

**“Differential responses of climate variability on
morphophysiological parameters and yield of
late sown direct seeded rice varieties”**

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By

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2012

CERTIFICATE-I

This is to certify that the thesis entitled “**Differential responses of climate variability on morphophysiological parameters and yield of late sown direct seeded rice varieties**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE Plant Physiology** in the department of **Plant Physiology Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur** is a record of the confide research work carried out by **Mr. DHARMENDRA PATIDAR** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by him.

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This is to certify that the thesis entitled “**Differential responses of climate variability on morphophysiological parameters and yield of late sown direct seeded rice varieties**” Submitted by **Mr. DHARMENDRA PATIDAR** to the J. N. Krishi Vishwa Vidyalaya, Jabalpur in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE, Plant Physiology** in the department of **PLANT PHYSIOLOGY** has been, after evaluation, approved by the External Examiner and by the student's Advisory Committee after an oral examination on the same.

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ABBREVIATIONS

CGR	:	Crop Growth Rate
Chl.	:	Chlorophyll
Ci	:	Intercellular CO ₂ concentration
DAS	:	Day After Sowing
HI	:	Harvest Index
LAD	:	Leaf Area Duration
LAI	:	Leaf Area Index
N	:	Nitrogen
NS	:	Non Significant
Pn	:	Net photosynthesis
QUE	:	Quantum Use Efficiency
RLWC	:	Relative Leaf Water Content
RGR	:	Relative Growth Rate
RH	:	Relative Humidity
SI	:	Seed Index
SLA	:	Specific Leaf Area
SLW	:	Specific Leaf Weight
Tr	:	Treatment
WSD	:	Water Use Efficiency
*	:	Significant at 5% Level of significant
*	:	Significant at 1% level of significant

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Chapter- I

INTRODUCTION

Rice (*Oryza sativa* L.) is probably the most important cereal in the world and serves as food for about 50% of the world's population (Ladha *et al.*, 1997).

About 90% of the rice in the world is grown in Asia (nearly 640 million tons), (IRRI, 2009). India has largest area in rice cultivation in the world. The total area of rice (44 million ha) under various ecosystems are 58% irrigated, 25% rainfed shallow, 12% rain fed upland and 5% deep and semi-deep water. The production level from the corresponding ecologies are 76%, 19%, 4% and 1% (productivity range 3.13 to 0.5 tones/ha) respectively. Apart from ecological factors, frequent floods, droughts, salinity are some of the reasons for low productivity (Voleti *et al.*, 2011).

It is grown in 43.8 million ha area in India with the production of 93.36 million tones and productivity of 2178 kg/ha (Rajput, 2011). Drought losses are most severe in the rice bowl states of Chhattisgarh, Madhya Pradesh, Bihar, Jharkhand, Orissa and Uttar Pradesh as well as in neighboring areas of Nepal. Whereas, in M.P. rice grown in 12.46 million ha area, with production of 16.02 million tones and productivity of 1285 kg/ha (Anonymous, 2011). Direct seeded rice cultivation is become popular and best alternative of transplanted rice in India; it reduces about 30% cost of cultivation. It is practiced nearly one third of the total rice area of the country in spite of many constrains because transplanting being a labor intensive and costly (Jha *et al.*, 2007).

Over half of the world's rice production is planted under rainfed conditions, and drought may be a factor to effect yield levels. There is a very slow progress in developing technology in these areas as compared to irrigated rice production (Maikill *et al.*, 1996).

The production of major 20 rice producing districts in M.P. generally comes under rainfed conditions. Their yield is directly correlated with the amount of rainfall occurred in that area. If there is less rainfall, rice

production will be less and vice-versa. Hence, there is a need to develop drought tolerant rice cultivars specifically for eastern M.P. region, where rice is grown as a major field crop along with soybean and pigeon pea. Based on these facts, a study was started in *Kharif* 2011 to evaluate different rice cultivars grown under rainfed, irrigated and semi irrigated conditions to explore the drought tolerant type favorable for planting in the eastern M.P. region.

Rainfed rice is planted as drilled or direct seeded rice particularly by mid-June, or the arrival of south-west monsoon in the eastern M.P. region. The long duration cultivars take around 130 days to mature for harvest. While the monsoon last by the first week of October, long duration rice cultivars was in a panicle initiation stage by that time (Rajput, 2011). Hence, there may be a necessity for irrigating during flowering stage. Water shortage during flowering and grain filling stage reduces yield drastically (Boonjung and Fukai, 1996) particularly delay in flowering under water limiting condition is a function of lower water status and further delays could relate to drought susceptibility (Guhey *et al.*, 2004). Moisture stress resulted in reduced plant height and its maintenance may be related with higher water status, which favors shoot growth and cell division (Boyer *et al.*, 1968). Applying deficit irrigation may improve yield than planted under rainfed condition. Therefore, semi-irrigated treatment was introduced in this experiment and plots under this treatment will be irrigated at the said stage.

The variability of climatic factors influences all processes involved in agricultural production. Changes of the intensity in solar radiation, temperature and the distribution/amount of rainfall provoke physiological reactions that affect crop growth and production (Yoshida and Parao, 1979).

The rice plant grown under upland conditions and hence subjected to plant stress under these conditions is a combined result of soil water deficit, radiation and high temperature (Dingkuhn, 1989). The physiological understanding of rice adaptations, however, is poor, particularly regarding gas exchange and carbon assimilation under tropical field conditions. Beside drought tolerance, weeds are major problem in rice fields, which can reduce

the yield of rice by 43 percent under irrigated and 74 percent in rainfed conditions (IRRI, 1991 and Johanson *et al.*, 2004).

Keeping the above point in view the experiment entitled different rice varieties grown under rainfed, irrigated, and semi irrigated conditions to explore the drought tolerant type favorable for planting in Kymore plateau and Satpura hills has been conducted with following specific objectives.

1. To identify drought tolerance characteristic among different rice cultivars.
2. To compare physiological responses of rice under irrigated, partially irrigated and rainfed conditions.

Chapter – II

REVIEW OF LITERATURE

2.1 Effect of Sowing Time

Time of sowing is the most critical factor in determining the yield levels of rice in a particular season and location. Delayed planting after start of the *kharif* season invariably results into reduction of growth duration which ultimately reduces the grain yield.

Khan *et al.* (1990) observed that all eighteen rice cultivars (15 rice cultures obtained from different part of India along with three local check) gave highest grain yield when sown on 11th July at Rewa, M.P. and there was a drastic reduction in yield beyond that period.

Lakepale *et al.* (1994) reported that rice planted in the third week of July gave significantly higher grain yield than the rice planted on first week and fourth week of August at Raipur (C.G.).

Korea, Lee *et al.* (1995) reported that rice cv. Donghaebyeon sown on 10th, 20th and 30th June and 10th and 20th July gave grain yields of 4.52, 4.67, 4.57, 4.49 and 4.03 t/ha, respectively and 1000-grain weight of 20.5, 19.8, 20.3, 20.5 and 21.4 g, respectively.

Mahapatra *et al.* (1997) studied that the rice variety Heera (duration 83 days) sown on 10th June utilized the rainfall during the cropping season better and gave higher grain yield mainly due to production of more panicles/m than that of crop sown on 20th and 30th June.

Singh and Prasad (1999) showed that the rain yield of rice averaged over years was higher with 15th June sowing than others dates of sowing (30th June and 15th July) under upland rainfed conditions of Majhera.

Patel (1999) concluded that grain yield of rice was significantly higher with 15th July transplanting than on later transplanting at Raipur (C.G.).

Sahoo *et al.* (1999) emphasized that the yield components of rice were optimum when sown on the normal date of 1st July at Balasore, Orissa.

Singh and Parsed (1999), Hari *et al.* (1999), and Pirdashfy *et al.* (2000) found that delayed sowing decrease grain and straw yield, harvest index, tiller number, panicle length, number of grains/panicle, and fertility percentage.

Dwivedi *et al.* (2001) reported that the highest mean grain and straw yield was recorded under 5th July (early) planting. A linear reduction in grain and straw yield with every 10 days delay in planting was recorded from 5th July to 14th August. The reduction in grain yield of rice was significant when planting was delayed to 25th July as compared to 15th July.

Reddy (2002) conducted field experiment during rainy season of 1997 and 1998 at Andhra Pradesh, to study the performance of 4 varieties of rice under different time of planting. Planting of rice varieties on 16th August gave significantly higher grain yield than that of other planting dates. Among rice varieties, NIR-33641 out yielded other varieties. Irrespective of rice varieties, the grain yield decreased by 175 and 170 kg/ha for every 15 days delayed in planting during 1997 and 1998, respectively.

El-Khoby (2004) showed that delaying sowing date sharply decreased the leaf area index, dry matter production and chlorophyll content.

Upadhyay *et al.* (2004) reported that higher number of tillers, panicles, spikelets per plant and panicles weight were obtained from the early planting (6th June) as compared to 22nd June and 16th July sowing for all varieties.

Khalifa (2005) found that number of days from sowing up to maximum tillering, panicle initiation and heading date was significant affected by different sowing dates.

Sreenivas *et al.* (2005) reported that significantly higher grain yield was obtained when crop was planted on 15th July and progressive decrease in grain yield was recorded with delay in planting.

Khakwani *et al.* (2006), Paraye and Kandalkar (1994) reported that plant height is significantly affected by sowing dates.

Singh (2006) found that among 3 dates of planting, 15 July (early) planting recorded significantly higher grain yield than other 2 dates. Late planting (6th August) recorded the lowest grain yield at Kanpur (U.P.). The higher grain yield was ascribed to more number of panicles and grain weight per panicle with late planting.

Susheela (2007) reported the higher grain yield under direct planting system of rice cultivation compared to conventional technique of transplanting.

Bashir *et al.* (2010) reported that the plant height decreased significantly as sowing was delayed. The lowest plant height (69.37 cm) was observed when the crop was sown on 20th July which was statistically at par with 10th July sowing (70.03 cm). Plants sown on June 10th and 20th produced statistically similar plant height while 30th June sown plants produce statistically different plant height.

Singh *et al.* (2010) conducted an experiment and results revealed that panicle length (39.6cm) and grains/panicle (158.5) were significantly more under 20kg seed sown in 20cm rows over all the treatments. Panicle length and grains/panicle decreased significantly with increase in seed rate and spacing and lowest panicle length (25.8) and grains/panicle (135.0) found fewer than 40 kg seed sown in 30cm row spacing.

2.2 Performance of varieties under different agro-ecosystems

Gautam (1990) observed in a field experiment that variety RWR-64 recorded significantly higher number of culms/plant, panicle weight, number of grain per panicle and grain and straw yield/ha as compared to other varieties.

Dubey (1993) observed that three rice varieties *viz.*, 6 Cauveri, Kranti and Patel-85 were found to differ significantly with respect to grain yield during both the years, kranti showed high yielding ability producing 49.51 and 41.43 q/ha and giving significantly higher yield by 15.03 and 48.82% during 1983, respectively in upland field condition.

Thakur (1993) evaluated the performance of several varieties and found that IET 6148 was superior to other varieties in 1987 but it was similar to IET 3279, Saket-4, IET 6263 and IET-7617 with respect to grain yield in 1988, IET 6148 was superior to IET 7613 only in 1988.

Lakepale *et al.* (1994) reported that rice cv. Kranti and Safari-17 being at par with each other gave higher grain yield than Ananda at Raipur (C.G.) in rainfed condition.

Panda *et al.* (1994) found higher grain yield of rice-cultivar Govinda coupled with more number of spikelets per panicle, grain weight/panicle and harvest index under transplanting in puddled field.

Paraye and Kandalkar (1994) noted that delayed sowing after 30th July significantly decreased the plant height, effective tillers/m², panicle weight, 1000-grain weight and grain and straw yield as well as leading to earlier flowering, cv. IET 7946 and Phalguna produced the highest grain yields. (2.2 and 1.9 t/ha, respectively), while IET 7946 and Jagrati maintained the highest straw yield (both 5.8 t/ha).

Ghille (1995) reported that rice cultivar IET 9219 produced more number of panicles per plant, length of panicle, grains per panicle, panicle weight, grain and straw yield as compared to other cultivars in rainfed upland.

Singh *et al.* (1995) reported that the grain yield of rice-varieties was higher in direct sowing than transplanting (2.01 vs 1.99 t/ha). They also observed that direct seeding in lines produced significantly more panicles/m², panicle weight and panicle length as compared to transplanting. However, 1000-grain weight was significantly higher in transplanting.

Kapre *et al.* (1996) conducted experiment on rice cv. Kranti on upland irrigate condition and reported that number of panicle/hill, grains/panicle, test weight, grain and straw yield increased significantly with increasing levels of nitrogen up to 150 kg/ha.

Reddy *et al.* (1998) compared three rice varieties under 5 crop establishment methods and found that direct sowing in rows produced the higher mean grain yield of 3.50 t/ha followed by 3.34 t/ha with broadcasting.

Mahal *et al.* (1999) observed that a field trial during Kharif (1993-94) in Ludhiana, rice cv. Basmati 370 and Basmati-385 were planted on 5th or 19th July or 2nd August. Basmati 385 gave significantly higher yields than Basmati-370. Crop planted on 19th July gave significantly higher yield than the other dates.

Salam and Senapati (1999) conducted a field trial on rice cultivars viz CR-289-1008, OR-KM-16, OR 583-4 Rudra and Saria which were direct sown. Saria gave the highest grain yield of 3364 kg/ha followed by OR-KM-16 (2875kg/ha).

Singh *et al.* (1999) observed that in the field trials evaluated at Rajendranagar, Andhra Pradesh in the 1994 and 1995 Kharif season, rice was sown on 6 dates between 15th June and 29th August. Grain yield was greater in Pusa Basmati-1 and Kasturi Dhan in the standard tall cultivar Tarori basmati, grain yield increased linearly upto the 30th July sowing date (3.87 t ha⁻¹) and after that it was decreased.

Balasubramani *et al.* (2000) reported that PA 6201 and IR 36 was moderately resistant from rice mite in upland condition.

Pandey *et al.* (2001) observed the grain yield was higher under lowland situations. One additional irrigation was required in midland due to the quick disappearance of water mainly attributed to seepage and other losses from midland to lowland. The irrigation water expense recorded under mid- and lowland situations were 19.20 and 12.00 cm for life-saving irrigation, and 26.40 and 19.20 cm for full irrigation, respectively. The highest irrigation water use efficiency (294.833 kg/ha-cm) was observed under lowland life-saving irrigation, while the lowest (134.508 kg/ha-cm) was noted under midland full irrigation.

Yadav *et al.* (2002) found that the long duration varieties, i.e. Mahsuri (142days) and Swarna (157 days) produced significantly higher dry matter than medium duration Sarjoo-52 (129 days) and mid early (121 days) IR 36. The former and later group of varieties remained at par. Swarna produced significantly higher grain yield of 5.86 t/ha which showed an increase of 1.11, 1.69 and 1.70 t/ha over Sarjoo-52, Mahsuri and IR 36.

Polon *et al.* (2004) noted the effects of different water management on rice (INCA LP-5) germination, dry weight, plant height and water use. The highest germination percentage of 90 to 100% was recorded in saturated soil.

