	13141	0.890	0.139
6	13156	2.591	2.278
6	13171	3.482	3.567
6	13186	2.928	2.567
6	13201	1.083	1.8
7	13141	1.116	0.156
7	13156	3.124	2.8
7	13171	3.805	4.056
7	13186	2.967	3.133
7	13201	1.739	3.028

@TRNO	DATE	LLAID	CGRD
8	13141	0.744	0.211
8	13156	2.133	1.811
8	13171	2.799	2.967
8	13186	2.427	2.6
8	13201	0	1.3
9	13156	0.660	0.256
9	13171	1.743	1.767
9	13186	2.189	2.694
9	13201	0.995	1.594
9	13216	0	1.089
10	13156	0.795	1.066
10	13171	2.056	2.228
10	13186	2.83	2.645
10	13201	2.098	2.296
10	13216	0.433	1.751
11	13156	1.104	0.206
11	13171	2.304	2.555
11	13186	3.516	3.551
11	13201	2.389	2.427
11	13216	0.723	2.927
12	13156	0.733	0.336
12	13171	1.912	1.594
12	13186	2.545	2.756
12	13201	1.608	2.272
12	13216	0	0.947

TRNO	DATE	CWPD
1	13126	4.720
1	13141	37.83
1	13156	81.33
1	13171	129.8
1	13186	148.9
1	13190	152
2	13126	2.730
2	13141	39.00
2	13156	101.5
2	13171	148.6
2	13186	167.9
2	13201	199.6
2	13210	208.6
3	13126	2.898
3	13141	45.56
3	13156	117.6
3	13171	170.1
3	13186	216.8
3	13201	247.3
3	13212	273.6
4	13126	3.653
4	13141	31.00
4	13156	89.00
4	13171	128.2
4	13186	148.6
4	13188	150.3
5	13141	4.833
5	13156	35.16

TRNO	DATE	CWPD
5	13171	75.5
5	13186	119.8
5	13201	138.4
5	13203	139.9
6	13141	4.167
6	13156	38.33
6	13171	91.83
6	13186	130.3
6	13201	157.3
6	13216	180.3
6	13224	189.3
7	13141	4.667
7	13156	46.67
7	13171	107.5
7	13186	154.5
7	13201	199.9
7	13216	233.6
7	13224	247.3
8	13141	6.333
8	13156	33.50
8	13171	78.00
8	13186	117.0
8	13201	136.5
9	13156	7.667
9	13171	34.16
9	13186	74.58
9	13201	98.50
9	13216	114.8
10	13156	8.750
10	13171	42.16
10	13186	87.66
10	13201	115.3
10	13216	141.5
10	13231	162
10	13238	168.6
11	13156	6.167
11	13171	44.50
11	13186	97.76
11	13201	134.2
11	13216	178.1
11	13231	218.7
11	13238	227.7
12	13156	10.08
12	13171	34.00
12	13186	75.33
12	13201	109.4
12	13216	123.6