Longshithung *et al.* (2005) studied the growth and yield of different direct seeded upland rice varieties, a field experiment was conducted in School of Agricultural Sciences and Rural Development, Medziphema, Nagaland, during *kharif* season of 2000. Significantly higher number of tillers/plant and shoot dry weight was recorded in the variety Saraju-52, whereas highest plant height was recorded in the local variety Leikhumo. The variety Saraju-52 also recorded significantly higher number of effective tillers, number of panicles/m², grain (40.03 q/ha) as well as straw (45.33 q/ha) yield compared to other varieties. The local variety Leikhumo recorded significantly higher number of filled grains/panicle as well as weight and length of panicle. The variety Pant-12 recorded lowest grain (22.10 q/ha) and straw (36.88 q/ha) yield.

Rai and Kushwaha (2005) observed that the reduction in days to panicle initiation (6-8), 50% flowering (12-15) and maturity stages (6-8) and 13.4, 9.8 and 4.9% decrease plant height (13.4%), leaf area index (9.8%) and shoots/m² (4.9%) due to delay in transplanting from 15 June to 15 July. While 19.5 and 11.3% decrease in plant height and shoots/m² due to change in soil water regimes from continuous submergence of 5+or-2.5 cm ponded water to 7.5 cm irrigation 3 days after disappearance of ponded water. Yield was increased in early transplanting and greater soil water regimes.

Yang *et al.* (2005) studied the five irrigation treatments were implemented. Under flooded conditions, JD305 yielded up to 8.8 t ha⁻¹, HD502 up to 6.8 t ha⁻¹, and HD297 up to 5.4 t ha⁻¹. Under aerobic conditions, the aerobic varieties yielded higher than the lowland variety. HD502 produced 3-3.5 t ha⁻¹ with 450-500 mm total water input and 5.3-5.7 t ha⁻¹ with 650 mm water input and more. HD297 produced 3-3.5 t ha⁻¹ with 450-500 mm total water input and 4.7-5.3 t ha⁻¹ with 650 mm water input and more.

Gill *et al.* (2006) carried out the dry matter accumulation, leaf area index, effective tillers etc. under direct seeding were significantly more than

transplanting rice. The productivity under direct-seeded paddy accrued was 53q/ha (during first year 65q/ha while in the second year 40q/ha) in loamy sand soil. The direct seeded crop matured 10 days earlier than transplanted crop.

Lar *et al.* (2007) found that there was a significant increase in grain, straw and biological yield of rice variety 'Pusa Sugandha 5' with 150 kg N/ha in rainfed condition.

Zhang *et al.* (2009) conducted an experiment at research farm of Yav Zhou University Jiangsu Province, China. They found that compared to the conventional irrigation(CI) the alternate wetting and moderate soil drying (WMD) regime significantly increased grain yield by 10% for variety 'YangFujing 8' and 12% for variety 'Yangdao 6'. Opposite to WMD regime the alternate wetting and severe soil drying (WSD) regime significantly reduced grain yield by 35% for variety 'YangFujing 8' and 29% for variety 'Yangdao 6' due to significant reduction in all yield component. Harvest index was significantly increased under both WMD and WSD regimes, with the latter increased more than the former, indicating that both water saving irrigation regimes enhance the remobilization of assimilate from vegetative tissues to grain.

Katiyar *et al.* (2010) carried out a field experiment during Kharif season at the Masodha farm of NDUAT, Kumarganj, Faizabad result showed that 'NDR-359' yielded 31.7% higher grain yield than 'NDR-97'.

Singh and Bhargava (2012) noted the significant difference in grains yield between mid and low land situation was observed-under rainfed, life saving irrigation and full irrigation conditions respectively. Higher water use efficiency (IWUE) obtained with low land situation under life saving irrigation. However the lowest IWUE was with saving irrigation under low land situation.

2.3 Morphological and yield attributing parameters

Akanda *et al.* (1986) studied in a survey of rice fields in 15 villages in the Rajshahi district conducted in 1982 during the aus season. Rice cv. Kalchina produced consistently high yields (0.987-1.972 t/ha) at all sites studied. Hizli, Bhorra and Dharial gave yields of 675-1414, 678-1174 and 877-1412 kg/ha, respectively. Yields recorded at the research station for Hizli, Bhorra, Kalchina and dharial were 1.63, 2.06, 2.47 and 2.13 t/ha, respectively.

Singh *et al.* (1999) conducted an experiment at the experimental farm, Directorate of Rice Research, Rajendra Nagar, Hyderabad and found that grain yield influenced due to different methods of crop establishment. Wet seeding in lines under puddled condition recorded the highest mean grain yield of 5.17 t/ha followed by transplanting (5.10 t/ha), broadcast of sprouted seeds (4.58 t/ha) and random transplanting (4.45 t/ha). The wet seeding in lines recorded 1.37, 12.88 and 16.18% increase in grain yield over the mean grain yield of transplanting, broadcast and random transplanting, respectively.

Kathiresan and Manoharan (2002) revealed that the seed rate of 150 kg/ha registered highest grain yield, but it was on a par with 125 kg/ha and both seed rates were significantly higher than 100 kg/ha. Higher seed rate recorded 4.4 and 13.1% more grain yield than 125 and 100 kg/ha, respectively.

Angadi *et al.* (2004) evaluated the response of direct sown rainfed lowland rice. Grain yield was mainly influenced by the number of tillers and panicles per M, which also showed similar variation due to different treatments. Other yield components i.e. mean panicle weight, 1000-grain weight, number of filled grains per panicle and straw yield did not differ among the different treatments.

Anonymous (2004) studies showed that the seed rate of 100 kg/ha under broadcasting method was better in regard to achieve higher yield coupled with more productive tillers/m² and higher test weight.

Krishnan and Rao (2005) and Sheehy (2007) observed that the reduced yield may be due to the high spikelet sterility.

Swain *et al.* (2006) conducted the field experiment during dry season under irrigated shallow lowland condition of the institute, Cuttack is characterized by sandy clay loam soil, rice hybrids NRN-1 both released and pre released along with 3 local released CR 749-20-2 and lalat were tested, PA 6201 was found to be most efficient with maximum leaf area index and total chlorophyll content at all growth stage least tiller mortality (7.6%) at maximum tillering stage, highest grain yield (6.4 t/ha), grain number/m² (35379) and harvest index (0.48) with moderate sterility (26%) and panicle number/m² (336) at maturity.

Saiedzadeh *et al.* (2010) according to significant differences between varieties for different traits *viz*: plant height, length of panicle, number of tillers per plant, number of seeds per panicle, number of filled empty seeds per panicle, biomass per hill and plot levels, paddy yield at plot and hectare levels. In respect of yield production, there was no significant differences between all varieties that ranged from 3962 to 4714 kg/ha, except the line 338 where produced the lowest paddy yield (2859 kg/ha).

Dhurve and Khan (2011) observed that the significantly superior rate of photosynthesis at flowering was found is IET-20708 (16.29 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) with the highest grain yield 585 g m^{-2} following by IET 20710 and IET 21106 varieties.

Mishra and Chaturvedi (2011) conducted the artificial drought treatment (80 k pa $\pm$) at flowering stage was given to six upland rice genotype (three traditional, Bagri, Nankawa, Bakaiya and three improved, N-22, Ashoka-228, NDR-97) with specific objective, effect of flowering stage drought on some morphophysiological parameters, yield and yield components.

Navendu and Upadhyay (2011) concerns that the phenotypic correlation coefficient (rp), grain yield per plant showed highly significant positive association with harvest index (0.59), biological yield (0.48) and test weight (0.42); non-significant but positive association with flag leaf width (0.21) and flag leaf length (0.13) and negative non-significant association for spikelets per panicle (0.32), plant height (0.19), panicles per plant (0.15) and tillers per plant (0.12). In genotypic correlation studies, grain yield per plant

showed highly significant positive association with harvest index (0.59), biological yield (0.58) and test weight (0.51); positive non-significant association with flag leaf width (0.25), flag leaf length (0.20) and days to 50 per cent flowering (0.15); and negative non-significant association with spikelet per panicle (0.41), panicles per plant (0.23), plant height (0.22) and tillers per plant (0.16).

2.4 Growth and Physiological parameters

Watson (1947) noted that the photosynthetic productivity depends on leaf area, chlorophyll content and gas exchange.

Watson (1952) observed in cereals, that variation in leaf area and leaf area duration was the main cause of differences in yield.

Watson (1958) noted that the biomass production of crop increased with an increase in LAI till the lower strata were not experience mutual shading.

Stern and Donald (1961) noticed that the crop growth rate interact with light at higher LAI values.

Bars and Weatherly (1962) reported that leaf water content which represents full turgidity in one species might represents severe wilting in another species might or even in another leaf of different age on the same plant. Just as soil water content must be interpreted in terms of soil water stress.

Thorne (1966) and Welbank *et al.* (1966) reported that the leaf area index could also be integrated over time to take into account persistence of leaf area. This integral value termed as leaf area duration was found to be closely related to dry matter production and yield.

Nichiporovich (1970) postulated that 3 to 4 LAI was needed for higher productivity. Further increased in LAI caused lodging and reduction in yield.

Yoshida *et al.* (1976) reported that plant sampling was done at anthesis to record LAI and at physiological maturity for growth and yield parameters. Chlorophyll content and leaf area index were determined.

Gupta and Olugbemi (1978) postulated that the maximum yield was achieved due to rapid attainment of optimum LAI.

Hason (1981) reported net rate of assimilates production and CO₂ exchange rates with reduced source in relation to sinks. Each genotypes need to maintain a characteristics balance in dry matter distribution between leaves, stem and roots, increased NAR had a beneficial effect on source sink primarily through increased leaf area and specific leaf weight (SLW).

Eastin (1983) have reported the positive association between LAI and CGR.

Monteith and Elston (1983) suggested that the analysis of crop growth should consider total dry matter (TDM) as a product of the amount of photosynthetically active radiation (PAR) intercepted by the crop, multiply by an efficiency factor. Such analysis suggested that radiation utilization efficiency is a conservative quantity.

Evans et al. (1984) showed that the non-significant difference in photosynthetic rate was reported in 50 traditional as well as new rice cultivars grown under upland and lowland from 1909 to 1980.

Turner *et al.* (1986) reported that the seven rice cultivars, Azucena, Tachiminori, IAC 25, IRAT 13, BPI 76, IR 20 and IR 36, represented a wide range of germplasm from traditional dryland to improved wet land types. The soil water potentials in the upper 30 cm of the soil decreased, canopy to air temperature differences increased, and dry matter production decreased. Leaves of the dry land cultivars, particularly Azucena and IAC 25, rolled and had higher canopy to air temperature differences at higher water potentials and higher turgor pressures than the wetland cultivars IR 20 and IR 36. No differences among cultivars were observed in either the rates of dry matter production or water use during the period of differential irrigation.

Welbank *et al.* (1988) reported that the ratio of grain yield to LAD increased with increase in daily radiation during grain filling.

Dey *et al.* (1989) the extent of variation was recorded between 3.5 and 5.8 for leaf area index (LAI), 88 to 124 for days to 50% flowering, 883 to 1341 g/m² for total dry matter (TDM), 35 to 48.5 per cent for harvest index (HI) and

350 to 593 g/m² for grain yield.

Dingkuhn *et al.* (1989) reported that net photosynthesis, leaf conductance, transpiration were determined during the stress cycle at pre-noon and afternoon, with all measurements on the same leaf.

Dhopte and Phadnawis (1989) outlined the procedure for estimation of quantitative analysis of chlorophyll.

Kuroda and Kumar (1989), Reynolds *et al.* (1994) stated that stomatal conductance which is a component of photosynthesis exhibited positive association with Pn and TDM while it had no relationship with grain yield.

Setter *et al.* (1989) indicated that complete submergence of rice led to low concentration of carbohydrate and reduced growth partly due to low rate of photosynthesis associated with slow diffusion of CO₂ in water and partly due to anaerobiosis, leakage of carbohydrate and high ethylene production.

Dingkuhn *et al.* (1991) observed a negative relationship between LAI at flowering and grain yield.

Krishnayya and Murthy (1991), Saxena *et al.* (1996), Yadav and Mathur (1996) and Rane *et al.* (2001) found that differential response of soil water stress at different stages on physiological parameters and yield performance has been reported in rice and wheat.

Choudhary *et al.* (1994) emphasized that the grain development was accompanied by decreases in chlorophyll contents of the leaf as a result of ageing.

Deshmukh and Patil (1995) observed that the physiological characters had significant positive correlation values for mean LAI with CGR, CGR with RGR and NAR and RGR with NAR. This indicates the importance of leaf area in increasing the rate of photosynthesis and quick accumulation of dry matter, thus increasing the harvest index and ultimately the yield.

Reddy *et al.* (1995) observed that a significant variation in terms of leaf area per plant among rice genotypes.

Fisher and Kohn (1996) reported that the optimum LAI reached well before anthesis and fell progressively as water stress increased.

Zhang *et al.* (1996) showed that increasing the conversion of photosynthate into starch during seed development should increase the sink strength, and in turn increase the yield potential of rice.

Matthews *et al.* (1997) found that in case of rice, simulated yield potential in major rice growing regions of Asia may decrease by 7% for every 1°C rise above the current mean temperature.

Islam *et al.* (1998) reported that percent reduction in relative water content was rapid in drought susceptible genotypes.

Leport *et al.* (1998) reported that the decrease in the rate of net photosynthesis with the decrease in leaf was similar to that observed in the field.

Sahoo and Guru (1998) observed the positive association of SLA, CGR, and LAD with grain yield.

Chauhan *et al.* (1999) reported that the LAD and LAI measured at 30-45 days after sowing (DAS) had positive and significant association with dry accumulation at 50% flowering.

Adak and Dasgupta (2000) reported that the photosynthetic rate, stomatal conductance, intercellular CO₂ concentration decrease in rice varieties and also opined the imbalances of normal plant water relations and productivity due to detrimental effects on photosynthesis in rice varieties subjected to high water stress by submergence.

Cornic, G. (2000) suggested that the drought induces stomatal closer and consequently increases the leaf internal Co₂ concentration.

Deka and Baruah (2000) observed that amongst the cultivars 'lharsal Ahu' and Maibee 'II' recorded better germination under stress, through relative leaf water content, leaf area, root and dry weight decreased significantly under stress, cultivars 'lharsal Ahu' and Maibee 'II' performed better under stress.

Ghosh *et al.* (2000) reported a positive and significance of chlorophyll content with yield, which confirmed its rate in sink development.

Haloi and Dey (2000) noted that the variation in productive efficiency between rice cultivars and plant population stress under a given set of environment depends on the rate at which a closed canopy develops leading to better use of incoming solar radiation.

Kumar *et al.* (2000) suggested that for selection of rice, ragi and barnyard genotypes suitable for low light/cloudy conditions, high contents of chlorophyll-b, total carotenoides and high photosynthetic efficiency under low light conditions may comprise the important criteria instead of high photosynthetic efficiency under normal condition for the hills.

Richards (2000) noted that the grain yield of cereals has almost doubled in this century despite of no change in the rate of photosynthesis per unit area to accompany these increase, total photosynthesis has increased as a result of an increase in leaf area.

Huijie *et al.* (2001) found in rice that the highest production rate exhibited by the cultivars during the middle and late growth stages. During these stages, the yield increased with the increase in net dry matter accumulation, and the crop growth rate (CGR) was significantly and positively correlated with the yield.

Kumudini *et al.* (2001) noted that yield is the product of dry matter accumulation and partitioning.

Haloi and Dey (2003) recorded the IET 10664 maintained stable rate of specific leaf weight during its inundation period. The cultivar produced a significant higher quantum of stem reserve mobilization (17.7%) as compared to other cultivars.

Mukherjee *et al.* (2003) noted that PAR interception by the whole canopy was maximum in the morning and afternoon. The maximum PAR interception was observed during fruit development stage of the crop.

Padmaja *et al.* (2003) observed that the ten rice varieties released during the last four decades of research in Andhra Pradesh did not differ significantly in photosynthetic rates as well as florescence.

Rajput *et al.* (2004) found that the differences in the leaf area index,

crop growth rate, and relative growth rate and leaf area ratio of the genotypes examined were not significant. Leaf area index, crop growth rate, leaf area ratio and relative growth rate ranged from 0.54 to 3.17, 0.30 to 25.6 (g/m²/day), 0.006 to 0.34 (m²/g) and 0.01 to 0.43 (g/m²/day), respectively.

Ryo Matsuda *et al.* (2004) found that In rice plants grown under red light supplemented with blue light (red/blue-light PPFD ratio was 4/1), photosynthetic rates per unit leaf area measured under white light at 1,600 and 250 (μmol m⁻² s⁻¹) were higher than those in the plants grown under red light alone. The higher photosynthetic rates were associated with higher total N content of leaves, which was accompanied by larger amounts of key components of photosynthesis-limiting processes. These results suggested that the increase in total N content of leaves induced by supplemental blue light enhanced both light-saturated and light-limited photosynthesis.

Gill *et al.* (2005) observed the maximum dry matter accumulation (leaf area index 4.37 – 4.97 and 5.24 – 6.06) under direct seeding.

Lin *et al.* (2005) noted that the daily average net photosynthesis increased by 20.8 and 29.7% at the earing stage under CO₂ levels of 550 and 750 μmol/mol compared with the ambient air CO₂ concentration.

Gill *et al.* (2006) showed that the water productivity in direct seeded rice ranged between 0.40 and 0.46 kg/grain/m³irrigation water clearly sowing the more water use efficiency.

Sharma and Piri (2006) revealed that application of two irrigation at 45 DAS and 90 DAS significantly increased plant height dry matter accumulation, relative growth rate and secondary branches/plant over one irrigation. However, effects of one irrigation and two irrigation were at par on leaf area index, net assimilation rate and primary branches/plant but recorded significantly higher values of above physiological parameters over no irrigation in both the years. Seed yield increased significantly with increasing levels of irrigation.

Yadav and Singh (2006) noted the highest value of leaf area index (3.28) at transplanting.

Zhao *et al.* (2007) suggested that the reduction in transpiration rate and stomatal conductance and concomitant increase in intercellular CO₂ concentration suggested that both stomatal and non stomatal factors were involved in the reduction of photosynthesis.

Singh *et al.* (2008) noted that the water use efficiency (WUE) ability of the plant to produce dry matter /unit of water is a genotypic character and two important physiological traits that determine the variability in WUE are photosynthetic rate (pm) and transpiration rate (T) are basically the function of leaf.

Sumesh *et al.* (2008) reported that the proline, amino acids, proteins and sugars are some of the common metabolites that accumulate under stress conditions.

Das and Kalita (2010) reported that the performance of the local varieties (Kolong and Luit) had comparatively higher seedling vigour and profuse root growth. The higher chlorophyll content was recorded in Kolong and Luit as compared to IR-50 and other genotypes. The higher values of RWC and chlorophyll stability index were also recorded in Luit followed by Kolong.

Deivanai *et al.*, (2010) reported that drought symptom was noticed by wilting of leaves. At the time of wilting, physiological parameters like relative water content (RWC), total chlorophyll content, proline accumulation and protein content were estimated for both stress induced and control plants. Mean performance of the genotypes also showed a sharp decline in RWC (%), total chlorophyll content and protein. Meanwhile, free proline accumulation was found to be more in water deficit condition.

Dhurve and Khan (2011) observed with respect to stomatal conductance, transpiration rate, chlorophyll content index and LAI. Higher photosynthetic rate in leaves of IET-20708 was resulted in to higher stem dry weight at flowering and harvest (25.2 and 12.3 g plant¹) respectively and TDM (1508.3 g⁻¹ m⁻²). Higher number of panicles⁻¹ m⁻², test weight and filled grain% also contributable for attaining superior sink size and grain yield. Thus, IET 20708 was found most tolerant rice genotype among 23 test entries with superior physiological parameters and found suitable in Kymore plateau sub-zone of M.P.

Khapke *et al.* (2011) showed that the photosynthetic pigments were highly reduced with increasing water stress at seedling and anthesis stage and also the plant height, number of leaves and leaf area decreased with increasing water stress at seedling and anthesis stage in the wheat.

Krishnapriya *et al.* (2011) showed that the increasing salinity levels caused a marked reduction in the leaf gas exchange parameters at different phenological stages of crop growth. Correlation analysis between key parameters like A_{gs} , A_{E} , A_{Ci} , A_{Yield} etc., revealed that tolerant genotypes exhibiting optimal gas exchange characteristics under salinity stress, accumulated higher biomass, yielded better and ultimately possessed a higher Harvest Index as compared to susceptible genotypes.

Pradhan and Singh (2011) reported that two varieties of paddy were used, namely Pant Dhan-11 (Submergence susceptible) and Jal Lahri (Submergence tolerant) for investigation. Percentage increase in plant height, leaf area and root length were less in Jal Lahri than to Pant Dhan-11. Photosynthetic rate and total chlorophyll content was less in Jal Lahri than Pant Dhan-11. These studies, suggest that, Jal Lahri is a submergence tolerant variety, which can survive under prolonged conditions of complete submergence.

Rajeswari *et al.* (2011) recorded the rice cultures MTU3 followed by MTU-4, MTU-1 and NLR-34449 have recorded higher grain yield (1.70 to 2.17 t/ha). The high grain yielding cultures have also recorded more number of filled grains/plant. The four high grain yielding cultures NLR-34449 was higher values for physiological parameters viz. photosynthetic rate, transpiration rate and Stomatal conductance ratio. The cultures viz. MTU 10, MTU 9, MTU 2, MTU 5, MTU 6, BPT 5204 though recorded higher photosynthetic rate, transpiration rate and stomatal conductance ratio, but were found to be low grain yielders because of low harvest index, more number of ill filled grains/plant.

Rao *et al.* (2011) showed that the slight decrease in plant height during wet season while varieties did not show any significant change, where as in the dry season the variations were not significant. Total number of tillers per

plant, number of productive tillers per plant and panicle length did not alter between alternate wetting and drying (AWD) and normal irrigated condition. The chlorophyll content did not alter significantly with the main treatment. Little increase in aerenchyma volume was detected in both hybrid and varieties under AWD conditions and the reduction in stomatal conductance, while the varieties were less affected than hybrids under alternate wetting and drying (AWD) situation.

Sravan Raju *et al.* (2011) determine the effect of high temperature during flowering and grain filling on different genotypes. The spikelet fertility varied from 33% in Azucena (sensitive) to 86% in N22 (tolerant); Suruchi, PHB 71(hybrids), RPHR 1005 and SG-27-77 were also observed to be moderately tolerant to heat stress. Other genotypes viz., BPT 5204, IR 58025B, DRR6B were affected adversely when flowering coincided with high temperature. Extreme temperature during booting to anthesis resulted in reduction of seed setting rate and partially filled grains. The cultivar N22 was the highly tolerant genotypes and Azucena was most sensitive genotypes in terms of spikelet fertility and grain yield.

Rao *et al.* (2012) recorded that the cultures IET 21023 and IET 20986 was higher, though not the highest, RUE at panicle initiation and maturity stages at all the three locations and produced TDM and grain yield higher than the mean TDM and grain yield for all the test cultures.

Gupta *et al.* (2012) suggested the drought stress led to a significant decrease in photosynthetic rate and stomatal conductance and concomitant increase in intercellular CO₂ concentration.

2.6 Biochemical parameters.

Bates *et al.* (1972) reported that the proline content of the third leaf at two development stage.

Yoshida *et al.*, (1976) observed that plants sampling was done both at flowering and maturity stages for recording various morphological, physiological, biochemical, growth and yield parameters. Nitrogen, total sugar and starch contents were estimated following.

Turner and Begg (1981) and Turner (1977) concluded that loss is compensated partially by the mobilization of carbohydrates stored in the vegetative plant parts which contributed up to 30% of the final grain yield when water deficits develop during grain filling.

Yadav *et al.* (1991) studied the physiological and biochemical evaluation of sorghum genotypes for drought. The higher rate of stomatal resistance, sugar content and proline accumulation with a lower rate of transpiration and CSI were considered to be importance parameters and could be used successfully for rapid screening of germplasm cultivars for drought tolerance.

Pawar *et al.* (1992) reported that seed protein content was the highest with three irrigations (23.75%) and lowest with no irrigation (22.00%).

Kengjika and Mathis (1995) observed that the chlorophyll a/b was found to be correlated with the photosynthetic efficiency of a crop.

Singh and Singh (1999) reported that the SG-11 and DHG-84-11 showed minimum reduction in total chlorophylls, Chl. 'a' and Chl. 'b'. Carotenoids increased in the tolerant genotypes, but decreased in susceptible genotypes, under salt stress.

Deka and Baruah (2000) observed that amongst the cultivars 'lharsal Ahu' and Maibee 'II' was differed significantly in respect of leaf chlorophyll II, proline, nitrate reductase activity and nitrogen, phosphorus and potassium content under stress and non stress condition. 'lharsal Ahu' and Maibee 'II' showed better results under stress indicating their tolerance to moisture stress.

Namita and Koundal (2000) studied that the total protein in mature seeds was found to be 22% (dry weight basis). The major storage protein, globulin synthesized actively between 9 days after flowering (DAF) until 29 DAF and was 66% on a total protein basis in the mature seeds.

Dhopte (2002) described procedure for calculation of chlorophyll stability index for drought tolerance in plant. CSI is found to be corresponded with low drought tolerance. Thus, CSI is inversely related with drought tolerance efficiency.

Kumar *et al.* (2006) observed that greater accumulation of solutes like sugar, soluble proteins and Proline content was observed under moisture stress condition at 105 DAS. However, at the later stage of crop growth (125 DAS) under rainfed condition, the soluble proteins and soluble sugar contents decreased below the irrigated-control plants, while Proline contents was slightly higher than control plants. Under rainfed condition greater accumulation of solutes occurred at comparatively higher osmotic potential at 105 DAS than at 125 DAS, when plants showed much lower osmotic potential.

Khapke *et al.* (2011) conducted the concentration of proline increased significantly with an increase in the degree of water stress.

Rao *et al.* (2011) showed that the total soluble sugars and proline levels did not vary significantly due to alternate wetting and drying (AWD) treatment, where as free amino acid content increased moderately under AWD situation.

Pawar *et al.* (2011) suggested that the morphologically leaves show bending characteristics in a gradient pattern from lower to higher concentration of PEG Proline content analysis using Bates method (1973) was performed and found out that increases in PEG concentration increases the proline and 11 protein bands were observed in stressed leaf samples in a gradient manner whereas only 3 protein bands were observed in control. This clearly shows that proteins and proline protect the cells from osmotic damage due to low water content.

Chapter- III

MATERIALS AND METHODS

The present investigation entitled “Ecophysiological studies of rice varieties in relation to climate change” was carried out at the Research Farm, Department of Physics and Agro-meteorology, College of Agriculture Engineering, JNKVV Jabalpur (M.P.) during *Kharif* season of 2011. Different materials were used and methodologies were followed to complete various studies in the field, which are systematically described in this chapter under appropriate heads. Besides the treatments tested under the investigation of edaphic and climatic factors which also exert their marked influence on growth, physiology and yield of crops. Hence, these parameters are also briefly described here.

1. Experimental site

The field experiment was conducted at Research Farm, Department of Physics and Agro-meteorology, College of Agricultural Engineering, J.N.K.V.V., Jabalpur (M.P.) during *Kharif* season, 2011. Almost all facilities and pre-requisites to conduct the present investigation successfully were adequately available on the research farm.

2. Climate and Weather

Jabalpur is situated in central part of Madhya Pradesh at 23° 09' North latitude and 79° 58' East longitude with an altitude of 411 meter mean sea level. The tropic of cancer passes through the middle of the district. It has sub-tropical climate characterized by hot dry summers and cool dry winters. Jabalpur lies in the "Kymore Plateau and Satpura hills" agro climatic zone of Madhya Pradesh. The average maximum temperature during the month of May - June varies between 45.5 to 46.4 °C, while the average minimum temperature varies between 8.2 to 8.7 °C during December-January which are the coldest month of the year. The average annual rainfall of this region is about 1250 mm, which mostly receive during between June to September with a little quantity (75 to 175mm) occasional showers in other seasons. The average humidity of the tract is about 83 percent during rainy season.

3. Weather condition during crop season

The weekly meteorological data on mean maximum and minimum temperature, relative humidity, rainfall and sunshine hours during the course of field experimentation (June to November, 2011) were recorded from the Meteorological observatory, College of Agriculture, Engineering, J.N.K.V.V, Jabalpur and are presented in Table 3.1 and depicted in Figure 3.1.,

In general, the weather conditions during *Kharif*, 2011 were favourable for growth and development of rice crop. The monsoon commenced in the third week of June and depleted in the last week of September. The rainfall during the crop season was 1834.50 mm and was received in 41 rainy days. Minimum and Maximum temperature observed 20.06°C and 31.76°C during this period, the average relative humidity was 48 to 96 percent in the morning and 20 to 85 percent in evening. Sunshine hours ranged from 0.4 to 9.5 hours per day.

Table 3.1 Weekly meteorological parameters during crop season (First of June to end of November, 2011-12)

Meteo. Week	Temperature (°C)		Rainfall (mm)	RH (%)		Sun Shine (hrs./day)	Wind speed (km/hr)	No. Of Rainy days
	Max.	Min.		Morn.	Even.			
22	41.8	25.6	0.0	48	20	9.5	7.3	0
23	40.1	26.4	15.4	61	28	7.4	7.4	1
24	39.6	25.2	23.4	73	37	6.2	8.4	3
25	31.0	22.5	253.2	89	84	2.8	11.3	5
26	27.4	22.8	91.3	90	80	0.4	9.5	4
27	32.8	23.8	15.2	86	61	4.9	5.7	2
28	32.0	23.5	46.4	92	71	3.1	6.2	3
29	30.3	22.8	429.1	93	83	2.5	7.3	6
30	29.9	22.7	119.2	90	70	9.4	6.3	3
31	31.1	23.6	140.0	92	82	3.9	5.3	5
32	28.7	22.7	118.5	93	85	1.5	6.7	6
33	29.8	22.7	57.6	92	78	4.0	6.4	3
34	30.9	22.9	14.6	93	70	6.3	3.2	3
35	31.5	22.8	150.6	96	71	5.8	4.5	7
36	29.5	22.6	221.6	94	80	1.2	5.3	4
37	29.7	22.4	92.2	93	73	3.9	5.1	3
38	30.8	21.9	41.0	93	67	5.1	5.7	4
39	31.3	20.8	0.0	86	56	6.9	5.1	0
40	32.2	18.6	5.2	90	47	9.0	3.1	1
41	32.4	19.1	0.0	92	43	8.3	2.3	0
42	32.6	15.8	0.0	89	31	9.3	2.5	0
43	31.8	13.9	0.0	87	30	8.9	2.5	0
44	31.0	11.0	0.0	86	24	9.0	2.4	0
45	31.8	12.1	0.0	89	29	8.3	2.5	0
46	30.9	12.4	0.0	89	28	8.0	2.4	0
47	29.4	11.3	0.0	92	33	8.7	2.3	0
48	27.2	9.6	0.0	89	36	7.3	2.2	0

4. Soil of the experimental field

In order to determine the physico-chemical properties of the soil of experimental field, soil samples were collected randomly from 10 places at 0-25 cm depth with the help of soil auger before application of fertilizer. These samples were mixed thoroughly to make a representative sample. This sample was subjected to various analytical work in the laboratory of the Department of Plant Physiology, College of Agriculture, Jabalpur (M.P.). The analytical values are given in Table 3.2.