Appendix 17. 'X file' used in spring maize experiment for running 01NP1301.MZX experiment file

```
*EXP.DETAILS: 01NP1301MZ SIMULATION OF EFFECT OF CLIMATE CHANGE IN
MAIZE

*GENERAL
@PEOPLE
Nepalese
@ADDRESS
Nawalparasi
@SITE
Shivamandir-2
@ PAREA  PRNO  PLEN  PLDR  PLSP  PLAY HAREA  HRNO  HLEN  HARM.........
    -99   -99   -99   -99   -99   -99   -99   -99   -99   -99

*TREATMENTS                        -------------FACTOR LEVELS------------
@N R O C TNAME.................... CU FL SA IC MP MI MF MR MC MT ME MH SM
 1 1 1 0 LOCAL + APRIL 7            1  1  0  0  1  0  0  0  0  0  0  0  1
 2 1 1 0 QPM + APRIL 7              2  1  0  0  2  0  0  0  0  0  0  0  2
 3 1 1 0 HYBRID-417 + APRIL 7       3  1  0  0  3  0  0  0  0  0  0  0  3
 4 1 1 0 ARUN-2 + APRIL 7           4  1  0  0  4  0  0  0  0  0  0  0  4
 5 1 1 0 LOCAL + APRIL 22           1  2  0  0  5  0  0  0  0  0  0  0  5
 6 1 1 0 QPM + APRIL 22             2  2  0  0  6  0  0  0  0  0  0  0  6
 7 1 1 0 HYBRID-417+ APRIL 22       3  2  0  0  7  0  0  0  0  0  0  0  7
 8 1 1 0 ARUN-2+ APRIL 22           4  2  0  0  8  0  0  0  0  0  0  0  8
 9 1 1 0 LOCAL + MAY 7              1  3  0  0  9  0  0  0  0  0  0  0  9
10 1 1 0 QPM + MAY 7                2  3  0  0 10  0  0  0  0  0  0  0 10
11 1 1 0 HYBRID-417 + MAY 7         3  3  0  0 11  0  0  0  0  0  0  0 11
12 1 1 0 ARUN-2 + MAY 7             4  3  0  0 12  0  0  0  0  0  0  0 12

*CULTIVARS
@C CR INGENO CNAME
 1 MZ IB0060 LOCAL
 2 MZ IB0064 QPM
 3 MZ IB0055 HYBRID-417
 4 MZ IB0061 ARUN-2

*FIELDS
@L ID_FIELD WSTA....  FLSA  FLOB  FLDT  FLDD  FLDS  FLST SLTX  SLDP  ID_SOIL    FLNAME
 1 IAAS0001 MUNA1301   -99   -99   -99   -99   -99   -99 -99    -99  UFBG760002 4/7/2013
 2 IAAS0002 MUNA1301   -99   -99   -99   -99   -99   -99 -99    -99  UFBG760002 4/22/2013
 3 IAAS0003 MUNA1301   -99   -99   -99   -99   -99   -99 -99    -99  UFBG760002 5/7/2013
@L ..XCRD ..YCRD  ELEV .AREA .SLEN  FLWR .SLAS FLHST FHDUR
 1    -99   -99   -99   -99   -99   -99   -99   -99   -99
 2    -99   -99   -99   -99   -99   -99   -99   -99   -99
 3    -99   -99   -99   -99   -99   -99   -99   -99   -99


*INITIAL CONDITIONS
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 1    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 LOCAL + APRIL 7
@C  ICBL  SH2O  SNH4  SNO3
 1    20   -99     8    15
 1    40   -99     6    18
 1    60   -99   5.7  19.5
 1    80   -99     5    21
 1   100   -99   4.7    25
```

```
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 2    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 QPM + APRIL 7
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 3    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 HYBRID-417 + APRIL 7
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 4    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 ARUN-2 + APRIL 7
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 5    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 LOCAL + APRIL 22
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 6    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 QPM + APRIL 22
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 7    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 HYBRID-417 + APRIL 22
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 8    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 ARUN-2 + APRIL 22
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
 9    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 LOCAL + MAY 7
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
10    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 QPM + MAY 7
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
11    MZ 13097   -99   -99     1     1   -99   -99   -99   -99   -99   -99 HYBRID-417 +MAY 7
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE  ICWD ICRES ICREN ICREP ICRIP ICRID ICNAME
12    MZ 13127   -99   -99     1     1   -99   -99   -99   -99   -99   -99 ARUN-2 + MAY 7

*PLANTING DETAILS
@P PDATE EDATE  PPOP  PPOE  PLME  PLDS  PLRS  PLRD  PLDP  PLWT  PAGE  PENV  PLPH  SPRL    PLNAME
 1 13097   -99   7.2     6     S     R    60   -99     5   -99   -99   -99   -99   -99    LOCAL + APRIL 7
 2 13097   -99   7.2 5.481     S     R    60   -99     5   -99   -99   -99   -99   -99    QPM + APRIL 7
 3 13097   -99   7.2 6.222     S     R    60   -99     5   -99   -99   -99   -99   -99    HYBRID-417 + APRIL 7
 4 13097   -99   7.2 5.925     S     R    60   -99     5   -99   -99   -99   -99   -99    ARUN-2 + APRIL 7
 5 13112   -99   7.2     6     S     R    60   -99     5   -99   -99   -99   -99   -99    LOCAL + APRIL 22
 6 13112   -99   7.2 5.703     S     R    60   -99     5   -99   -99   -99   -99   -99    QPM + APRIL 22
 7 13112   -99   7.2 5.629     S     R    60   -99     5   -99   -99   -99   -99   -99   HYBRID417+APRIL 22
 8 13112   -99   7.2 5.703     S     R    60   -99     5   -99   -99   -99   -99   -99    ARUN-2+APRIL22
 9 13127   -99   7.2 5.925     S     R    60   -99     5   -99   -99   -99   -99   -99    LOCAL + MAY 7
10 13127   -99   7.2 5.707     S     R    60   -99     5   -99   -99   -99   -99   -99    QPM + MAY 7
11 13127   -99   7.2 5.629     S     R    60   -99     5   -99   -99   -99   -99   -99    HYBRID-417 + MAY 7
12 13127   -99   7.2 5.925     S     R    60   -99     5   -99   -99   -99   -99   -99    ARUN-2 + MAY 7

*IRRIGATION AND WATER MANAGEMENT
@I  EFIR  IDEP  ITHR  IEPT  IOFF  IAME  IAMT IRNAME
 1     1    30    50   100 GS000 IR001    10 LOCAL + APRIL 7
@I IDATE  IROP IRVAL
 1 13097 IR001   150
 1 13099 IR001   150
 1 13101 IR001   150
 1 13105 IR001   150
 1 13108 IR001   150
 1 13117 IR001   150
 1 13122 IR001   150
 1 13132 IR001   150
@I  EFIR  IDEP  ITHR  IEPT  IOFF  IAME  IAMT IRNAME
 2     1    30    50   100 GS000 IR001    10 QPM + APRIL 7
@I IDATE  IROP IRVAL
 2 13097 IR001   150
 2 13099 IR001   150
 2 13099 IR001   150
 2 13099 IR001   150
 2 13101 IR001   150
 2 13101 IR001   150
 2 13101 IR001   150
@I  EFIR  IDEP  ITHR  IEPT  IOFF  IAME  IAMT IRNAME
 3     1    30    50   100 GS000 IR001    10 HYBRID-417 + APRIL 7
@I IDATE  IROP IRVAL
 3 13097 IR001   150
 3 13097 IR001   150
 3 13097 IR001   150
 3 13099 IR001   150
 3 13099 IR001   150
```

```
 3 13099 IR001   150
 3 13099 IR001   150
 3 13101 IR001   150
 3 13101 IR001   150
 3 13101 IR001   150
 3 13101 IR001   150
@I  EFIR  IDEP  ITHR  IEPT  IOFF  IAME  IAMT IRNAME
 4     1    30    50   100 GS000 IR001    10 ARUN-2 + APRIL 7
@I IDATE  IROP IRVAL
 4 13097 IR001   150
 4 13099 IR001   150
 4 13101 IR001   150

*FERTILIZERS (INORGANIC)
@F FDATE  FMCD  FACD  FDEP  FAMN  FAMP  FAMK  FAMC  FAMO  FOCD FERNAME
 1 13097   -99   -99     1     5     6     4   -99   -99   -99 LOCAL + APRIL 7
 2 13097   -99   -99     1     5     6     4   -99   -99   -99 QPM + APRIL 7
 3 13097   -99   -99     1     5     6     4   -99   -99   -99 HYBRID-417 + APRIL 7
 4 13097  FE00   -99     1     5     6     4   -99   -99   -99 ARUN-2 + APRIL 7
 5 13097  FE01   -99     1     5     6     4   -99   -99   -99 LOCAL + APRIL 22
 6 13097  FE00   -99     1     5     6     4   -99   -99   -99 QPM + APRIL 22
 7 13097  FE00   -99     1     5     6     4   -99   -99   -99 HYBRID-417 + APRIL 22
 8 13097  FE01   -99     1     5     6     4   -99   -99   -99 ARUN-2 + APRIL 22
 9 13097  FE00   -99     1     5     6     4   -99   -99   -99 LOCAL + MAY 7
10 13097  FE00   -99     1     5     6     4   -99   -99   -99 QPM + MAY 7
11 13097  FE01   -99     1     5     6     4   -99   -99   -99 HYBRID-417 + MAY 7
12 13097  FE00   -99     1     5     6     4   -99   -99   -99 ARUN-2 + MAY 7
 1 13013  FE01   -99   -99     5   -99   -99   -99   -99   -99 LOCAL + APRIL 7
 2 13013  FE00   -99   -99     5   -99   -99   -99   -99   -99 QPM + APRIL 7
 3 13013  FE00   -99   -99     5   -99   -99   -99   -99   -99 HYBRID-417 + APRIL 7
 4 13013  FE00   -99   -99     5   -99   -99   -99   -99   -99 ARUN-2 + APRIL 7
 5 13015  FE00   -99   -99     5   -99   -99   -99   -99   -99 LOCAL + APRIL 22
 6 13015  FE01   -99   -99     5   -99   -99   -99   -99   -99 QPM + APRIL 22
 7 13015  FE00   -99   -99     5   -99   -99   -99   -99   -99 HYBRID-417 + APRIL 22
 8 13015  FE01   -99   -99     5   -99   -99   -99   -99   -99 ARUN-2 + APRIL 22
 9 13016  FE00   -99   -99     5   -99   -99   -99   -99   -99 LOCAL + MAY 7
10 13016  FE00   -99   -99     5   -99   -99   -99   -99   -99 QPM + MAY 7
11 13016  FE01   -99   -99     5   -99   -99   -99   -99   -99 HYBRID-417 + MAY 7
12 13016  FE00   -99   -99     5   -99   -99   -99   -99   -99 ARUN-2 + MAY 7

*HARVEST DETAILS
@H HDATE  HSTG  HCOM HSIZE   HPC  HBPC HNAME
 1 13097 GS000   -99   -99   -99   -99 Maize

*SIMULATION CONTROLS
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 1 GE              1     1     S 13097  2150 LOCAL + APRIL 7           MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 1 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 1 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 1 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 1 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 1 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 1 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 1 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 1 RE            100     1    20
```

```
@N HARVEST      HFRST HLAST HPCNP HPCNR
 1 HA               0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 2 GE              1     1     S 13097  2150 QPM + APRIL 7              MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 2 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 2 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 2 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 2 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 2 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 2 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 2 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 2 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 2 HA              0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 3 GE              1     1     S 13097  2150 HYBRID-417 + APRIL 7       MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 3 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 3 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 3 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 3 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 3 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 3 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 3 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 3 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 3 HA              0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 4 GE              1     1     S 13097  2150 ARUN-2 + APRIL 7           MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 4 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 4 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 4 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 4 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y
```

```
@  AUTOMATIC MANAGEMENT
@N PLANTING     PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 5 PL           13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 5 IR              30    50   100 GS000 IR001    10     1
@N NITROGEN     NMDEP NMTHR NAMNT NCODE NAOFF
 5 NI              30    50    25 FE001 GS000
@N RESIDUES     RIPCN RTIME RIDEP
 5 RE             100     1    20
@N HARVEST      HFRST HLAST HPCNP HPCNR
 5 HA               0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 6 GE              1     1     S 13112  2150 QPM + APRIL 22            MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 6 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 6 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 6 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 6 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING     PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 6 PL           13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 6 IR              30    50   100 GS000 IR001    10     1
@N NITROGEN     NMDEP NMTHR NAMNT NCODE NAOFF
 6 NI              30    50    25 FE001 GS000
@N RESIDUES     RIPCN RTIME RIDEP
 6 RE             100     1    20
@N HARVEST      HFRST HLAST HPCNP HPCNR
 6 HA               0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 7 GE              1     1     S 13112  2150 HYBRID-417 + APRIL 22     MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 7 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 7 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 7 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 7 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING     PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 7 PL           13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 7 IR              30    50   100 GS000 IR001    10     1
@N NITROGEN     NMDEP NMTHR NAMNT NCODE NAOFF
 7 NI              30    50    25 FE001 GS000
@N RESIDUES     RIPCN RTIME RIDEP
 7 RE             100     1    20
@N HARVEST      HFRST HLAST HPCNP HPCNR
 7 HA               0 01001   100     0
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 8 GE              1     1     S 13112  2150 ARUN-2 + APRIL 22         MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 8 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 8 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 8 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 8 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y
```

```
@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 8 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 8 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 8 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 8 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 8 HA              0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 9 GE              1     1     S 13127  2150 LOCAL + MAY 7             MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 9 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 9 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 9 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 9 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 9 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 9 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 9 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 9 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 9 HA              0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
10 GE              1     1     S 13127  2150 QPM + MAY 7               MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
10 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
10 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
10 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
10 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
10 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
10 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
10 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
10 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
10 HA              0 01001   100     0
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
11 GE              1     1     S 13127  2150 HYBRID-417 + MAY 7        MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
11 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
11 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
11 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
11 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y
```

```
@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
11 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
11 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
11 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
11 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
11 HA              0 01001   100     0

@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
12 GE              1     1     S 13127  2150 ARUN-2 + MAY 7            MZCER
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
12 OP              Y     Y     Y     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
12 ME              M     M     E     R     S     L     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
12 MA              R     R     R     R     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
12 OU              N     Y     Y     1     Y     Y     Y     Y     Y     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
12 PL          13001 13001    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
12 IR             30    50   100 GS000 IR001    10     1
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
12 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
12 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
12 HA              0 01001   100     0
```