Table 3.2 Physico-chemical properties of the soil of experiment field;

Constituents	Value	Class/groups	Method used		
A. Mechanical method					
Sand (%) Silt (%) Clay (%)	62.8 15.8 21.4	Sandy clay loam	International pipette method (Piper,1967)		
B. Chemical analysis					
Organic carbon (%)	0.82			Medium	Walkley and Black rapid titration method
Available nitrogen(kg/ha)	285			Medium	Alkaline permangnet method (Subbaiah and Asija, 1956)
Available P ₂ O ₅ (kg/ha)	17.45	Medium	Calorimeter method (Olsen <i>et al.</i> ,1954)		
Available K ₂ O	260	Medium	Flame photometer method (Chapman and Pratt,1961)		
Soil PH	6.72	Neutral	Glass electric PH meter (Piper,1967)		
Electrical Conductivity (ds/m at 25 ⁰ C)	0.06	Low	Solu-bridge method (Black, 1965)		

It is clear from the data given in Table 3.2 that the soil of experimental field was sandy clay loam in texture and neutral in reaction, low in electrical conductivity with medium organic carbon content and analysing in medium available N, P and K contents.

5. Cropping history of experimental field

The previous crops grown in the experimental field during the three years are presented in Table 3.3

Table 3.3 The cropping history of the experiment field

Year	Kharif	Rabi
2009-10	Rice	Chickpea
2010-11	Rice	Chickpea
2011-12	Rice	Chickpea

The commercial production of crops was done in the field with the uniform dose of fertilizer application. Thus, it could be said that fertility status of soil in experimental area was homogenous. The topography of the field was also fairly uniform with a gentle slope of 0.5%;

6. Experimental details

6.1 Experimental Design and layout

A field experiment conducted on rice with 27 treatments combination of 9 varieties (sub plot treatment), 3 irrigations (main plot treatment) were tested in a Strip Plot Design with 3 replications. The detail of the layout plan of experiment is depicted in Figure 3.2. Other details were as under treatments

Main treatments (irrigation factors):

Irrigated	Plots remain irrigated all the time.
Rainfed	Irrigation is not given in these plots. These plot were dependent on rainfall water.
Semi irrigated	One irrigation was applied in this treatment in the first week of October after depleting of south-west monsoon. Rice was in flowering to grain filling stages and required irrigation during that time.

Sub treatments (Varieties):

V ₁	Rice (JGL-3844)
V ₂	Rice (WGL-32100)
V ₃	Rice (IR-36)
V ₄	Rice (IR-64)
V ₅	Rice (Kranti)
V ₆	Rice (PS-4)
V ₇	Rice (PS-5)
V ₈	Rice (MR-219)
V ₉	Rice (Mahamaya)

6.2 Details of layout in the field

Design	:	Strip plot design
Main treatments	:	03
Sub treatments	:	09
Replications	:	03
Gross plot size	:	4.0 m x 4.0 m
Net plot size	:	3.6 m x 3.5 m
Strip between strip	:	3.0 m
Planting geometry-		
Row to row spacing	:	20 cm
Seed rate	:	80 Kg/ha
Fertilizer application	:	120:60:40 NPK (Kg/ha), 25 ZnSo ₄ (kg/ha)

6.3 Schedule of Agronomic Operations

The details of various agronomic operations performed on the field experiment are described below in tabular form Table 3.4:

Table 3. 4 Schedule of field operations during the crop season

S. No.	Field Operations	Dates
1.	Ploughing and levelling	7 th Jan
2.	Fertilizer application	7 th Feb
3.	Seed sowing	3 rd July
4.	Fertilization application	3 rd July, 28 th July, 16 th August, 14 th Sept.
5.	Hand weeding	30 th July, 30 th August
6.	Irrigation in irrigated strip plots	19 th August, 23 th August, 27 th August, 30 th August, 19 th Sept., 26 th Sept., 30 th Sept., 5 th Oct., 14 th Oct.
7.	Irrigation in Scheduling irrigating strip plots	10 th Oct. (Panicle initiation flowering stage)
8.	Physiological maturity	18 th Oct.
9.	Crop harvesting	9 th Nov.

6.3.1 Preparation of field

The field was prepared by tilling the land with tractor drawn cultivator followed by two harrowings with disc harrow to develop fine tilth. The field was then finally levelled by using tractor operated leveller. After this, treatments were laid out on well prepared seed bed. Then the raised beds were made as per treatments.

6.3.2 Sowing

Seed at 80 kg/ha was sown in all treatments as line sowing by hand methods at depth of 4-5 cm. The date of sowing was 3rd July, 2011.

6.3.3 Water management

Since experiment was based on irrigated, semi-irrigated and rainfed conditions, therefore, irrigation was provided to the selected strips of the experiment. However, bunds were prepared around all the individual plots for storage of rainfall water and to check the nutrient movement from one to another plot and their loss.

6.3.4 Irrigation management

In irrigated treatments, water remains available all the time. Generally, during, July, August, and September very less water is applied through irrigation due to rainfall occurred during these months. Irrigation was applied from last week of September to October in such a manner that field remained wet all the time in these treatments. On the contrary, no irrigation was supplied in rainfed treatments, and it was totally dependent on rainfall. The third treatment include marginal irrigated in which irrigation is applied only once in the second week of October after flowering stage, as this is the critical stage of irrigation.

6.3.5 Weeding and Interculture

The infestation of *Echinochloa crusigalli*, *Commelina benghalensis*, *Eclipta alba* and *Cyperus iria* were observed in the field. Therefore, two hand weedings was done at 25 days after sowing (DAS) in to keep the experimental plots weeds free and the crop was irrigated as per crop requirements.

6.3.6 Fertilizer and manure application

Nitrogen, phosphorus and potassium were applied at 120, 60, 40 and 25 kg N:P:K:Zn/ha respectively in each plot. Total phosphorus, potassium and zinc were applied as basal dose in all treatments. 50% nitrogen was applied as basal at time of sowing while 25% nitrogen as first top dressing during

tillering stage (45 DAS) and remaining 25% nitrogen as second top dressing during panicle initiation (60 DAS).

6.3.7 Plant protection

The infestation of leaf folder (*Cnaphalocris medinalis*) was observed during 3rd week of September on crop sowing. Spraying of 750 ml Chlorpyrifos/ha was done by using 500 liters of water uniformly to avoid the losses by insect. The infestation of army worm (*Spodoptera mauritia*) was noticed in crop sowing hence; again a uniform spraying of 750 ml chlorpyrifos/ha was done by using 500 litres of water.

6.3.8. Harvesting, Threshing, Winnowing and Weighing

Harvesting was done manually with the help of sickle. The physiological maturity of all the treatments was judged visually before the crop was harvested. The harvesting was done on the basis of varietal characters. In order to eliminate the border effects, two outer rows and 50cm at both the ends were removed first from each plots keeping net plot 3.6m x 3.5m. Before harvesting the crop, ten randomly selected sampled plants were removed first for post-harvest studies. The harvested produce was left in their respective plots for sun drying for three days. One day before threshing the produce (total plant biomass) was stacked in the centre of the respective plots. The bundles were tied with rope, and then weighed by means of spring balance and bundle weight was recorded. The threshing was done by labour with the help of stick. Care was taken to avoid loss of grain during the operation of threshing and winnowing. Winnowing was done by Supas. The weight of cleaned grains from each net plot was recorded in kilogrammes and then converted into quintal/hectare.

7. Experimental studies

The fine competitive sample plants were randomly selected in each plot and tagged for recording the observations on grain yield and yield-attributing characters as detailed below:

7.1. Pre-harvest observations

7.1.1 Plant population

Population counts were recorded from a meter row length of 5 rows in each plot and then mean was computed. After this, the population/m row length was converted in plant population/m².

7.1.2 Plant-height (cm)

The height of plants from five randomly selected plants were measured in centimeters from the base of the plant to the base of the upper most leaf, after panicle emergence stage, height was measured from base of plants to the base of panicle. These observations were recorded at physiological maturity stage. Finally, the mean height was worked out for each plot.

7.1.3 Number of Tillers/m²

Number of tillers per plant was counted from five tagged plants of each plot at physiological maturity stages. After this number of tillers/m² was recorded by multiplying with appropriate factor.

7.1.4 Number of leaves/plant

Total number of leaves was counted in five marked plants of each plot at 30, 45, 60, 75, 90, 105 DAS and maturity stage. Then mean was computed.

7.1.5 Leaf area (cm²)

The leaf area of 3 leaves from each plot was recorded on laser area meter (Model LI-300) at 30, 45, 60, 75, 90, 105, DAS and physiological maturity stages. Then mean was computed. After this, total leaf area per plant was worked out by multiplying mean leaf area with number of leaves/plant. Then leaf area/m² was determined as below:

$$\text{Leaf area/m}^2 = \text{leaf area/plant} \times \text{plant population/m}^2$$

7.1.6 Dry matter production

Three plants from border area of each plot were uprooted along with roots with the help of fork. After this, uprooted plant samples were cleaned in

fresh water. Then tagged with luggage labels for each plot separately. The samples were allowed to sundry for two days and again dried in an oven till to reach the constant weight. These observations were made at 30, 45, 60, 75, 90, 105 DAS and at physiological maturity stages. Finally, the weight of oven dried samples was recorded on electronic balance.

7.2 Post-harvest Observations

7.2.1 Number of effective tillers/m²

The number of ear bearing tillers per plant was counted from fine tagged plants in each plot just before harvesting. After this, the average number of tillers per plant was calculated. Then, the values were converted into tillers/m² by multiplying with appropriate factor.

7.2.2 Seed index (1000- grain weight)

One thousand grains were taken from the produce of each plot and their weight was recorded by electronic balance.

7.2.3 Number of grains/panicle

The number of grains/panicle obtained from main tillers of the selected plants were counted plot wise and the average values were worked out.

7.2.4 Biological yield (kg/ha)

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated with the following formula.

$$\text{Biological yield (kg/ha)} = \text{Grain yield (kg/ha)} + \text{Straw yield (kg/ha)}$$

7.2.5 Grain Yields (kg/ha)

The weight of cleaned grain obtained from each plot was recorded separately and then the values were converted into yield per hectare by multiplying with appropriate factor.

7.2.6 Straw yields (kg/ha)

Straw yield was obtained by subtracting the grain yield of each plot from the total biological yield of the same plot. After this, straw yield in per hectare was determined in the same manner as in case of grain yield.

7.2.7 Harvest Index

Harvest index is the ratio of economic yield to biological yield which is expressed in percentage. It was calculated as per formula given below as suggested by Nichiporovich (1967):

$$\text{Harvest Index} = \frac{\text{Economical yield (grain yield q/ha)}}{\text{Biological yield (grain + straw yield q/ha)}} \times 100$$

7.3 Growth analytical parameters

7.3.1 Leaf area index (LAI)

LAI expressed the ratio of leaf surface (One side only) to the ground area occupied by the plant or a crop stand worked out as per specification of Gardner *et al.* (1985).

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Land area}} \qquad \text{LAI} = \frac{(LA_2 + LA_1)}{2/p}$$

Where the LA_1 and LA_2 represents the leaf area during the consecutive intervals and 'P' ground area.

7.3.2 Leaf area duration (LAD)

Leaf area duration expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth. It reflects the extent of seasonal integral of light interaction and correlated with yield LAD was computed as follows : (Watson, 1952).

$$\text{LAD} = \frac{(LA_2 + LA_1)}{2} \times (t_2 - t_1) \text{ (m}^2 \times \text{day)}$$

Where the LA_1 and LA_2 represents the leaf area at two successive time intervals (t_1 and t_2).

7.3.3 Specific leaf area (SLA)

The specific leaf area expresses the ratio between the leaf area (LA) and leaf dry weight (LW) (Gardner *et al.*, 1985).

$$SLA = \frac{(LA_2/LW_2 + LA_1/LW_1)}{2} (\text{cm}^2/\text{g})$$

7.3.4 Specific leaf weight (SLW)

It is the ratio between the leaf dry weight (LW) and the leaf area (LA). It indicated the leaf thickness on a weight basis (Gardner *et al.*, 1985).

$$SLW = \frac{(LW_2/LA_2 + LW_1/LA_1)}{2} (\text{g}/\text{cm}^2)$$

7.3.5 Crop growth rate (CGR)

The daily increment in plant biomass is termed as crop growth rate (Watson, 1952) or productivity rate (Leith, 1965) or rate of dry matter production. It was determined as per the following formula attained by Watson, 1952).

$$CGR = \frac{W_2 - W_1}{p (t_2 - t_1)} (\text{g}/\text{cm}^2 \text{ ground area}/\text{day})$$

where,

p = ground area (m^{-2})

W_1 = dry weight per unit area at t_1

W_2 = dry weight per unit area at t_2

t_1 = first sampling and

t_2 = second sampling

7.3.6 Relative growth rate (RGR)

The Relative growth rate expresses the dry weight increase in time interval in relation to initial weight. In practical situations, the mean relative growth rate is calculated from measurements at t_1 t_2 .

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1} (\text{g g}^{-1}\text{day}^{-1})$$

where,

W_1 = dry weight per unit area at t_1 ,

W_2 = dry weight per unit area at t_2 ,

t_1 = first sampling, and

t_2 = second sampling.

7.4 Physiological observations

7.4.1 Chlorophyll content index (g/m^2)

Chlorophyll content in the 4th leaf of five weeks old plant were determined as chlorophyll index using a non-destructive method that uses an optical instrument called chlorophyll meter (Apogee, instruments in c, 721w1800N, Logan,(VT84321)USA). (Measure by Chlorophyll content meter Model: CCM 200) (Made in USA).

7.4.2 Relative Leaf water content (RLWC) and Water saturation deficit (WSD) (%)

The relative water content (RWC) and water saturation deficit (WSD) were estimated as per method given by Barrs and Weatherly (1962):

A leaf that is physiological functional (third from the top) is selected for RWC and WSD estimation.

Its fresh weight is immediately recorded after it is excised. The leaf samples can be brought to the lab after carefully sealing in double walled thermocole chamber or plastic bag in order to prevent from water loss and fresh weight (Fw) is recorded. The petiole may be detached keeping only leaf lamina. Secondly, keep these leaf samples floating on water under diffused light to get turgid weight (Tw) for 4-6 hrs. depending upon the degree of imbibitions.

Finally, the same leaf is kept in an oven at 75⁰ C for assessing dry weight (Dw) further, the value are plugged in the fallowing formula:

$$\text{RLWC (\%)} = \frac{\text{Fw}-\text{Dw}}{\text{Tw}-\text{Dw}} \times 100$$

Where Fw is fresh weight, Dw is dry weight and Tw is turgid weight of the leaf samples (4-mm diameter leaf discs).

The water saturation deficit was determined as follows.

$$\text{Water saturation deficit (WSD)} = 100 - \text{RWC}.$$

7.4.3 Drought susceptibility index (DSI)

Drought susceptibility index was calculated by the formula given by Fischer and Maurer (1978).

$$\text{DSI} = (1 - Y_d / Y_p) / D$$

Y_d = Grain yield of the genotype under moisture stress condition.