Appendix 18. 'W file' used in spring maize experiment for running 01NP1301. MZX experiment file

Weather year: 2013

@ INSI	LAT	LONG	ELEV	TAV	AMP	REFHT	WNDHT
MUNA	27.417	84.217	154	-99.0	-99.0	-99.0	-99.0

@DATE	SRAD	TMAX	TMIN	RAIN
13097	25.5	35.0	16.4	0.0
13098	25.1	35.5	18.2	0.0
13099	24.6	35.8	20.6	0.0
13100	25.4	37.8	21.8	0.0
13101	25.0	39.0	19.4	0.0
13102	25.6	38.8	19.6	0.0
13103	26.4	39.0	19.6	0.0
13104	25.1	37.5	19.0	0.0
13105	25.1	35.8	20.0	0.0
13106	25.1	34.0	19.6	0.0
13107	24.5	31.2	19.4	0.0
13108	23.5	32.8	20.2	0.0
13109	26.4	33.0	18.6	0.0
13110	16.6	32.8	20.8	0.0
13111	4.5	21.8	17.8	0.0
13112	18.1	29.5	19.0	0.0
13113	20.5	30.6	18.4	0.0
13114	18.2	28.6	21.2	0.0
13115	23.2	32.0	21.6	0.0
13116	24.3	33.4	22.6	0.0
13117	26.3	35.0	22.8	0.0
13118	25.9	34.8	23.4	0.0
13119	23.4	33.0	24.6	0.0
13120	25.3	34.8	23.8	0.0
13121	26.2	32.4	23.4	0.0
13122	23.9	30.8	23.0	0.0
13123	27.5	36.8	18.4	0.0
13124	27.4	37.8	18.8	0.0
13125	26.4	34.8	20.6	11.2
13126	26.0	33.8	23.4	15.0
13127	25.2	33.8	24.2	0.0
13128	23.0	33.8	25.6	0.0
13129	23.8	35.0	25.4	0.0
13130	25.9	36.8	24.8	0.0
13131	26.4	38.8	23.6	0.0
13132	26.9	34.8	22.2	0.0
13133	18.7	36.0	22.0	0.0
13134	25.3	36.0	23.0	83.5
13135	24.4	33.0	21.2	2.5
13136	22.6	33.8	21.6	0.0
13137	27.2	33.8	23.4	1.0
13138	24.9	34.8	26.0	0.0
13139	23.4	32.8	24.4	49.0
13140	17.4	33.0	24.4	55.6
13141	18.5	33.0	26.6	5.6
13142	17.1	33.6	24.4	45.0
13143	20.1	34.4	24.6	6.5
13144	23.1	35.0	26.2	17.0
13145	23.4	34.2	29.8	32.2

@DATE	SRAD	TMAX	TMIN	RAIN
13146	17.2	31.8	23.6	0.0
13147	17.4	35.0	24.6	0.0
13148	26.0	34.8	23.6	59.2
13149	25.3	32.8	25.2	12.5
13150	12.9	25.8	23.2	22.0
13151	4.9	33.0	23.2	17.4
13152	15.9	36.0	24.6	0.0
13153	26.4	36.5	27.4	0.0
13154	24.7	35.6	26.4	0.0
13155	21.7	34.8	26.4	12.7
13156	22.0	34.8	24.2	48.4
13157	21.6	33.6	22.8	38.0
13158	19.5	35.8	26.8	0.0
13159	21.5	34.0	24.4	0.0
13160	19.1	35.8	26.8	0.0
13161	20.9	35.0	28.4	0.0
13162	17.7	36.8	27.4	0.0
13163	17.2	36.9	26.4	0.0
13164	24.7	35.0	26.4	8.0
13165	21.6	31.6	25.6	8.6
13166	11.6	33.0	24.6	98.2
13167	12.6	26.0	24.2	156.0
13168	6.1	24.6	22.8	25.0
13169	2.2	29.0	23.4	9.0
13170	12.7	33.8	24.4	2.0
13171	18.4	33.8	25.4	2.0
13172	17.2	34.4	27.2	36.6
13173	15.2	33.8	26.6	2.2
13174	15.4	30.8	23.6	14.0
13175	8.8	34.2	25.0	0.0
13176	20.7	32.4	26.8	0.0
13177	15.4	33.0	27.2	15.0
13178	16.6	33.0	26.4	0.0
13179	13.2	29.0	25.8	50.2
13180	6.6	33.8	27.0	17.4
13181	16.2	33.8	26.0	10.0
13182	9.8	34.0	27.0	0.0
13183	17.6	34.8	26.4	40.0
13184	18.9	33.8	27.4	0.0
13185	15.4	32.2	25.4	0.0
13186	12.8	31.0	26.4	0.0
13187	10.8	32.0	25.4	70.0
13188	13.1	32.8	25.6	195.0
13189	11.5	31.8	25.0	102.0
13190	12.6	31.8	25.2	156.0
13191	12.1	31.8	25.8	113.0
13192	13.3	34.8	23.0	0.0
13193	20.3	35.8	21.8	29.0
13194	17.1	32.2	26.8	7.0
13195	19.0	35.2	27.2	15.0
13196	19.8	34.8	27.2	10.0
13197	18.3	33.8	27.4	5.0
13198	16.6	31.8	26.4	0.0
13199	11.3	31.8	25.6	30.0
13200	9.0	32.8	25.6	0.0
13201	15.7	32.8	26.4	35.0

@DATE	SRAD	TMAX	TMIN	RAIN
13202	20.4	35.8	26.4	65.0
13203	14.3	31.0	27.6	5.0
13204	22.0	36.8	26.4	1.5
13205	19.7	34.8	27.2	3.0
13206	15.0	32.8	25.6	5.0
13207	21.9	34.2	26.4	5.0
13208	18.1	33.0	23.0	0.0
13209	14.0	33.8	26.0	0.0
13210	19.5	34.0	27.2	0.0
13211	20.5	35.0	28.0	0.0
13212	20.6	34.0	27.0	0.0
13213	17.8	34.0	24.6	17.5
13214	19.5	34.8	26.2	7.0
13215	20.2	35.0	27.4	17.0
13216	20.2	32.0	25.8	135.0
13217	15.3	33.8	25.0	0.0
13218	18.6	33.2	25.8	0.0
13219	15.6	33.8	25.8	13.0
13220	16.2	32.0	28.2	24.0
13221	17.7	32.0	26.2	29.4
13222	13.4	33.0	25.4	80.0
13223	17.0	32.4	25.2	175.0
13224	18.0	34.0	26.4	0.0
13225	20.5	34.8	24.0	0.0
13226	22.3	33.0	25.6	200.0
13227	11.3	33.8	24.4	0.0
13228	20.6	32.8	24.6	0.0
13229	15.8	34.8	25.6	0.0
13230	19.2	34.8	25.4	0.0
13231	20.2	34.0	26.8	0.0
13232	18.3	31.4	26.2	47.0
13233	9.9	33.6	25.0	0.0
13234	19.7	34.8	25.6	0.0
13235	20.9	34.8	27.0	0.0
13236	20.7	35.0	26.8	0.0
13237	21.4	31.8	24.8	38.2
13238	11.8	29.0	24.6	127.0
13239	0.4	31.0	23.2	9.0

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*WEATHER DATA : 2011
@ INSI      LAT     LONG  ELEV   TAV   AMP REFHT WNDHT
  MUN2   27.417   84.133   154  25.7   7.6 -99.0 -99.0
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@DATE	SRAD	TMAX	TMIN	RAIN
11097	24.9	39.8	21.8	0.0
11098	25.8	40.4	23.2	0.0
11099	24.2	40.5	24.5	1.0
11100	25.4	40.8	24.4	1.7
11101	24.8	40.5	24.7	1.4
11102	23.3	41.3	25.6	2.5
11103	19.2	33.8	25.4	5.4
11104	25.7	39.0	23.3	0.3
11105	27.0	37.2	23.1	0.0
11106	26.0	39.6	22.9	0.0
11107	24.6	41.8	24.2	1.2
11108	17.1	35.8	27.3	1.8

@DATE	SRAD	TMAX	TMIN	RAIN
11109	22.6	35.4	24.7	3.1
11110	26.9	39.8	23.2	0.0
11111	27.4	41.1	24.0	0.0
11112	27.9	40.8	24.5	0.0
11113	27.0	42.0	24.8	0.0
11114	25.9	40.8	26.2	0.0
11115	22.9	33.3	24.5	7.5
11116	25.8	31.3	21.9	0.0
11117	25.7	36.6	23.2	0.1
11118	25.7	37.7	23.8	0.8
11119	23.3	32.9	24.2	1.5
11120	16.1	33.1	24.4	0.1
11121	24.9	34.2	23.4	3.8
11122	26.5	33.5	23.4	0.0
11123	26.5	37.3	23.3	0.5
11124	26.0	32.2	24.3	0.0
11125	26.1	35.1	24.1	0.0
11126	25.2	38.1	25.1	0.0
11127	7.5	35.3	24.9	0.0
11128	26.4	36.8	24.9	0.0
11129	26.4	35.2	24.1	0.0
11130	24.6	41.4	25.1	0.2
11131	26.2	38.8	26.1	2.4
11132	25.7	34.7	26.1	0.0
11133	17.5	40.3	25.6	0.0
11134	26.7	36.1	24.8	0.8
11135	26.7	37.3	24.9	0.0
11136	26.4	39.9	25.6	23.3
11137	26.0	35.4	27.2	21.5
11138	25.1	30.7	26.3	28.4
11139	22.7	35.1	24.6	7.0
11140	24.1	37.8	23.8	0.0
11141	19.1	34.4	25.3	0.0
11142	22.5	34.9	26.0	0.2
11143	26.4	38.1	25.4	0.0
11144	23.3	36.8	27.0	0.0
11145	23.5	34.0	27.4	5.5
11146	16.1	34.0	26.2	20.9
11147	19.0	33.7	26.1	2.8
11148	23.7	31.5	26.0	0.0
11149	24.2	39.2	24.9	0.0
11150	21.6	34.9	26.1	0.0
11151	21.7	33.0	26.0	0.0
11152	25.3	36.1	25.1	0.0
11153	26.5	36.0	26.0	2.9
11154	26.8	32.4	25.8	4.8
11155	27.6	38.5	25.3	0.0
11156	26.1	39.9	26.4	0.0
11157	26.1	39.4	26.6	3.2
11158	9.4	35.8	26.3	2.5
11159	22.2	34.9	26.0	0.5
11160	21.5	38.5	26.0	0.0
11161	25.2	40.0	26.6	0.0
11162	22.6	37.4	27.7	0.0
11163	25.5	38.8	27.1	0.4
11164	22.5	39.1	27.2	2.5

@DATE	SRAD	TMAX	TMIN	RAIN
11165	25.0	37.5	27.3	0.9
11166	23.4	34.5	27.0	0.8
11167	25.0	34.9	26.6	1.9
11168	22.3	34.9	27.0	3.6
11169	9.6	34.0	26.2	0.3
11170	5.1	34.7	26.0	19.8
11171	20.5	33.4	25.5	2.2
11172	23.5	35.8	27.0	5.6
11173	21.9	37.7	27.1	0.9
11174	23.1	36.1	26.8	10.1
11175	20.9	36.5	26.4	41.2
11176	15.6	34.4	26.6	29.4
11177	20.5	35.6	26.6	15.9
11178	22.4	37.5	25.8	24.1
11179	16.3	34.9	25.6	6.4
11180	8.9	34.9	25.9	9.7
11181	5.0	29.9	24.3	41.6
11182	8.7	32.5	24.3	5.8
11183	20.3	34.0	24.9	38.1
11184	13.0	32.0	26.2	13.5
11185	20.2	36.0	25.3	28.4
11186	14.5	31.8	25.1	0.0
11187	19.0	35.6	24.9	0.0
11188	13.9	34.2	24.6	0.4
11189	18.6	34.0	25.3	0.0
11190	24.5	32.2	25.2	27.3
11191	22.1	32.0	25.4	3.5
11192	21.3	32.7	25.5	9.3
11193	17.9	35.1	25.6	8.8
11194	16.5	35.0	25.5	19.9
11195	18.0	33.0	25.5	7.9
11196	19.0	31.9	25.3	0.2
11197	21.3	34.6	25.1	0.0
11198	21.0	33.8	25.0	3.1
11199	23.9	36.2	25.3	8.1
11200	18.2	34.5	25.9	33.7
11201	10.8	32.3	27.1	13.6
11202	21.7	33.0	25.1	8.7
11203	16.8	34.3	25.7	7.7
11204	15.0	33.3	25.2	0.0
11205	18.7	35.1	25.0	1.7
11206	19.3	34.4	25.5	0.1
11207	16.3	34.7	25.6	0.5
11208	4.5	30.1	25.8	39.3
11209	11.3	31.3	25.6	0.0
11210	16.4	30.9	25.9	0.2
11211	15.2	32.3	25.4	10.6
11212	12.4	31.3	26.4	29.9
11213	19.2	31.9	26.1	2.9
11214	7.5	33.5	26.2	22.8
11215	19.6	30.4	25.9	6.8
11216	18.6	30.5	25.4	13.3
11217	13.8	31.4	26.0	49.3
11218	19.5	30.1	25.1	26.8
11219	20.2	32.1	24.3	14.5
11220	20.1	30.9	24.8	1.9