Y_p = Grain yield of the genotype under irrigated condition.

$$D = \frac{\text{Mean yield of all strains under moisture stress condition}}{\text{Mean yield of all strains under irrigated condition}}$$

7.5 Other physiological traits

The quantification of the physiological traits Viz, photosynthetically active radiance absorption, net photosynthesis, stomatal conductance, transpiration rate, intercellular CO₂ concentration, water use efficiency, carboxylation efficiency, quantum use efficiency was carried out by using infra red gas analyser (IRGA) Li Cor-6400 (Li Cor instruments, USA) as per method suggested by Kannan *et al.* (2007).

7.5.1 Photosynthesis Active Radiation ($\mu \text{ mol/m}^2/\text{sec}$).

7.5.2 Net photosynthesis ($\mu \text{ mol/m}^2/\text{sec}$).

7.5.3 Transpiration rate ($\mu \text{ mol/m}^2/\text{sec}$).

7.5.4 Intercellular CO₂ concentration ($\mu \text{ mmol CO}_2 \text{ mol}^{-1}$)

7.5.5 Water Use Efficiency (WUE) ($\ll \text{mol/mol}$)

The water use efficiency was determined as per method given by as follows: Kannan and Vankataraman (2010).

$$\text{WUE} = \frac{P_n}{E}$$

Where, P_n represent the net photosynthetic and E refers to the transpiration rate.

7.5.6 Carboxylation efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1}$)/($\mu\text{mol mol}^{-1}$)

The carboxylation efficiency was worked out as per method suggested by Kannan and Vankataraman (2010) as follows:

$$\text{C.E.} = \frac{P_n}{C_i}$$

Where, the P_n refers to the net photosynthetic, where C_i refers to the intercellular CO₂ concentration.

7.5.7 Quantum Use Efficiency (QUE) ($\mu\text{mol m}^{-2} \text{s}^{-1}$)/($\mu\text{mol mol}^{-1}$)

The quantum use efficiency was also determined as per methods given by Pandey *et al.* (2001) as follows:

$$\text{Q.E.} = \frac{P_n}{Q}$$

Where, the P_n refers to the net photosynthetic, whereas Q refers to the PAR absorption.

7.6 Biochemical estimation

The plant parts were analysed for the biochemical constituents at different crop growth stages as follows:

S. No.	Biochemical contents	Plant parts	Stages
1.	Carbohydrate	Seed	Maturity
2.	Protein & nitrogen	Seed	Maturity
3.	Proline	Leaf	Grain filling

7.6.1 Estimation of total carbohydrates percentage

Total carbohydrates in the sample was estimated by the hydrolysis method as described in AOAC (1984)

Reagents

- 1) 5% phenol: Dissolve 50g of redistilled (reagent grade) phenol in water and dilute to one litre.
- 2) 96% sulphuric acid (reagent grade).
- 3) Standard glucose: stock - 100mg in 1(x) ml of water.

Working Standard 10ml of stock diluted to 100ml with distilled water.

Procedure:

- 1) Weigh 100mg of the sample into a boiling tube.
- 2) Hydrolyze by keeping it in a boiling water bath for 3hr. with 5ml of 2.5N HCL and cool to room temperature.
- 3) Neutralize it with solid sodium carbonate until the effervescence ceases.
- 4) Make up the volume to 100ml and centrifuge.
- 5) Pipette out 0.2, 0.6, 0.8 and 1ml of working standard into a series of test tubes.
- 6) Pipette out 0.1 and 0.2ml of the sample solution in two separate test tubes. Make up the volume in each tube to 1ml with water.
- 7) Set a blank with 1ml of water.
- 8) Add 1ml of phenol solution to each tube.
- 9) Add 5ml of 96% sulphuric acid to each tube and shake well.
- 10) After 10 min shakes the contents in the tubes and place in a water bath at 25-30⁰ C for 20 min.
- 11) Read the colour at 490nm.
- 12) Calculate the amount of total carbohydrate present in the sample solution using the standard graph.

Calculate

$$\text{Total carbohydrate in the sample} = \frac{\text{sugar value from graph } (\mu\text{g})}{\text{Aliquot sample used (0.1 or 0.2)}} \times \frac{\text{Total volume of extract (100 ml)}}{\text{Weight of sample (100mg)}} \times 100$$

7.6.2 Estimation of protein and nitrogen in seed

The nitrogen content was estimated by micro kjeldhal method (A.O.A.C., 1965) as given under by Gopalan *et al.* (1985):

0.1 gm of sample was digested with concentrated sulphuric acid (10 ml) in 9 digestion of (CuSO_4 , 5 H_2O and 0.34 g solution selenate). After digestion for about 3 hours till liquid becomes colourless, the digestion tube was allowed to cool and the contents carefully diluted to 100 ml with distilled water. The solution is then transferred quantitatively to a distillation apparatus, 15 ml of 40% of sodium hydroxide was added and the liberating ammonia was collected in a flask containing 10 ml of 2 percent boric acid with two drops of mixed indicator (Bromocrysol green + methyl red). Distillation was continued for 5 minute appearance of green colour to ensure the complete evaluation of ammonia. After distillation solution was titrated with 0.1N H_2SO_4 .

Nitrogen and protein percent was calculated by the following formula:

$$\text{Nitrogen} = \frac{14 \times \text{Normality of } \text{H}_2\text{SO}_4 \times \text{Vol. of } \text{H}_2\text{SO}_4 \times 100}{\text{weight of sample} \times 100}$$

Protein percent in the sample was estimated multiplying nitrogen percent of sample by factor 6.25.

$$\text{Protein (\%)} = \text{Nitrogen \%} \times 6.25$$

7.6.3 Estimation of proline in Leaves

Principle

Proline estimation is based on the formation of brick red coloured proline – ninhydrin complex in acidic medium. This complex is soluble in toluene and thus can be separated from aqueous phase. This ensures that there is no interference with other amino acids, which also formed a blue coloured complex with ninhydrin. The toluene soluble brick red coloured complex absorbs at 520 nm.

Free proline content in leaves was determined following the method of (Bates *et al.*, 1973). The protocol was based on the formation of red coloured formazone by proline with ninhydrin in acidic medium, which is soluble in organic solvents like toluene.

Requirements

Test tube, test stand, micropipette, Whatman No. 1 filter papers, visible spectro-photometer and chemicals as listed in reagents below.

Reagents

Sulphosallysic acid (3%); Three gram of sulphosalicylic acid was dissolved in 100 ml of distilled water.

Orthophosphoric acid (6 N)

Required volume of orthophosphoric acid (38%) was taken and volume was made to 100 ml using distilled water to get 6 N orthophosphoric acid.

Acid Ninhydrin

Ninhydrin (1.25 g) was dissolved in a blend of 30 ml of glacial acetic acid and 20 ml of 6 N orthophosphoric acid.

Procedure

Seed sample (0.5g) was homogenized in 5 ml of sulphosalicylic acid (3%) using mortar and pestle. The homogenate is filtered through whatman No. 1 filter paper and filtrate was collected, which was used for the estimation of protein content. Two ml of extract was taken in test tube and to it 2 ml of glacial acetic acid was added. The reaction mixture was heated in boiling water bath at 100 °C for 30 minutes brick red colour developed after cooling the reaction mixture, 6 ml of toluene was added and then transferred to a separating funnel. After thorough mixing the chromophore containing toluene through mixing the chromophore containing toluene was separated and its absorbance read at 520 nm in spectrophotometer against toluene

blank. Concentrate of proline was estimated by referring to a standard curve made from known concentration of proline.

8. Statistical analysis

Analysis of observations taken on different variables was carried out to know the degree of variation among all the treatments. The pooled data was statistically analysed through strip plot design. (Dr S.R.S.Chandel- A Hand book of agricultural statistics). The results obtained through analysis of various are given in appendix and in the skeleton of analysis of variance table is outlined as follows:

Table 3.5 Analysis of variance (ANOVA)

SOURCE	d.f.	S.S.	M.S.S	F
Replication (R)	(r-1)=3	ssR	-	-
Irrigation Factors (A)	(a-1)=3	ssA	MsA	msA/msE ₁
Error (a)	(r-1)(a-1)=9	ssE ₁	msE ₁ =E _a	
Varieties (B)	(b-1)=2	ssB	MsB	msB/msE ₂
Error (b)	(r-1)(b-1)=6	ssE ₂	msE ₂ =E _b	
Interaction (AxB)	(a-1)(b-1)=6	ss(AB)	ms(AB)	ms(AB)/msE ₃
Error (c)	(r-1)(a-1)(b-1)=18	ssE ₃	msE ₃ =E _c	
Total	(rab-1)=47	sstot		

Standard Error and Critical Differences :

$$\text{Estimate of S.E. of difference between two A level means} = \sqrt{\frac{2Ea}{rb}}$$

$$\text{Estimate of S.E. of difference between two B level means} = \sqrt{\frac{2Eb}{ra}}$$

Estimate of S.E. of difference between two A level means at the same level of B

$$\text{means} = \sqrt{\frac{2[(b-1)Ec + Ea]}{rb}}$$

Critical Difference = $SEd_{\pm} \times t$ at 5% level

Where,

r = Number of replications

E.M.S = Error mean square

$SEm_{\pm}$ = Standard error of treatment mean

$SEd_{\pm}$ = Standard error of difference to two treatment mean

CD = Critical difference to two treatment mean

Chapter-IV

RESULTS

The experimental findings aimed at investigating the Ecophysiological studies in relation to climate change” was carried out various staggered irrigation factors and varieties on rice phenology, different growth parameters, morpho-physiological traits and grain yield have been presented in this chapter under following sub heads.

- 4.1. Morphological and yield attributes
- 4.2. Functional attributes (growth analysis)
- 4.3. Physiological attributes
- 4.4. Other physiological traits
- 4.5. Biochemical estimation attributes
- 4.6. Phenological development

4.1 Morphological and yield attributes

4.1.1 Plant height (cm)

Table: 4.1 and Figure 3 revealed that the plant height (cm) was significantly affected by irrigation factors and varieties as well as by their interaction.

The plant height (cm) was differed significantly due to the irrigation factors and varieties as well as by their interaction. The plant height ranged between 42.59 to 67.10 cm at tillering and 81.22 to 116.33 at maturity stage.

The irrigation factors significantly affected plant height (cm) at both stages of growth. At tillering maximum plant height was recorded under rainfed condition (52.01) significantly followed by semi irrigated (51.78) and irrigated (51.19) conditions while at maturity under irrigated conditions maximum height of plant was measured (98.97) significantly followed by semi irrigated (95.59) and rainfed (91.29) conditions.

Table 4.1 Impact of staggered Irrigation factors and varieties on plant height (cm)

	at tillering stage	at maturity stage
Main treatments (Irrigation factors)		
Irrigated	51.19	98.97
Semi irrigated	51.78	95.59
Rainfed	52.01	91.29
SEm±	0.61	0.17
CD 5%	6.00	1.63
Sub treatments (Varieties)		
V ₁ (JGL-3844)	44.85	86.89
V ₂ (WGL-32100)	45.78	88.59
V ₃ (IR-36)	50.27	89.85
V ₄ (IR-64)	51.68	97.26
V ₅ (Kranti)	65.09	107.66
V ₆ (PS-4)	55.11	96.74
V ₇ (PS-5)	48.17	94.92
V ₈ (MR-219)	52.26	94.52
V ₉ (Mahamaya)	51.73	101.11
SEm±	1.47	0.38
CD 5%	5.37	1.40
Interactions		
V ₁ x Irrigated	45.64	93.11
V ₁ x Semi irrigated	44.34	84.00
V ₁ x Rainfed	44.56	83.55
V ₂ x Irrigated	46.67	93.33
V ₂ x Semi irrigated	48.08	91.22
V ₂ x Rainfed	42.59	81.22
V ₃ x Irrigated	51.03	95.44
V ₃ x Semi irrigated	52.56	92.66
V ₃ x Rainfed	47.21	81.44
V ₄ x Irrigated	52.56	98.89
V ₄ x Semi irrigated	50.39	98.33
V ₄ x Rainfed	52.10	94.55
V ₅ x Irrigated	65.84	116.33
V ₅ x Semi irrigated	62.33	108.22
V ₅ x Rainfed	67.10	98.44
V ₆ x Irrigated	54.16	96.77
V ₆ x Semi irrigated	55.21	95.66
V ₆ x Rainfed	55.98	97.77
V ₇ x Irrigated	45.84	98.11
V ₇ x Semi irrigated	47.58	93.77
V ₇ x Rainfed	51.09	92.88
V ₈ x Irrigated	51.98	97.33
V ₈ x Semi irrigated	51.44	95.00
V ₈ x Rainfed	53.34	91.22
V ₉ x Irrigated	46.97	101.33
V ₉ x Semi irrigated	54.09	101.44
V ₉ x Rainfed	54.14	100.55
SEm±	1.24	0.38
CD (5%)	3.14	0.95

The rice varieties also differed significantly among themselves in relation to their plant height (cm) at tillering as well as at maturity stage. V₅ recorded maximum plant height (65.09) significantly followed by V₆ (55.11) and V₈ (52.26). Similar trend was also maintained at maturity stage as V₅ (107.66) measured significantly more height followed by V₉ (101.11) and V₄ (97.26) varieties.

The interaction of irrigation factors and paddy varieties also influenced plant height (cm) significantly at tillering and maturity stages. At tillering stage, variety V₅ under rainfed condition (67.10) exhibited significantly maximum plant height and minimum in V₂ under rainfed condition (42.59). While at maturity stage variety V₅ (116.33) showed maximum plant height under irrigated condition and short statured plant height were obtained in variety V₂ (81.22) under rainfed conditions.

4.1.2 No. of productive tillers m⁻²

Table 4.2 and Figure 4 showed that the no. of productive tillers was significantly affected by irrigation factors and varieties as well as by their interaction.

The no. of productive tillers was obtained significantly due to the irrigation factors and varieties as well as by their interaction. The no. of productive tillers m⁻² ranged between 194.98 to 422.71.

The irrigation factors significantly affected no. of productive tillers m⁻² at maturity stage. The maximum no. of productive tillers m⁻² (311.84) was expressed under irrigated conditions significantly followed by semi irrigated (263.18) and rainfed (246.79) conditions.

The rice varieties also differed significantly among themselves in their no. of productive tillers m⁻² at maturity. Variety V₇ registered maximum no. of productive tillers m⁻² (343.78) significantly followed by V₃ (311.65) and V₅ (299.80) varieties at maturity stage.

The interaction of irrigation factors and paddy varieties also influenced no. of productive tillers significantly variety V₇ (422.71) under irrigated conditions exhibited significantly maximum no. of productive tillers m⁻² and minimum in variety V₆ (194.48) under rainfed conditions at maturity stage.

4.1.3 No. of panicles/plant

Table 4.2 and Figure 4 noted that the no. of panicles per plant was significantly affected by irrigation factors and varieties as well as by their interaction.

The no. of panicles per plant was differed significantly due to the irrigation factors and varieties as well as by their interaction. The no. of panicles per plant ranged between 3.33 to 5.22.

The irrigation factors significantly affected no. of panicles per plant at maturity stage. Significantly maximum no. of panicles per plant (4.23) was expressed under irrigated conditions followed by semi irrigated (112.64) and rainfed (3.78) conditions.

The rice varieties also registered significantly among themselves in their no. of panicles per plant at maturity. Variety V₆ recorded maximum no. of panicles per plant (4.37) significantly followed by varieties V₇ (4.33) and V₄ (4.26) at maturity stage.