@DATE	SRAD	TMAX	TMIN	RAIN
11221	22.1	31.5	23.8	0.1
11222	19.0	31.5	24.1	11.0
11223	16.5	31.6	24.9	4.3
11224	16.5	30.4	23.9	2.5
11225	19.8	31.2	24.9	7.9
11226	15.1	28.4	23.0	1.2
11227	10.9	27.9	24.2	6.5
11228	16.7	29.3	24.1	8.2
11229	9.8	28.7	25.6	18.7
11230	12.2	29.6	23.9	0.0
11231	11.8	30.1	23.3	0.1
11232	23.5	32.3	23.4	0.3
11233	22.2	31.6	24.9	20.1
11234	17.0	30.3	25.3	17.9
11235	8.3	32.1	24.8	30.4
11236	19.4	30.0	25.0	12.9
11237	20.1	29.9	25.2	15.7
11238	22.0	30.9	23.9	0.0
11239	25.6	31.8	24.2	0.0
11240	20.8	31.7	24.5	3.0
11241	21.6	32.0	24.9	0.2
11242	20.2	33.8	25.2	5.5
11243	16.7	31.4	25.5	4.4
11244	21.2	31.1	24.7	0.2
11245	20.8	30.8	24.1	1.1
11246	21.4	30.7	23.9	0.5
11247	22.2	31.4	24.0	3.0
11248	22.4	30.8	24.8	2.9
11249	16.8	31.0	24.8	14.0
11250	16.3	31.5	24.4	12.4
11251	10.3	30.0	24.9	8.0
11252	16.4	30.4	24.6	6.8
11253	19.0	30.6	24.3	15.0
11254	18.9	31.0	24.0	0.8
11255	21.5	31.7	24.5	0.7
11256	21.0	32.7	24.5	2.7
11257	13.1	31.4	25.1	15.8
11258	16.1	30.0	24.6	1.5
11259	17.7	29.7	23.9	10.8
11260	18.2	30.1	23.9	16.4
11261	15.8	27.9	24.4	34.2
11262	15.7	31.4	24.3	0.5
11263	8.7	30.9	24.8	0.2
11264	12.0	29.9	24.3	0.3
11265	17.6	29.6	23.9	7.4
11266	12.5	29.2	24.0	14.5
11267	9.5	27.5	24.5	1.4
11268	12.0	28.3	23.9	9.6
11269	13.2	31.0	22.5	9.9
11270	18.1	29.6	22.2	0.0
11271	19.4	30.7	23.9	0.0
11272	19.2	31.2	23.3	0.0
11273	20.9	30.6	23.9	0.0
11274	19.9	30.4	24.1	0.0
11275	18.5	30.1	23.6	0.0
11276	19.9	30.1	21.9	0.0

@DATE	SRAD	TMAX	TMIN	RAIN
11277	19.9	29.8	22.7	0.0
11278	20.0	31.1	21.8	0.0
11279	19.9	30.2	23.2	0.0
11280	19.8	29.3	22.6	0.0
11281	19.9	30.6	22.3	0.0
11282	19.6	31.3	23.2	0.0
11283	19.8	30.3	22.6	0.0
11284	19.6	31.0	23.6	0.0
11285	20.1	30.2	21.4	0.0
11286	19.2	30.2	21.5	0.0
11287	19.2	30.1	19.7	0.0
11288	18.0	29.8	21.9	0.0
11289	17.9	30.3	22.8	0.0
11290	17.9	28.6	22.6	0.0
11291	17.8	29.9	21.8	0.0
11292	18.2	30.0	21.5	0.0
11293	14.4	28.9	21.9	1.2
11294	17.5	28.4	21.7	0.7
11295	18.1	28.6	20.4	0.0
11297	18.3	29.1	21.0	0.0
11298	17.6	28.4	21.2	0.0
11299	17.3	28.1	20.8	0.0
11300	17.7	27.6	20.1	0.0
11301	17.5	27.4	19.3	0.0
11302	17.4	27.6	18.7	0.0
11303	17.5	27.0	20.5	0.0
11304	17.2	26.1	17.6	0.0
11305	16.4	27.3	18.3	0.0
11306	14.1	26.6	18.6	0.0

Weather Data: 2008

@ INSI	LAT	LONG	ELEV	TAV	AMP	REFHT	WNDHT
MUN6	27.417	84.133	154	-99.0	-99.0	-99.0	-99.0

@DATE	SRAD	TMAX	TMIN	RAIN
08097	16.3	27.9	22.3	0.5
08098	25.4	35.1	19.5	0.0
08099	25.7	37.1	20.1	0.0
08100	26.0	39.7	21.8	0.0
08101	26.1	40.5	23.2	0.5
08102	25.5	41.5	24.0	6.5
08103	25.4	42.8	25.1	2.6
08104	26.3	41.8	24.9	0.6
08105	26.1	42.1	24.7	0.7
08106	25.8	42.2	24.7	0.0
08107	25.1	43.5	26.9	7.0
08108	26.0	41.1	25.7	0.0
08109	26.9	42.0	25.5	0.0
08110	27.8	42.0	24.6	0.0
08111	27.5	43.5	25.5	0.0
08112	26.7	42.2	25.1	0.0
08113	26.9	43.3	25.3	0.0
08114	26.5	44.1	26.7	0.0
08115	27.5	44.6	25.9	0.0
08116	27.0	45.1	27.0	0.0

@DATE	SRAD	TMAX	TMIN	RAIN
08117	26.6	44.9	27.0	0.0
08118	27.1	43.6	26.8	0.3
08119	27.0	45.6	28.0	0.0
08120	25.3	43.2	25.8	0.4
08121	24.9	43.6	26.4	0.0
08122	27.0	44.0	25.3	3.7
08123	27.3	45.8	26.9	7.0
08124	26.3	40.3	27.0	0.1
08125	24.3	42.1	26.0	1.2
08126	23.3	42.6	27.5	0.0
08127	25.0	42.7	25.5	2.1
08128	26.9	43.0	26.6	1.9
08129	26.2	43.0	26.2	0.2
08130	26.9	42.8	26.1	2.9
08131	27.1	43.1	27.8	1.3
08132	23.2	42.5	27.7	1.2
08133	26.9	41.6	28.1	1.3
08134	26.9	42.6	26.0	0.0
08135	26.4	43.6	28.7	9.2
08136	27.1	42.2	27.0	0.0
08137	25.5	43.1	27.0	0.0
08138	25.8	44.3	30.8	2.3
08139	23.0	44.6	29.0	2.8
08140	24.0	36.7	28.6	1.2
08141	21.2	34.1	24.1	1.1
08142	16.1	39.0	25.5	13.3
08143	15.9	37.7	27.8	6.3
08144	13.5	37.4	25.1	7.0
08145	10.7	37.2	25.6	14.2
08146	18.8	31.9	25.9	2.1
08147	25.7	33.7	25.2	0.2
08148	24.3	41.3	26.3	0.2
08149	27.6	42.8	26.2	0.0
08150	28.0	43.2	27.4	0.0
08151	28.0	43.8	27.3	0.9
08152	27.7	42.2	27.9	0.1
08153	26.8	40.4	27.8	0.5
08154	26.6	34.4	26.4	9.8
08155	26.2	41.7	25.7	0.0
08156	9.8	37.1	27.6	4.7
08157	23.4	36.4	27.3	0.8
08158	18.9	36.2	26.9	2.1
08159	19.0	38.0	27.4	3.9
08160	21.5	40.6	27.7	4.7
08161	22.0	34.9	28.7	3.0
08162	20.4	39.7	26.8	5.1
08163	19.7	41.2	27.6	13.9
08164	21.9	41.5	28.2	0.7
08165	15.7	33.5	28.3	36.0
08166	10.6	35.7	26.3	55.9
08167	10.8	37.2	25.2	3.5
08168	24.6	39.1	26.0	1.3
08169	13.2	34.2	26.9	5.3
08170	15.6	37.9	26.5	18.5
08171	11.3	33.9	25.7	0.0
08172	14.8	37.8	25.3	0.0

@DATE	SRAD	TMAX	TMIN	RAIN
08173	19.7	35.3	25.6	0.5
08174	16.7	39.3	27.1	1.3
08175	21.5	37.2	26.4	29.0
08176	22.0	37.6	27.3	20.1
08177	22.0	33.3	27.2	2.8
08178	17.4	34.1	27.2	27.3
08179	14.5	31.2	26.6	5.5
08180	11.0	30.8	25.4	30.1
08181	7.9	30.5	24.2	13.8
08182	17.0	34.5	23.8	5.8
08183	15.3	33.8	24.6	10.0
08184	16.6	33.4	24.2	0.3
08185	14.7	35.3	24.5	7.3
08186	17.3	33.3	25.1	10.9
08187	19.7	34.9	25.7	6.1
08188	16.8	34.9	25.2	0.6
08189	23.9	36.3	25.4	0.0
08190	23.2	38.1	26.4	0.9
08191	24.5	37.8	25.9	4.6
08192	21.0	37.3	26.6	1.6
08193	14.0	35.6	25.8	7.9
08194	17.4	35.0	24.8	21.8
08195	8.4	31.2	24.9	19.6
08196	15.7	31.1	24.6	22.6
08197	12.3	30.1	25.9	2.0
08198	13.6	34.4	23.9	16.8
08199	17.1	32.9	25.1	13.6
08200	9.0	33.9	24.9	24.8
08201	13.6	29.7	24.4	28.1
08202	13.1	32.8	24.4	2.4
08203	12.5	30.3	25.0	5.2
08204	17.3	31.3	24.5	14.2
08205	10.2	30.5	24.7	22.9
08206	11.8	31.5	24.2	0.0
08207	19.4	32.2	24.6	6.2
08208	18.0	32.0	24.6	1.0
08209	21.0	33.2	24.7	3.7
08210	23.0	35.0	25.8	2.0
08211	19.7	32.2	24.8	0.9
08212	14.6	32.7	24.5	0.1
08213	17.3	32.2	25.4	0.4
08214	18.1	31.8	25.3	4.4
08215	21.3	30.8	25.3	21.0
08216	16.0	31.2	25.4	4.2
08217	20.4	32.4	24.6	1.4
08218	18.0	32.3	24.6	0.6
08219	17.3	30.8	24.3	12.8
08220	11.1	28.1	24.8	32.8

*WEATHER DATA : 2007

@ INSI	LAT	LONG	ELEV	TAV	AMP	REFHT	WNDHT
MUN7	27.417	84.133	154	18.2	5.3	-99.0	-99.0

@DATE	SRAD	TMAX	TMIN	RAIN
07097	26.1	27.7	15.6	1.9
07098	26.2	26.1	16.0	0.7
07099	24.2	22.6	17.2	0.4
07100	26.8	20.4	15.9	0.1
07101	25.0	20.7	15.6	15.6
07102	24.0	19.5	14.2	0.0
07103	22.6	19.5	13.9	1.2
07104	24.7	22.8	14.8	0.0
07105	27.3	21.8	15.9	2.1
07106	22.0	21.1	16.9	0.6
07107	25.2	22.5	17.6	0.0
07108	19.5	22.0	16.9	0.0
07109	23.9	21.5	17.2	0.1
07110	27.8	22.6	16.9	0.0
07111	26.6	22.7	17.9	0.0
07112	28.8	22.3	18.0	0.0
07113	29.4	22.1	17.7	0.0
07114	26.0	21.8	17.6	0.0
07115	28.4	21.7	17.1	0.0
07116	26.5	21.3	16.2	0.0
07117	27.5	22.8	16.4	0.0
07118	27.7	22.9	15.3	0.0
07119	24.6	22.2	15.4	3.1
07120	16.0	21.6	18.2	0.0
07121	29.6	21.3	17.1	0.0
07122	29.3	22.9	17.1	5.8
07123	27.9	23.2	16.4	1.3
07124	25.9	23.1	18.2	1.1
07125	26.7	24.1	17.6	0.6
07126	17.6	24.2	17.7	4.3
07127	8.9	22.2	17.9	0.0
07128	22.1	23.8	18.1	0.0
07129	19.2	22.6	18.6	0.0
07130	25.6	22.4	18.4	0.1
07131	24.8	22.8	18.2	17.8
07132	28.4	22.2	18.2	0.0
07133	30.6	22.9	16.9	0.0
07134	26.2	22.7	16.9	0.0
07135	13.6	23.0	17.2	5.6
07136	10.6	23.2	18.0	2.5
07137	20.2	22.7	18.4	0.3
07138	18.6	22.6	19.0	0.9
07139	20.0	24.7	19.2	0.0
07140	20.9	23.3	18.6	2.5
07141	20.5	23.7	20.1	3.7
07142	28.0	25.5	18.9	0.0
07143	30.3	27.1	17.0	0.0
07144	30.3	27.1	17.2	0.0
07145	31.3	27.4	16.3	0.0
07146	26.3	27.0	17.5	0.0
07147	26.4	26.1	17.1	7.4
07148	30.6	26.4	18.2	0.0
07149	25.9	28.5	15.5	0.0

@DATE	SRAD	TMAX	TMIN	RAIN
07150	30.6	28.0	16.6	0.0
07151	31.6	29.2	17.9	0.0
07152	30.9	30.9	18.7	0.0
07153	30.9	29.6	20.2	0.0
07154	23.0	24.9	21.0	19.0
07155	23.9	24.2	19.8	0.9
07156	18.5	23.2	20.0	5.6
07157	21.8	25.4	19.9	0.6
07158	18.8	24.7	20.5	0.0
07159	16.1	25.0	20.8	0.1
07160	7.8	23.9	20.8	27.5
07161	5.6	22.0	19.6	10.0
07162	13.1	25.4	18.9	1.4
07163	22.5	26.3	19.9	8.8
07164	9.5	23.7	21.7	13.3
07165	9.8	22.7	20.8	4.4
07166	3.9	22.6	20.6	15.5
07167	19.3	24.0	19.7	2.8
07168	24.8	23.6	20.3	1.2
07169	25.2	24.3	20.5	0.4
07170	24.9	24.0	19.7	6.7
07171	23.3	23.2	20.0	0.0
07172	24.3	24.2	17.3	0.0
07173	22.0	24.2	20.3	5.3
07174	23.1	24.3	20.3	0.8
07175	20.8	23.9	20.2	2.7
07176	17.1	23.9	20.5	6.3
07177	15.4	23.3	20.6	23.3
07178	18.8	23.6	20.6	26.8
07179	27.7	24.5	20.6	7.1
07180	21.6	26.1	20.6	1.7
07181	20.4	25.3	18.8	2.9
07182	20.9	25.2	19.9	11.0
07183	18.0	24.1	21.8	4.8
07184	9.4	25.1	20.8	37.2
07185	22.2	24.9	21.2	20.5
07186	21.0	24.8	21.5	38.6
07187	19.2	25.6	21.8	8.8
07188	20.9	27.1	20.3	0.1
07189	19.4	24.4	21.4	0.0
07190	20.7	24.9	21.0	1.6
07191	18.4	24.9	21.5	9.0
07192	8.1	24.6	21.8	38.8
07193	17.6	25.2	21.7	5.5
07194	13.9	24.5	22.3	12.1
07195	19.9	25.3	21.6	5.1
07196	10.5	25.0	21.5	15.3
07197	12.9	26.1	17.6	14.9
07198	7.1	25.0	19.4	16.5
07199	14.5	25.3	20.2	1.2
07200	18.8	25.2	20.2	25.4
07201	12.7	24.7	22.1	16.8
07202	8.5	24.8	21.7	24.8
07203	7.7	23.5	20.8	40.7
07204	10.7	24.6	20.5	0.6
07205	7.2	23.1	19.4	2.3

@DATE	SRAD	TMAX	TMIN	RAIN
07206	10.4	22.4	20.1	3.5
07207	6.6	23.3	21.1	13.7
07208	7.1	21.9	21.1	8.2
07209	8.3	22.8	20.3	0.0
07210	7.4	22.8	20.0	4.3
07211	7.6	23.6	21.1	7.1
07212	10.5	24.6	20.7	2.1
07213	11.5	24.3	21.3	0.8
07214	13.7	25.0	20.9	1.0
07215	21.9	24.4	21.4	0.8
07216	24.2	24.7	20.9	10.1
07217	23.2	26.0	21.5	0.8
07218	22.3	26.8	21.1	9.4
07219	20.3	26.5	20.6	0.1
07220	21.2	25.6	20.8	0.4
07221	21.1	25.7	20.9	4.9
07222	23.1	27.0	20.5	5.8
07223	21.2	26.4	21.7	18.3
07224	13.7	27.6	21.1	37.3
07225	13.1	25.6	20.8	6.9
07226	8.7	24.8	21.1	10.2
07227	15.5	25.2	21.5	19.0
07228	15.0	24.5	21.3	47.2
07229	7.5	25.5	20.8	21.1
07230	16.0	25.6	20.9	5.0
07231	14.0	25.2	18.9	2.7
07232	18.5	23.5	19.2	0.0
07233	23.7	25.6	17.5	0.0
07234	23.8	24.2	18.1	0.0
07235	18.6	25.1	19.4	13.9
07236	16.7	24.4	20.7	10.4
07237	22.6	25.1	19.5	0.2
07238	17.3	23.8	19.9	9.5
07239	20.8	24.0	20.3	5.1
07240	18.4	22.9	19.4	2.1
07241	18.6	25.1	19.9	12.0
07242	12.4	23.6	19.7	38.5
07243	0.0	25.2	19.7	9.2
07244	23.0	25.7	20.1	25.5
07245	19.0	24.4	19.5	12.8
07246	17.8	24.6	20.2	10.8
07247	15.2	24.0	21.5	12.3
07248	12.0	22.6	19.6	51.3
07249	8.6	24.6	19.2	19.3
07250	18.4	23.7	19.0	7.0
07251	17.1	25.6	19.0	33.3
07252	19.0	24.8	20.8	28.6