The interaction of irrigation factors and paddy varieties also influenced no. of panicles per plant significantly variety V₄ (5.22) under semi irrigated conditions exhibited significantly maximum no. of panicles per plant and minimum in variety V₂ (3.33) under rainfed conditions at maturity stage.

4.1.4 No. of spikelets m⁻²

Table 4.2 and Figure 4 revealed that the no. of spikelets m⁻² was significantly affected by irrigation factors and varieties as well as by their interaction.

The no. of spikelets was differed significantly due to the irrigation factors and varieties as well as by their interaction. The no. of spikelets m⁻² ranged between 454.63 to 845.30.

The irrigation factors significantly affected no. of spikelets m⁻² at maturity stage. Significantly maximum no. of spikelets m⁻² (760.44) was recorded under irrigated conditions followed by semi irrigated (680.68) and rainfed (623.93) conditions.

The rice varieties also noted significantly among themselves in their no. of spikelets m^{-2} at maturity. Variety V_5 recorded maximum no. of spikelets m^{-2} (775.67) significantly followed by varieties V_8 (760.10) and V_2 (709.38) at maturity stage.

The interaction of irrigation factors and paddy varieties also influenced no. of spikelets significantly variety V_8 (845.30) under irrigated conditions exhibited significantly maximum no. of spikelets m^{-2} and minimum in variety V_6 (454.63) under rainfed conditions at maturity stage.

4.1.5 No. of seeds/panicle

Table 4.2 and Figure 4 showed that the no. of seeds per panicle was significantly affected by irrigation factors and varieties as well as by their interaction.

The no. of seeds was differed significantly due to the irrigation factors and varieties as well as by their interaction. The no. of seeds per panicle ranged between 59.11 to 144.77.

The irrigation factors significantly affected no. of seeds per panicle at maturity stage. Significantly maximum no. of seeds per panicle (123.21) was obtained under irrigated conditions followed by semi irrigated (112.64) and rainfed (110.14) conditions.

The rice varieties also exhibited significantly among themselves in their no. of seeds per panicle at maturity. Variety V_5 recorded maximum no. of seeds per panicle (133.59) significantly followed by varieties V_3 (126.44) and V_8 (124.07) at maturity stage.

The interaction of irrigation factors and paddy varieties also influenced no. of seeds per panicle significantly obtained in variety V_5 (144.77) under irrigated conditions expressed significantly maximum no. of seeds per panicle and minimum in variety V_6 (59.11) under rainfed conditions at maturity stage.

Table 4.2 Impact of staggered irrigation factors and varieties on number of productive tillers/plant, number of panicles/plant, number of spikelets/ m², number of seeds.

	No. of productive tillers/m ²	No. of panicles/plant	No. of spikelets/m ²	No. of seeds/panicle
Main treatments (Irrigation factors)				
Irrigated	311.84	4.23	760.44	123.21
Semi irrigated	263.18	4.23	680.68	112.64
Rainfed	246.79	3.78	623.93	110.14
SEm±	2.19	0.331	9.91	0.198
CD 5%	21.49	3.25	97.33	1.94
Sub treatments (Varieties)				
V ₁ (JGL-3844)	270.71	4.07	691.83	121.63
V ₂ (WGL-32100)	231.56	3.85	709.38	121.44
V ₃ (IR-36)	311.65	4.07	705.05	126.44
V ₄ (IR-64)	268.21	4.26	685.47	120.14
V ₅ (Kranti)	299.80	4.07	775.67	133.59
V ₆ (PS-4)	214.58	4.37	509.52	67.03
V ₇ (PS-5)	343.78	4.33	675.30	100.74
V ₈ (MR-219)	279.41	3.67	760.10	124.07
V ₉ (Mahamaya)	245.73	4.04	682.84	122.89
SEm±	4.16	0.308	11.92	0.399
CD (5%)	15.23	1.13	43.69	1.460
Interactions				
V ₁ x Irrigated	306.89	4.33	775.83	137.11
V ₁ x Semi irrigated	261.36	3.67	669.67	120.77
V ₁ x Rainfed	243.88	4.22	630.00	107.00
V ₂ x Irrigated	251.88	3.67	782.83	125.77
V ₂ x Semi irrigated	229.03	4.56	703.31	120.44
V ₂ x Rainfed	213.76	3.33	642.00	118.11
V ₃ x Irrigated	364.53	4.22	776.27	132.88
V ₃ x Semi irrigated	292.30	4.22	709.50	125.11
V ₃ x Rainfed	278.12	3.78	629.37	121.33
V ₄ x Irrigated	288.72	3.78	741.02	118.55
V ₄ x Semi irrigated	264.83	5.22	669.16	112.33
V ₄ x Rainfed	251.08	3.78	646.23	129.55
V ₅ x Irrigated	338.94	4.44	862.42	144.77
V ₅ x Semi irrigated	296.61	3.67	766.78	136.22
V ₅ x Rainfed	263.84	4.11	697.81	119.77
V ₆ x Irrigated	246.50	4.67	593.26	79.55
V ₆ x Semi irrigated	202.77	4.56	480.67	62.44
V ₆ x Rainfed	194.48	3.89	454.63	59.11
V ₇ x Irrigated	422.71	5.00	736.52	110.22
V ₇ x Semi irrigated	317.40	4.33	669.85	97.55
V ₇ x Rainfed	291.22	3.67	619.52	94.44
V ₈ x Irrigated	310.88	3.56	845.30	126.55
V ₈ x Semi irrigated	277.14	3.89	759.87	122.55
V ₈ x Rainfed	250.22	3.56	675.15	123.11
V ₉ x Irrigated	275.54	4.44	730.49	133.44
V ₉ x Semi irrigated	227.18	4.00	697.33	116.33
V ₉ x Rainfed	234.48	3.67	620.70	118.89
SEm±	4.98	0.469	16.98	0.601
CD (5%)	12.57	1.18	42.88	1.517

4.1.6 Spikelets dry weight (g)/panicle

Table 4.3 and Figure 6, revealed that the no. of spikelets dry wt. (g) per panicle was significantly affected by irrigation factors and varieties as well as by their interaction.

The spikelets dry wt. (g) was differed significantly due to the irrigation factors and varieties as well as by their interaction. The spikelets dry weight (g) per panicle ranged between 4.45 to 10.94.

The irrigation factors significantly affected spikelets dry weight (g) per panicle at maturity stage. Significantly maximum spikelets dry weight (7.80) was recorded under irrigated conditions followed by rainfed (6.33) and semi irrigated (6.22) conditions.

The rice varieties also differed significantly among themselves in spikelets dry weight (g) per panicle at maturity. Variety V₉ recorded highest spikelets dry weight (8.47) significantly followed by varieties V₅ (8.11) and V₃ (7.53) at maturity stage.

The interaction of irrigation factors and paddy varieties also influenced spikelets dry weight (g) per panicle significantly variety V₉ (10.94) under irrigated conditions exhibited significantly maximum spikelets dry weight and minimum in variety V₇ (4.45) under rainfed conditions at maturity stage.

4.1.7 Seed yield (kg/ha)

Table 4.3 and Figure 5 observed that the seed yield (kg/ha) was significantly affected by irrigation factors and varieties as well as by their interaction.

Seed yield (kg) per ha was differed significantly due to the irrigation factors and varieties as well as by their interaction. The seed yield (kg/ha) ranged between 1153.06 to 3108.16.

The irrigation factors significantly affected seed yield (kg/ha) of rice varieties. Significantly maximum seed yield (2456.85) was noted under irrigated conditions followed by semi irrigated (2127.24) and rainfed (1865.02) conditions.

The rice varieties were significantly different in their seed yield (kg/ha). Variety V₅ recorded maximum seed yield (2759.68) significantly followed by V₄ (2617.69) and V₉ (2469.16) varieties.

The interaction of irrigation factors and paddy varieties also influenced seed yield significantly variety V₅ (3108.16) under irrigated conditions exhibited significantly maximum seed yield and minimum in variety V₆ (1153.06) under rainfed conditions.

4.1.8 Biological yield (kg/ha)

Table 4.3 and Figure 5 revealed that the biological yield (kg/ha) was significantly affected by irrigation factors and varieties as well as by their interaction.

The biological yield (kg/ha) was differed significantly due to the irrigation factors and varieties as well as by their interaction. The biological yield ranged between 5578.23 to 11020 kg per ha.

The irrigation factors significantly affected biological yield (kg/ha) of rice varieties. Significantly maximum biological yield (9123.37) was obtained under irrigated conditions followed by semi irrigated (7629.27) and rainfed (7363.91) conditions.

The rice varieties also obtained significantly among themselves in their biological yield (kg/ha). Variety V₈ recorded maximum biological yield (9841.27) significantly followed by varieties V₅ (9320.18) and V₄ (8874.18).

The interaction of irrigation factors and paddy varieties also influenced biological yield (kg/ha) significantly variety V₅ (11020.41) under irrigated conditions exhibited significantly maximum biological yield and minimum in variety V₃ (12.04) under rainfed conditions.

4.1.9 Harvest Index (%)

Table 4.3 and Figure 6 found that the harvest index (%) was significantly affected by irrigation factors and varieties as well as by their interaction.

The harvest index was differed significantly due to the irrigation factors and varieties as well as by their interaction. The harvest index ranged between 12.04 to 41.20.

The irrigation factors significantly affected harvest index of rice varieties. Significantly maximum harvest index (27.58) was noted under semi irrigated conditions followed by irrigated (27.06) and rainfed (21.38) conditions.

The rice varieties also differed significantly among themselves in their harvest index. Variety V_3 expressed maximum harvest index (35.18) significantly followed by varieties V_4 (31.34) and V_9 (30.40).

The interaction of irrigation factors and paddy varieties also influenced harvest index significantly variety V_3 (41.20) under irrigated conditions exhibited significantly maximum harvest index and minimum in variety V_7 (12.04) under rainfed conditions.

4.1.10 Seed index (1000 seeds weight) (g)

Table 4.3 and Figure 6 showed that the seed index was significantly affected by irrigation factors and varieties as well as by their interaction.

The seed index was differed significantly due to the irrigation factors and varieties as well as by their interaction. The seed index ranged between 13.17 to 31.09.

The irrigation factors significantly affected seed index of rice varieties. Significantly maximum seed index (23.33) was noted under irrigated conditions followed by semi irrigated (22.18) and rainfed (20.98) conditions.

The rice varieties also expressed significantly among themselves in their seed index. Variety V_9 recorded maximum seed index (29.78) significantly followed by varieties V_8 (25.08) and V_4 (24.84).

The interaction of irrigation factors and paddy varieties also influenced seed index significantly variety V_9 (31.09) under irrigated conditions exhibited significantly maximum seed index and minimum in variety V_2 (13.17) under rainfed conditions.

Table 4.3 Impact of staggered irrigation factors and varieties on spikelets dry weight (g)/plant, seed yield (kg/ha), biological yield (kg/ha), harvest index (%), seed index /1000 seed weight (g).

	Spikelets dry weight (g)/panicle	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Seed index
Main treatments (Irrigation factors)					
Irrigated	7.80	2456.85	9123.37	27.06	23.331
Semi irrigated	6.22	2127.24	7629.27	27.58	22.188
Rainfed	6.33	1865.02	7363.91	21.38	20.980
SEm±	0.088	15.459	150.51	0.291	0.196
CD 5%	0.862	151.82	1478.16	2.86	1.929
Sub treatments (Varieties)					
V ₁ (JGL-3844)	6.43	1863.94	6813.83	24.30	14.29
V ₂ (WGL-32100)	6.09	1990.93	7318.26	26.89	14.27
V ₃ (IR-36)	7.53	2441.14	6984.13	35.18	23.69
V ₄ (IR-64)	7.24	2617.69	8874.18	31.34	24.84
V ₅ (Kranti)	8.11	2759.68	9320.18	22.33	24.15
V ₆ (PS-4)	5.03	1384.35	7997.00	17.44	23.60
V ₇ (PS-5)	5.35	1573.95	6949.83	18.72	19.79
V ₈ (MR-219)	6.79	2246.48	9841.27	21.47	25.08
V ₉ (Mahamaya)	8.47	2469.16	8250.98	30.40	29.78
SEm±	0.108	41.359	149.559	0.488	0.270
CD 5%	0.395	151.549	548.017	1.789	0.988
Interactions					
V ₁ x Irrigated	8.35	2511.56	8196.60	30.63	15.27
V ₁ x Semi irrigated	5.76	1678.91	6394.56	27.42	14.13
V ₁ x Rainfed	5.17	1401.36	5850.34	14.85	13.48
V ₂ x Irrigated	6.40	2378.23	8435.34	28.03	15.12
V ₂ x Semi irrigated	5.62	2125.17	6666.67	30.90	14.52
V ₂ x Rainfed	6.24	1469.39	6852.76	21.73	13.17
V ₃ x Irrigated	8.54	2609.52	8979.59	29.30	24.71
V ₃ x Semi irrigated	7.38	2422.72	6394.56	35.05	23.40
V ₃ x Rainfed	6.67	2291.16	5578.23	41.20	22.95
V ₄ x Irrigated	7.89	2651.02	9523.81	30.27	25.63
V ₄ x Semi irrigated	6.49	2619.73	8935.46	31.93	24.40
V ₄ x Rainfed	7.35	2582.31	8163.27	31.80	24.48
V ₅ x Irrigated	9.72	3108.16	11020.41	27.31	27.12
V ₅ x Semi irrigated	6.96	2740.82	9115.65	26.94	24.82
V ₅ x Rainfed	7.64	2430.07	7824.49	12.74	20.51
V ₆ x Irrigated	5.45	1561.91	8208.68	19.42	24.58
V ₆ x Semi irrigated	4.97	1438.09	7755.10	19.43	23.38
V ₆ x Rainfed	4.68	1153.06	8027.21	13.47	22.84
V ₇ x Irrigated	5.65	1868.79	8027.03	24.03	20.37
V ₇ x Semi irrigated	5.94	1370.75	6938.78	20.08	19.76
V ₇ x Rainfed	4.45	1482.31	5883.68	12.04	19.24
V ₈ x Irrigated	7.26	2736.73	10340.14	25.46	26.09
V ₈ x Semi irrigated	6.13	2326.53	9659.86	21.32	25.80
V ₈ x Rainfed	6.99	1676.19	9523.81	17.63	23.36
V ₉ x Irrigated	10.94	2685.71	9378.76	29.09	31.09
V ₉ x Semi irrigated	6.73	2422.45	6802.76	35.15	29.48
V ₉ x Rainfed	7.74	2299.32	8571.43	26.97	28.78
SEm±	0.150	37.537	238.097	0.644	0.389
CD 5%	0.379	94.783	601.214	1.626	0.982

4.2. Functional attributes (growth analysis)

4.2.1. Leaf Area Index (LAI)

Table 4.4 and Figure 7 revealed that the LAI was significantly affected by irrigation factors and varieties as well as by their interaction during crop growth period. The LAI ranged between 0.515 to 0.831 (30-45 DAS), 0.98 to 1.65 (45-60 DAS), 2.26 to 3.68 (60-75 DAS), 3.76 to 6.06 (75-90 DAS), (3.84) to 6.38 (90-105 DAS) and 2.63 to 4.98 (105-120 DAS).