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*WEATHER DATA : 2006
@ INSI      LAT     LONG  ELEV   TAV   AMP REFHT WNDHT
  MUN8   27.417   84.133   154  18.2   5.1 -99.0 -99.0
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@DATE	SRAD	TMAX	TMIN	RAIN
06097	23.1	25.8	14.5	9.8
06098	23.9	22.1	16.3	0.1
06099	16.2	21.7	15.2	0.1
06100	24.6	22.6	15.7	4.0
06101	26.1	23.3	13.4	0.0
06102	24.4	27.9	13.8	0.0
06103	25.2	27.8	13.2	0.0
06104	29.2	27.3	13.8	0.0
06105	26.5	28.8	15.1	0.0
06106	26.1	27.1	13.1	0.0
06107	19.2	23.6	16.5	17.6
06108	8.1	18.4	15.0	3.4
06109	19.5	17.5	13.9	7.0
06110	24.9	17.9	13.1	0.0
06111	22.6	19.4	13.3	0.0
06112	18.3	19.7	15.3	5.0
06113	22.4	19.4	15.1	7.9
06114	21.3	20.8	14.1	1.3
06115	26.7	20.1	14.8	0.1
06116	22.2	20.4	14.2	1.1
06117	24.1	22.9	16.3	0.0
06118	27.2	22.9	16.3	0.0
06119	29.1	24.3	16.7	0.0
06120	29.4	22.9	17.3	0.0
06121	29.8	25.0	17.6	2.4
06122	27.6	24.6	16.2	6.6
06123	28.7	22.8	16.3	1.2
06124	26.8	23.5	16.0	1.5
06125	28.5	26.0	17.3	0.0
06126	22.1	25.5	18.4	1.5
06127	22.7	23.3	17.2	5.2
06128	16.6	23.3	17.7	0.0
06129	21.3	22.3	18.6	0.2
06130	5.4	21.2	18.5	9.6
06131	26.1	22.8	17.5	0.9
06132	14.1	22.8	18.4	1.0
06133	21.2	21.0	17.9	0.0
06134	29.4	23.6	16.1	1.7
06135	22.4	22.0	17.4	0.0
06136	23.5	24.7	17.3	0.0
06137	25.4	25.8	18.7	0.0
06138	15.0	23.4	19.0	9.6
06139	20.2	22.0	18.7	0.0
06140	20.9	23.5	16.1	0.0
06141	11.7	24.3	19.7	0.0
06142	20.6	26.3	19.6	0.2
06143	18.7	27.9	19.8	4.3
06144	17.7	26.2	20.0	1.3
06145	21.1	25.9	20.8	1.6
06146	19.0	26.7	21.3	22.1
06147	19.6	23.9	21.0	18.5
06148	17.2	24.2	20.8	10.4
06149	18.9	23.0	20.0	9.0

@DATE	SRAD	TMAX	TMIN	RAIN
06150	21.9	25.4	20.4	1.8
06151	23.1	26.4	21.2	0.0
06152	16.1	24.6	20.6	10.9
06153	6.9	24.3	18.1	15.9
06154	4.3	23.5	20.0	14.3
06155	7.5	22.0	19.7	25.4
06156	18.3	24.0	18.6	16.0
06157	3.7	24.0	20.3	33.2
06158	5.5	22.8	20.3	10.6
06159	14.4	22.9	20.8	14.2
06160	20.1	22.9	21.0	10.7
06161	14.1	23.2	20.3	16.4
06162	21.7	25.3	20.4	0.0
06163	24.2	27.5	19.3	0.1
06164	22.1	26.5	17.7	0.0
06165	23.8	25.6	18.1	0.0
06166	25.3	24.6	17.0	0.2
06167	23.1	25.7	17.4	1.2
06168	20.8	23.2	20.0	1.5
06169	23.2	25.0	19.1	0.0
06170	23.7	24.4	19.3	0.0
06171	17.9	24.7	19.0	6.2
06172	26.0	24.2	19.6	0.0
06173	22.6	24.9	19.4	0.0
06174	20.0	24.9	20.1	4.9
06175	.8	24.7	20.2	9.5
06176	16.2	24.2	19.9	20.9
06177	13.1	23.8	20.6	23.1
06178	11.1	22.3	20.3	0.0
06179	17.5	22.4	19.1	6.0
06180	10.6	23.8	19.7	15.1
06181	.4	24.4	20.9	0.8
06182	21.5	25.2	20.8	0.1
06183	19.7	26.0	22.0	9.9
06184	23.4	26.4	21.8	0.1
06185	19.7	26.6	20.9	4.6
06186	19.6	25.3	21.5	1.9
06187	17.4	24.8	21.5	7.3
06188	9.9	25.0	19.7	36.0
06189	5.0	25.8	21.6	18.5
06190	10.2	25.9	22.6	9.0
06191	13.5	25.1	21.8	11.3
06192	12.9	24.9	21.3	18.7
06193	10.6	22.3	21.1	13.6
06194	8.7	25.0	20.5	5.8
06195	14.1	25.7	20.7	13.2
06196	15.0	24.1	21.5	10.3
06197	19.8	24.7	21.6	2.1
06198	20.7	25.1	21.5	9.2
06199	18.1	25.2	21.5	9.0
06200	13.7	24.8	20.0	16.5
06201	17.6	24.9	21.5	3.0
06202	19.6	25.5	0.8	4.2
06203	16.7	24.0	18.6	2.2
06204	15.7	23.3	20.1	0.0
06205	10.8	22.1	19.7	0.1

@DATE	SRAD	TMAX	TMIN	RAIN
06206	6.5	22.9	19.3	17.1
06207	11.6	24.6	20.6	3.2
06208	17.9	22.4	19.8	12.3
06209	16.3	22.8	20.0	2.3
06210	21.1	25.0	19.5	9.6
06211	20.7	25.7	19.3	4.9
06212	20.7	25.8	20.1	2.3
06213	21.8	25.3	20.6	12.3
06214	20.1	25.6	20.5	13.3
06215	14.5	24.1	21.0	8.5
06216	20.0	24.1	19.6	7.3
06217	17.7	24.0	19.5	5.9
06218	16.2	22.9	19.2	1.9
06219	19.0	23.2	20.1	0.2
06220	19.7	23.9	19.6	7.9
06221	21.2	25.6	18.6	1.0
06222	15.1	25.8	19.4	13.7
06223	25.2	26.4	19.3	0.1
06224	18.5	25.9	20.7	15.6
06225	18.1	26.7	20.7	27.4
06226	19.7	26.2	20.2	8.5
06227	20.9	24.6	20.6	1.1
06228	21.3	25.3	19.9	5.2
06229	22.7	27.2	17.9	0.0
06230	18.5	26.4	18.8	0.8
06231	17.9	23.8	20.6	13.8
06232	11.8	24.6	20.6	10.3
06233	19.1	27.2	21.0	27.6
06234	17.0	24.2	16.2	1.6
06235	14.2	24.1	20.8	6.3
06236	13.0	25.3	20.6	11.1
06237	12.3	23.1	21.3	9.6
06238	1.1	21.8	20.8	43.0
06239	2.8	23.5	20.5	14.8
06240	9.3	22.8	20.9	0.0
06241	10.4	25.0	19.2	10.8
06242	13.4	25.1	18.5	0.2
06243	15.6	23.8	18.9	5.9
06244	19.3	23.6	19.3	1.3
06245	23.0	25.5	17.0	0.1
06246	23.4	24.6	18.8	13.4
06247	17.3	22.2	19.7	2.2
06248	20.5	22.5	19.1	0.0
06249	18.6	23.3	17.6	0.0
06250	18.4	23.1	19.5	0.0
06251	14.1	23.2	19.5	42.8
06252	2.3	24.4	20.5	71.3
06253	2.6	24.1	20.8	33.0
06254	8.6	23.6	20.2	7.9
06255	16.2	24.6	18.9	11.8
06256	15.8	24.1	19.0	5.4
06257	19.6	24.3	18.6	1.3
06258	17.8	22.3	18.2	12.7
06259	20.2	24.0	18.0	0.1
06260	17.2	23.7	19.3	0.7
06261	16.9	23.8	19.0	3.5

@DATE	SRAD	TMAX	TMIN	RAIN
06262	19.5	25.4	18.7	1.8
06263	18.1	24.8	19.8	3.3
06264	11.6	23.0	17.7	0.0
06265	4.3	24.8	18.0	1.4
06266	8.8	23.8	19.6	3.7
06267	7.2	24.1	17.9	35.1
06268	8.6	22.5	19.0	10.1
06269	20.7	23.5	18.5	0.0
06270	20.0	24.4	16.8	0.0
06271	20.3	25.4	15.0	0.0
06272	20.9	24.7	16.6	2.8
06273	16.8	23.7	17.9	0.9
06274	20.6	22.1	16.5	0.0
06275	17.1	23.9	19.6	0.0
06276	19.7	24.4	16.2	0.0
06277	18.9	24.7	15.1	0.0
06278	22.5	22.4	14.3	0.0
06279	16.1	21.3	14.2	3.4
06280	16.5	22.3	15.8	0.3
06281	17.5	21.9	15.2	0.0
06282	20.4	22.2	15.8	0.0
06283	20.3	22.8	14.9	0.0
06284	17.7	22.9	13.4	0.0
06285	15.0	22.6	14.4	2.2
06286	14.7	21.0	13.2	0.1
06287	16.8	22.5	2.0	0.0
06288	17.9	22.1	13.9	0.0
06289	18.9	22.8	13.1	0.0

Appendix 19. Calibration runs to determine genetic coefficients of Local maize during spring, 2013 at Shivamandir-2, Nawalparasi

Run No.	Genetic coefficient						Simulated Value		
	P1	P2	P3	G2	G3	PHINT	A	PM	GY
1.	365	0.520	850	680	6.50	38.90	61	100	4136
2.	355	0.520	850	680	6.50	38.90	61	100	4135
3.	345	0.520	850	680	6.30	38.90	59	99	4038
4.	335	0.520	850	680	6.20	38.90	59	99	3983
5.	325	0.520	850	680	6.10	38.90	57	97	3911
6.	315	0.520	850	680	6.00	38.90	57	97	3847
7.	305	0.520	850	680	5.90	38.90	57	97	3783
8.	295	0.520	850	680	5.80	38.90	55	95	3578
9.	285	0.520	850	680	5.70	38.90	55	95	3516
10.	275	0.520	850	680	5.60	38.90	54	93	3096
11.	265	0.520	850	680	5.50	38.90	54	93	3041
12.	255	0.520	850	680	5.40	38.90	51	91	2923
13.	245	0.520	850	680	5.42	38.90	51	91	2934
14.	235	0.520	850	680	5.42	38.90	49	89	2716
15.	230	0.520	940	360	9.28	38.90	49	94	3124

Appendix 20. Calibration runs to determine genetic coefficients of Poshilo makai-1 during spring, 2013 at Shivamandir-2, Nawalparasi

Run No.	Genetic coefficient						Simulated value		
	P1	P2	P3	G2	G3	PHINT	A	PM	GY
1.	370	0.800	785	907.9	10.15	38.90	63	99	7243
2.	380	0.700	885	907.9	10.15	38.90	64	106	6106
3.	390	0.600	985	907.9	10.15	38.90	63	109	8972
4.	400	0.600	985	907.9	10.15	28.10	62	108	9809
5.	400	0.600	985	907.9	9.15	18.90	61	107	8424
6.	400	0.600	985	907.9	8.15	18.90	61	107	7504
7.	400	0.600	985	907.9	7.15	18.90	61	107	6583
8.	400	0.600	985	907.9	6.15	18.90	61	107	5662
9.	400	0.600	985	907.9	5.15	18.90	61	107	4742
10.	400	0.600	985	907.9	5.25	18.90	61	107	4834
11.	400	0.600	985	907.9	5.35	18.90	61	107	4926
12.	400	0.600	985	907.9	5.45	18.90	61	107	5018
13.	400	0.600	985	907.9	5.50	18.90	61	107	5110
14.	400	0.600	985	907.9	5.60	18.90	61	107	5202
15.	400	0.600	1130	590.9	8.38	18.90	61	114	5931

Appendix 21. Calibration runs to determine genetic coefficients of RML-4/17 during spring, 2013 at Shivamandir-2, Nawalparasi

Run No.	Genetic coefficient						Simulated value		
	P1	P2	P3	G2	G3	PHINT	A	PM	GY
1.	345	0.260	825	907.9	9.80	18.9	55	94	7336
2.	365	0.260	825	907.9	9.80	8.9	54	93	6001
3.	380	0.260	825	907.9	8.80	8.9	56	95	6173
4.	380	0.260	825	907.9	7.80	8.9	56	95	5471
5.	380	0.260	850	887.9	7.70	8.9	56	96	5506
6.	380	0.260	875	867.9	7.70	8.9	56	97	5592
7.	380	0.260	900	847.9	7.70	8.9	56	98	5667
8.	380	0.260	925	827.9	7.70	8.9	56	100	5907
9.	380	0.260	950	807.9	7.60	8.9	56	101	5816
10.	380	0.260	975	807.9	7.50	8.9	56	102	5857
11.	380	0.260	1000	807.9	7.40	8.9	56	103	5906
12.	380	0.260	1100	807.9	7.36	8.9	56	108	6547
13.	380	0.260	1200	807.9	7.36	8.9	56	112	7037
14.	380	0.260	1290	807.9	7.36	8.9	56	116	7687
15.	380	0.260	1290	816.9	7.36	8.9	56	116	7685

Appendix 22. Calibration runs to determine genetic coefficients of Arun-2 during spring, 2013 at Shivamandir-2, Nawalparasi

Run No.	Genetic coefficient						Simulated value		
	P1	P2	P3	G2	G3	PHINT	A	PM	GY
1.	300	0.520	990	440	7.00	38.90	55	102	3548
2.	280	0.520	990	440	7.00	38.90	54	100	3346
3.	260	0.520	990	440	7.00	38.90	51	98	3295
4.	240	0.520	990	440	7.00	38.90	49	96	3057
5.	230	0.520	980	440	7.00	38.90	49	96	2956
6.	230	0.520	970	440	7.20	38.90	49	95	3041
7.	230	0.520	960	440	7.40	38.90	49	95	3017
8.	230	0.520	950	440	7.60	38.90	49	94	3099
9.	230	0.520	940	440	7.80	38.90	49	94	3080
10.	230	0.520	930	440	8.00	38.90	49	93	3159
11.	230	0.520	920	440	8.20	38.90	49	93	3238
12.	230	0.520	910	440	8.40	38.90	49	92	3201
13.	230	0.520	910	440	8.60	38.90	49	92	3277
14.	230	0.520	910	440	8.80	38.90	49	92	3353
15.	230	0.520	910	440	9.88	38.90	49	92	3768

BIOGRAPHICAL SKETCH

Mr. Umesh Shrestha, was born on 3rd October, 1988 in Mangalpur-1, Chitwan as elder son of Mr. Mukunda Shrestha and Mrs. Renu Shrestha. He has received his School leaving Certificate from Pragati Shiksha Sadan, East Rampur, Chitwan in 2004 A.D. He has passed his Intermediate level from Orchid science college, Bharatpur, Chitwan in 2007 A.D. After that he joined Institute of Agriculture and Animal science (IAAS), Rampur, Chitwan and completed the Bachelor degree with major in plant pathology in 2012 A.D. Just After his graduation, he was enrolled on post graduate programme in the same Institute to persue his Master's degree in Agronomy in 2014 A.D.

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

Author