The irrigation factors significantly affected LAI at all stages of rice varieties. At 30-45 DAS maximum LAI was noted under irrigated condition (0.684) significantly followed by semi irrigated (0.637) and rainfed (0.589) conditions while at 45-60 DAS under irrigated condition maximum LAI was measured (1.35) significantly followed by semi irrigated (1.22) and rainfed (1.11) conditions while at 60-75 DAS under irrigated condition maximum LAI was measured (3.12) significantly followed by semi irrigated (2.78) and rainfed (2.60) conditions while at 75-90 DAS under irrigated condition maximum LAI was measured (5.37) significantly followed by semi irrigated (4.71) and rainfed (4.35) conditions while at 90-105 DAS under irrigated condition maximum LAI was found (5.61) significantly followed by semi irrigated (4.92) and rainfed (4.43) conditions and at 105-120 DAS under irrigated condition maximum LAI was measured (4.17) significantly followed by semi irrigated (3.70) and rainfed (3.23) conditions.

The rice varieties also differed significantly variation among themselves in relation to their LAI at crop growth stages. Variety V₅ recorded maximum LAI (0.721) significantly followed by varieties V₈ (0.701) and V₉ (0.666) at 30-45 DAS. Similar trend was obtained at 45-60 DAS variety V₉ (1.40) measured significantly maximum LAI followed by varieties V₈ (1.38) and V₅ (1.34) and at 60-75 DAS varieties V₅ and V₉ (3.19) observed significantly maximum LAI followed by V₈ (3.08) and V₃ (2.88) and at 75-90 DAS V₅ (5.50) measured significantly maximum LAI followed by varieties V₉ (5.27) and V₈ (5.20) and at 90-105 DAS variety V₅ (5.67) noted significantly maximum LAI followed by varieties V₈ (5.38) and V₉ (5.34) and 105-120 DAS variety V₅ (4.23) expressed significantly followed by varieties V₈ (4.16) and V₃ (3.93).

Table 4.4 Impact of staggered irrigation factors and varieties on LAI

	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	105-120 DAS
Main treatments (Irrigation factors)						
Irrigated	0.684	1.35	3.12	5.37	5.61	4.17
Semi irrigated	0.637	1.22	2.78	4.71	4.92	3.70
Rainfed	0.589	1.11	2.60	4.35	4.43	3.23
SEm±	0.003	0.003	0.007	0.011	0.010	0.015
CD 5%	0.028	0.033	0.072	0.106	0.096	0.149
Sub treatments (varieties)						
V ₁ (JGL-3844)	0.608	1.22	2.68	4.46	4.67	3.45
V ₂ (WGL-32100)	0.589	1.04	2.62	4.50	4.61	3.39
V ₃ (IR-36)	0.621	1.20	2.88	4.95	5.18	3.93
V ₄ (IR-64)	0.645	1.20	2.79	4.70	4.87	3.68
V ₅ (Kranti)	0.721	1.34	3.19	5.50	5.67	4.23
V ₆ (PS-4)	0.568	1.06	2.43	4.26	4.49	3.23
V ₇ (PS-5)	0.611	1.19	2.62	4.47	4.67	3.34
V ₈ (MR-219)	0.701	1.38	3.08	5.20	5.38	4.16
V ₉ (Mahamaya)	0.666	1.40	3.19	5.27	5.34	3.91
SEm±	0.007	0.012	0.020	0.028	0.032	0.027
CD 5%	0.024	0.044	0.074	0.101	0.116	0.100
Interactions						
V ₁ x Irrigated	0.641	1.24	2.65	4.58	4.89	3.69
V ₁ x Semi irrigated	0.572	1.25	2.81	4.49	4.70	3.60
V ₁ x Rainfed	0.611	1.18	2.58	4.31	4.41	3.05
V ₂ x Irrigated	0.611	1.09	2.84	5.18	5.40	3.86
V ₂ x Semi irrigated	0.577	0.99	2.27	3.85	4.16	3.22
V ₂ x Rainfed	0.580	1.04	2.76	4.46	4.58	3.09
V ₃ x Irrigated	0.703	1.37	3.32	5.80	6.12	4.65
V ₃ x Semi irrigated	0.608	1.20	2.79	4.75	4.97	3.85
V ₃ x Rainfed	0.551	1.03	2.53	4.30	4.47	3.28
V ₄ x Irrigated	0.679	1.29	3.13	5.44	5.59	4.11
V ₄ x Semi irrigated	0.678	1.25	2.85	4.75	4.90	3.78
V ₄ x Rainfed	0.580	1.07	2.39	3.91	4.11	3.14
V ₅ x Irrigated	0.831	1.46	3.45	5.98	6.32	4.82
V ₅ x Semi irrigated	0.690	1.29	3.04	5.19	5.33	4.18
V ₅ x Rainfed	0.643	1.26	3.07	5.34	5.37	3.70
V ₆ x Irrigated	0.553	1.01	2.43	4.37	4.53	3.31
V ₆ x Semi irrigated	0.578	1.10	2.60	4.58	4.91	3.41
V ₆ x Rainfed	0.574	1.06	2.27	3.83	4.04	2.98
V ₇ x Irrigated	0.682	1.44	3.05	5.32	5.63	3.98
V ₇ x Semi irrigated	0.636	1.15	2.54	4.34	4.54	3.41
V ₇ x Rainfed	0.515	0.98	2.26	3.76	3.84	2.63
V ₈ x Irrigated	0.752	1.65	3.68	6.06	6.38	4.98
V ₈ x Semi irrigated	0.716	1.36	2.95	5.07	5.22	3.92
V ₈ x Rainfed	0.636	1.13	2.62	4.47	4.53	3.59
V ₉ x Irrigated	0.707	1.57	3.49	5.63	5.68	4.18
V ₉ x Semi irrigated	0.679	1.37	3.13	5.40	5.59	3.95
V ₉ x Rainfed	0.611	1.27	2.94	4.78	4.87	3.58

SEm±	0.008	0.017	0.027	0.034	0.040	0.033
CD 5%	0.021	0.042	0.068	0.086	0.101	0.083

The interaction of irrigation factors and paddy varieties also influenced LAI significantly at crop growth stages. At 30-45 DAS variety V₅ under irrigated condition (0.831) exhibited significantly maximum LAI and minimum in variety V₇ under rainfed condition (0.515) while at 45-60 DAS variety V₈ (1.65) noted maximum LAI under irrigated condition and minimum obtained variety V₇ (0.98) under rainfed conditions while at 60-75 DAS variety V₈ (3.68) noted maximum LAI under irrigated condition and minimum obtained in variety V₇ (2.26) under rainfed conditions while at 75 -90 DAS variety V₈ (6.06) noted maximum LAI under irrigated condition and minimum obtained in variety V₇ (3.76) under rainfed conditions while at 90-105 DAS variety V₈ (6.38) noted maximum LAI under irrigated condition and minimum found in variety V₇ (3.84) under rainfed conditions and at 105-120 DAS variety V₈ (4.98) noted maximum LAI under irrigated condition and minimum expressed in variety V₇ (2.63) under rainfed conditions.

4.2.2 Leaf Area Duration (LAD) (m². day)

Table 4.5 and Figure 8 revealed that the LAD was significantly affected by irrigation factors and varieties as well as by their interaction during crop growth period. The LAD ranged between 8.99 to 15.00 (30-45 DAS), 15.68 to 30.41 (45-60 DAS), 35.59 to 67.71 (60-75 DAS), 60.00 to 111.41 (75-90 DAS), 61.73 to 117.41 (90-105 DAS) and 42.28 to 91.69 (105-120 DAS).

The irrigation factors significantly affected LAD at all stages of rice varieties. At 30-45 DAS maximum LAD was noted under irrigated condition (12.86) significantly followed by semi irrigated (10.83) and rainfed (9.74) conditions while at 45-60 DAS under irrigated condition maximum LAD was measured (25.31) significantly followed by semi irrigated (20.65) and rainfed (18.40) conditions while at 60-75 DAS under irrigated condition maximum LAD was measured (58.52) significantly followed by semi irrigated (47.13) and rainfed (43.05) conditions while at 75-90 DAS under irrigated condition maximum LAD was measured (100.94) significantly followed by semi irrigated

(80.04) and rainfed (71.96) conditions while at 90-105 DAS under irrigated condition maximum LAD was found (105.40) significantly followed by semi irrigated (83.62) and rainfed (73.22) conditions and at 105-120 DAS under irrigated condition maximum LAD was measured (78.39) significantly followed by semi irrigated (62.91) and rainfed (53.44) conditions.

The rice varieties also differed significantly variation among themselves in relation to their LAD at crop growth stages. Variety V₅ recorded maximum LAD (12.52) significantly followed by varieties V₈ (12.07) and V₄ (11.81) at 30-45 DAS. Similar trend was obtained at 45-60 DAS variety V₉ (24.21) measured significantly maximum LAD followed by varieties V₈ (23.93) and V₅ (23.20) and at 60-75 DAS V₅ (55.22) observed significantly maximum LAD followed by varieties V₉ (54.89) and V₈ (53.32) and at 75-90 DAS variety V₅ (95.28) measured significantly maximum LAD followed by varieties V₉ (90.74) and V₃ (90.39) and at 90-105 DAS variety V₅ (98.33) noted significantly maximum LAD followed by varieties V₃ (94.61) and V₈ (93.01) and at 105-120 DAS variety V₅ (73.44) expressed significantly followed by varieties V₈ (72.00) and V₃ (71.68).

The interaction of irrigation factors and paddy varieties also influenced LAD significantly at crop growth stages. At 30-45 DAS variety V₅ under irrigated condition (15.00) exhibited significantly maximum LAD and minimum in variety V₆ under rainfed condition (8.99) while at 45-60 DAS variety V₈ (30.41) noted maximum LAD under irrigated condition and minimum obtained variety V₇ (15.68) under rainfed conditions while at 60-75 DAS variety V₈ (67.71) noted maximum LAD under irrigated condition and minimum obtained in variety V₆ (35.69) under rainfed conditions while at 75 -90 DAS variety V₈ (111.41) noted maximum LAD under irrigated condition and minimum obtained in variety V₆ (60.00) under rainfed conditions while at 90-105 DAS variety V₈ (117.41) noted maximum LAD under irrigated condition and minimum obtained in variety V₇ (61.73) under rainfed conditions and at 105-120 DAS variety V₈ (91.69) noted maximum LAD under irrigated condition and minimum obtained in variety V₇ (42.28) under rainfed conditions.

**Table 4.5 Impact of staggered irrigation factors and varieties on LAD
(m².day)**

	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	105-120 DAS
Main treatments (Irrigation factors)						
Irrigated	12.86	25.31	58.52	100.94	105.40	78.39
Semi irrigated	10.83	20.65	47.13	80.04	83.62	62.91
Rainfed	9.74	18.40	43.05	71.96	73.22	53.44
SEm±	0.073	0.146	0.356	0.571	0.47	0.291
CD 5%	0.712	1.43	3.49	5.61	4.60	2.86
Sub treatments (Varieties)						
V ₁ (JGL-3844)	10.68	21.40	46.86	78.20	82.00	60.59
V ₂ (WGL-32100)	10.37	18.26	46.17	79.27	81.42	59.81
V ₃ (IR-36)	11.32	21.90	52.56	90.39	94.61	71.68
V ₄ (IR-64)	11.81	22.02	51.10	86.22	89.22	67.40
V ₅ (Kranti)	12.52	23.20	55.22	95.28	98.33	73.44
V ₆ (PS-4)	9.70	18.00	41.62	73.02	76.97	55.42
V ₇ (PS-5)	10.33	20.19	44.40	75.91	79.31	56.62
V ₈ (MR-219)	12.07	23.93	53.32	89.79	93.01	72.00
V ₉ (Mahamaya)	11.48	24.21	54.89	90.74	91.84	67.25
SEm±	0.169	0.291	0.729	1.22	1.23	0.900
CD 5%	0.619	1.07	2.67	4.48	4.51	3.30
Interactions						
V ₁ x Irrigated	12.67	24.50	52.37	90.56	96.74	72.89
V ₁ x Semi irrigated	9.37	20.42	45.92	73.52	77.02	58.93
V ₁ x Rainfed	10.00	19.27	42.29	70.52	72.25	49.95
V ₂ x Irrigated	11.28	20.19	52.44	95.71	99.64	71.27
V ₂ x Semi irrigated	10.05	17.15	39.54	66.97	72.43	56.00
V ₂ x Rainfed	9.77	17.45	46.53	75.13	72.18	52.16
V ₃ x Irrigated	13.39	26.17	63.38	110.60	116.57	88.53
V ₃ x Semi irrigated	10.97	21.56	50.31	85.73	89.56	69.36
V ₃ x Rainfed	9.59	17.96	43.99	74.84	77.69	57.15
V ₄ x Irrigated	13.04	24.77	60.14	104.56	107.33	78.97
V ₄ x Semi irrigated	12.06	22.26	50.68	84.51	87.14	67.30
V ₄ x Rainfed	10.32	19.02	42.47	69.58	73.20	55.93
V ₅ x Irrigated	15.00	26.44	62.33	107.88	114.05	86.93
V ₅ x Semi irrigated	11.92	22.27	52.49	89.67	92.15	72.27
V ₅ x Rainfed	10.64	20.89	50.84	88.28	88.80	61.12
V ₆ x Irrigated	10.73	19.54	47.13	84.79	88.01	64.24
V ₆ x Semi irrigated	9.38	17.76	42.14	74.28	79.59	55.25
V ₆ x Rainfed	8.99	16.69	35.59	60.00	63.31	46.77
V ₇ x Irrigated	12.49	26.35	55.97	97.66	103.28	72.83
V ₇ x Semi irrigated	10.22	18.53	40.86	69.74	72.91	54.73
V ₇ x Rainfed	8.28	15.68	36.37	60.35	61.73	42.28
V ₈ x Irrigated	13.83	30.41	67.71	111.41	117.41	91.69
V ₈ x Semi irrigated	12.12	23.10	49.98	85.82	88.45	66.32
V ₈ x Rainfed	10.26	18.28	42.27	72.14	73.17	57.98
V ₉ x Irrigated	13.27	29.46	65.25	105.28	105.55	78.17
V ₉ x Semi irrigated	11.35	22.81	52.28	90.16	93.34	66.02
V ₉ x Rainfed	9.82	20.36	47.15	76.79	76.64	57.58
SEm±	0.208	0.459	0.842	1.31	1.36	0.919
CD 5%	0.526	1.16	2.12	3.31	3.43	2.32

4.2.3 Specific Leaf Area (SLA) (cm²/g)

Table 4.6 and Figure 9 revealed that the SLA was significantly affected by irrigation factors and varieties as well as by their interaction during crop growth period. The SLA ranged between 43.06 to 62.86 (30-45 DAS), 39.60 to 72.70 (45-60 DAS), 51.15 to 92.07 (60-75 DAS), 64.60 to 101.14 (75-90 DAS), 60.23 to 90.51 (90-105 DAS) and 54.73 to 83.06 (105-120 DAS).

The irrigation factors significantly affected SLA at all stages of rice varieties. At 30-45 DAS maximum SLA was noted under irrigated condition (51.42) significantly followed by rainfed (49.85) and semi irrigated (49.73) conditions while at 45-60 DAS under rainfed condition maximum SLA was measured (61.41) significantly followed by irrigated (59.02) and semi irrigated (58.31) conditions while at 60-75 DAS under rainfed condition maximum SLA was measured (73.62) significantly followed by irrigated (71.28) and semi irrigated (70.06) conditions while at 75-90 DAS under rainfed condition maximum SLA was measured (82.21) significantly followed by irrigated (81.16) and semi irrigated (78.33) conditions while at 90-105 DAS under irrigated condition maximum SLA was found (75.38) significantly followed by rainfed (74.12) and semi irrigated (73.67) conditions and at 105-120 DAS under irrigated condition maximum SLA was measured (67.53) significantly followed by rainfed (67.10) and semi irrigated (64.86) conditions.

The rice varieties also differed significantly variation among themselves in relation to their SLA at crop growth stages. Variety V₂ recorded maximum SLA (54.31) significantly followed by varieties V₁ (52.90) and V₆ (52.79) at 30-45 DAS. Similar trend was obtained at 45-60 DAS variety V₁ (67.30) measured significantly maximum SLA followed by varieties V₂ (67.06) and V₆ (64.44) and at 60-75 DAS variety V₁ (84.79) observed significantly maximum SLA followed by varieties V₆ (83.10) and V₂ (82.55) and at 75-90 DAS variety V₆ (92.67) measured significantly maximum SLA followed by varieties V₁ (90.08) and V₂ (87.46) and at 90-105 DAS variety V₆ (84.29) noted

significantly maximum SLA followed by varieties V₁ (83.69) and V₂ (79.50) and 105-120 DAS variety V₁ (78.50) expressed significantly followed by varieties V₆ (72.24) and V₂ (70.05).

Table 4.6 Impact of staggered irrigation factors and varieties on SLA (cm²/g)

	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	105-120 DAS
Main treatments (Irrigation factors)						
Irrigated	51.42	59.02	71.28	81.16	75.38	67.53
Semi irrigated	49.73	58.31	70.06	78.33	73.67	67.10
Rainfed	49.85	61.41	73.62	82.21	74.12	64.86
SEm±	0.202	0.136	0.250	0.235	0.440	0.306
CD 5%	1.987	1.340	2.454	2.310	4.323	3.003
Sub treatments (Varieties)						
V ₁ (JGL-3844)	52.90	67.30	84.79	90.08	83.69	78.50
V ₂ (WGL-32100)	54.31	67.06	82.55	87.46	79.50	70.05
V ₃ (IR-36)	49.63	57.01	68.72	78.10	71.37	65.93
V ₄ (IR-64)	50.85	63.14	73.19	83.31	76.29	66.87
V ₅ (Kranti)	46.49	46.02	53.34	68.44	62.63	56.05
V ₆ (PS-4)	52.79	64.44	83.10	92.67	84.29	72.24
V ₇ (PS-5)	50.47	63.58	70.41	76.61	72.84	63.54
V ₈ (MR-219)	50.68	54.81	62.35	68.56	65.33	59.31
V ₉ (Mahamaya)	44.86	52.85	66.42	79.87	73.56	66.00
SEm±	0.383	0.346	0.555	0.438	0.395	0.470
CD 5%	1.404	1.266	2.034	1.604	1.448	1.722
Interactions						
V ₁ x Irrigated	55.77	68.48	79.77	83.89	76.06	71.35
V ₁ x Semi irrigated	47.13	60.73	82.70	91.95	87.64	83.06
V ₁ x Rainfed	55.80	72.70	91.92	94.39	87.36	81.09
V ₂ x Irrigated	62.86	71.76	82.80	86.58	81.09	73.47
V ₂ x Semi irrigated	53.06	60.10	72.77	74.65	71.28	64.65
V ₂ x Rainfed	47.01	69.32	92.07	101.14	86.12	72.02
V ₃ x Irrigated	48.66	56.78	71.11	82.40	78.71	72.21
V ₃ x Semi irrigated	46.58	55.34	70.23	79.99	70.77	64.08
V ₃ x Rainfed	53.65	58.92	64.81	71.92	64.62	61.48
V ₄ x Irrigated	52.59	60.65	71.96	83.95	80.10	71.18
V ₄ x Semi irrigated	51.98	63.20	72.24	78.88	73.84	66.04
V ₄ x Rainfed	47.99	65.58	75.37	87.11	74.95	63.40
V ₅ x Irrigated	43.09	39.60	52.05	69.95	63.75	57.30
V ₅ x Semi irrigated	47.07	44.62	51.15	66.24	61.79	56.12
V ₅ x Rainfed	49.30	53.85	56.81	69.14	62.36	54.73
V ₆ x Irrigated	57.08	60.64	74.44	89.90	76.44	65.91
V ₆ x Semi irrigated	49.76	64.82	86.41	95.20	90.51	77.93
V ₆ x Rainfed	51.53	67.86	88.45	92.91	85.93	72.88
V ₇ x Irrigated	43.06	62.59	73.26	78.25	74.94	67.02
V ₇ x Semi irrigated	55.16	65.41	68.32	74.65	71.76	66.22
V ₇ x Rainfed	53.19	62.76	69.66	76.93	71.81	57.37
V ₈ x Irrigated	52.23	55.84	66.11	73.48	71.76	62.49
V ₈ x Semi irrigated	53.22	57.41	64.02	67.59	64.02	59.75

V ₈ x Rainfed	46.60	51.19	56.94	64.60	60.23	55.69
V ₉ x Irrigated	47.41	54.83	70.00	82.03	75.58	66.86
V ₉ x Semi irrigated	43.62	53.16	62.72	75.84	71.39	66.07
V ₉ x Rainfed	43.56	50.56	66.53	81.72	73.70	65.06
SEm±	0.412	0.488	0.446	0.563	0.604	0.526
CD 5%	1.040	1.233	1.126	1.421	1.525	1.328

The interaction of irrigation factors and paddy varieties also influenced SLA significantly at crop growth stages. At 30-45 DAS variety V₂ under irrigated condition (62.86) exhibited significantly maximum SLA and minimum in variety V₇ under irrigated condition (43.06) while at 45-60 DAS variety V₁ (72.70) noted maximum SLA under rainfed condition and minimum obtained variety V₅ (39.60) under irrigated conditions while at 60-75 DAS cultivar V₂ (92.07) noted maximum SLA under rainfed condition and minimum obtained in V₇ (51.15) under semi irrigated conditions while at 75-90 DAS variety V₂ (101.14) noted maximum SLA under rainfed condition and minimum obtained in variety V₈ (64.60) under rainfed conditions while at 90-105 DAS variety V₆ (90.51) noted maximum SLA under semi irrigated condition and minimum obtained in variety V₈ (60.23) under rainfed conditions and at 105-120 DAS variety V₁ (83.06) noted maximum SLA under semi irrigated condition and minimum obtained in variety V₅ (54.73) under rainfed conditions.

4.2.4 Specific Leaf Weight (SLW) (cm²/g)

Table 4.7 and Figure 10 revealed that the SLW was significantly affected by irrigation factors and varieties as well as by their interaction during crop growth period. The SLW ranged between 0.0168 to 0.0237 (30-45 DAS), 0.0140 to 0.0225 (45-60 DAS), 0.0114 to 0.0436 (60-75 DAS), 0.0106 to 0.0477 (75-90 DAS), 0.0114 to 0.0440 (90-105 DAS) and 0.0182 to 0.0237 (105-120 DAS).

The irrigation factors significantly affected SLW at all stages of rice varieties. At 30-45 DAS maximum SLW was noted under semi irrigated and rainfed condition (0.0206) significantly followed by irrigated (0.0202) conditions while at 45-60 DAS under semi irrigated condition maximum SLW was measured (0.0179) significantly followed by irrigated (0.0173) and rainfed (0.0173) conditions while at 60-75 DAS under rainfed condition maximum SLW was measured (0.0180) significantly followed by semi irrigated (0.0149) and irrigated (0.0148) conditions while at 75-90 DAS under irrigated condition maximum SLW was measured (0.0165) significantly followed by semi irrigated (0.0133) and rainfed (0.0131) conditions while at 90-105 DAS under rainfed

condition maximum SLW was found (0.0226) significantly followed by irrigated (0.0172) and semi irrigated (0.0161) conditions and at 105-120 DAS under rainfed condition maximum SLW was measured (0.0213) significantly followed by semi irrigated (0.0204) and irrigated (0.0199) conditions.

Table 4.7 Impact of staggered sowing dates and varieties on SLW (cm²/g)

	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	105-120 DAS
Main treatments (Irrigation factors)						
Irrigated	0.0202	0.0173	0.0148	0.0165	0.0172	0.0199
Semi irrigated	0.0206	0.0179	0.0149	0.0133	0.0161	0.0204
Rainfed	0.0206	0.0173	0.0180	0.0131	0.0226	0.0213
SEm±	0.00024	0.00012	0.00219	0.00235	0.00380	0.00013
CD 5%	0.00233	0.00115	0.02152	0.02311	0.03732	0.00132
Sub treatments (Varieties)						
V ₁ (JGL-3844)	0.0193	0.0160	0.0120	0.0113	0.0174	0.0189
V ₂ (WGL32100)	0.0193	0.0151	0.0234	0.0239	0.0128	0.0195
V ₃ (IR-36)	0.0204	0.0185	0.0148	0.0133	0.0142	0.0205
V ₄ (IR-64)	0.0198	0.0164	0.0138	0.0131	0.0139	0.0205
V ₅ (Kranti)	0.0221	0.0216	0.0198	0.0145	0.0155	0.0223
V ₆ (PS-4)	0.0197	0.0159	0.0126	0.0110	0.0187	0.0197
V ₇ (PS-5)	0.0205	0.0162	0.0145	0.0140	0.0152	0.0214
V ₈ (MR-219)	0.0206	0.0186	0.0171	0.0147	0.0155	0.0214
V ₉ (Mahamaya)	0.0225	0.0192	0.0152	0.0127	0.0136	0.0205
SEm±	0.00029	0.00044	0.00385	0.00395	0.0115	0.00022
CD 5%	0.00104	0.00163	0.01411	0.01448	0.0423	0.00081
Interactions						
V ₁ x Irrigated	0.0180	0.0149	0.0126	0.0116	0.0184	0.0190
V ₁ x Semi irrigated	0.0218	0.0188	0.0119	0.0112	0.0175	0.0182
V ₁ x Rainfed	0.0180	0.0141	0.0114	0.0110	0.0178	0.0193
V ₂ x Irrigated	0.0168	0.0140	0.0127	0.0477	0.0127	0.0190
V ₂ x Semi irrigated	0.0189	0.0168	0.0139	0.0135	0.0142	0.0203
V ₂ x Rainfed	0.0222	0.0146	0.0436	0.0106	0.0116	0.0194
V ₃ x Irrigated	0.0208	0.0179	0.0144	0.0121	0.0125	0.0189
V ₃ x Semi irrigated	0.0216	0.0191	0.0145	0.0140	0.0148	0.0207
V ₃ x Rainfed	0.0189	0.0186	0.0155	0.0139	0.0154	0.0220
V ₄ x Irrigated	0.0192	0.0166	0.0141	0.0122	0.0126	0.0198
V ₄ x Semi irrigated	0.0195	0.0163	0.0139	0.0127	0.0137	0.0201
V ₄ x Rainfed	0.0208	0.0163	0.0134	0.0144	0.0153	0.0216
V ₅ x Irrigated	0.0234	0.0220	0.0204	0.0144	0.0148	0.0216
V ₅ x Semi irrigated	0.0214	0.0225	0.0202	0.0153	0.0162	0.0222
V ₅ x Rainfed	0.0216	0.0204	0.0188	0.0140	0.0154	0.0230
V ₆ x Irrigated	0.0188	0.0171	0.0145	0.0116	0.0127	0.0203
V ₆ x Semi irrigated	0.0204	0.0159	0.0121	0.0106	0.0440	0.0195
V ₆ x Rainfed	0.0198	0.0147	0.0114	0.0107	0.0114	0.0193
V ₇ x Irrigated	0.0237	0.0168	0.0138	0.0131	0.0137	0.0194
V ₇ x Semi irrigated	0.0184	0.0151	0.0147	0.0139	0.0155	0.0211
V ₇ x Rainfed	0.0193	0.0168	0.0152	0.0150	0.0164	0.0237
V ₈ x Irrigated	0.0200	0.0180	0.0159	0.0136	0.0145	0.0204

V ₈ x Semi irrigated	0.0201	0.0176	0.0173	0.0149	0.0157	0.0214
V ₈ x Rainfed	0.0218	0.0202	0.0179	0.0155	0.0163	0.0225
V ₉ x Irrigated	0.0212	0.0184	0.0145	0.0125	0.0133	0.0206
V ₉ x Semi irrigated	0.0235	0.0189	0.0160	0.0133	0.0137	0.0205
V ₉ x Rainfed	0.0227	0.0202	0.0152	0.0124	0.0136	0.0206
SEm±	0.00044	0.00034	0.00451	0.00497	0.00671	0.00029
CD 5%	0.00111	0.00087	0.01139	0.01256	0.01695	0.00074

The rice varieties also differed significantly variation among themselves relation to their SLW at crop growth stages. Variety V₉ recorded maximum SLW (0.0225) significantly followed by varieties V₅ (0.0221) and V₈ (0.0206) at 30-45 DAS. Similar trend was obtained at 45-60 DAS variety V₅ (0.0216) measured significantly maximum SLW followed by varieties V₉ (0.0192) and V₈ (0.0186) and at 60-75 DAS variety V₂ (0.0234) observed significantly maximum SLW followed by varieties V₅ (0.0198) and V₈ (0.0171) and at 75-90 DAS variety V₂ (0.0239) measured significantly maximum SLW followed by varieties V₈ (0.0147) and V₅ (0.0145) and at 90-105 DAS varieties V₆ (0.0187) noted significantly maximum SLW followed by varieties V₁ (0.0174) and V₅, V₈ (0.0155) and 105-120 DAS variety V₅ (0.0223) expressed significantly followed by varieties V₇ and V₈ (0.0214).

The interaction of irrigation factors and paddy varieties also influenced SLW significantly at crop growth stages. At 30-45 DAS variety V₇ under irrigated condition (0.0237) exhibited significantly maximum SLW and minimum in variety V₂ under irrigated condition (0.0168) while at 45-60 DAS variety V₅ (0.0225) noted maximum SLW under semi irrigated condition and minimum obtained variety V₂ (0.0140) under irrigated conditions while at 60-75 DAS variety V₂ (0.0436) noted maximum SLW under rainfed condition and minimum obtained in variety V₁ (0.0114) under rainfed conditions while at 75 - 90 DAS variety V₂ (0.0477) noted maximum SLW under irrigated condition and minimum obtained in variety V₆ (0.0106) under semi irrigated conditions while at 90-105 DAS variety V₆ (0.0440) noted maximum SLW under semi irrigated condition and minimum obtained in variety V₆ (0.0114) under rainfed conditions and at 105-120 DAS variety V₇ (0.0237) noted maximum SLW under rainfed condition and minimum obtained in variety V₁ (0.0182) under semi irrigated conditions.

4.2.5 Crop Growth Rate (CGR) (g/cm²/day)

Table 4.8 and Figure 11 revealed that the CGR was significantly affected by irrigation factors and varieties as well as by their interaction during

crop growth period. The CGR ranged between 3.83 to 7.86 (30-45 DAS), 6.24 to 19.97 (45-60 DAS), 11.11 to 26.71 (60-75 DAS), 16.89 to 29.92 (75-90 DAS), 13.44 to 22.84 (90-105 DAS) and 11.06 to 21.41 (105-120 DAS).

The irrigation factors significantly affected CGR at all stages of rice varieties. At 30-45 DAS maximum CGR was noted under irrigated condition (5.89) significantly followed by semi irrigated (5.48) and rainfed (5.10) conditions while at 45-60 DAS under irrigated condition maximum CGR was measured (12.57) significantly followed by semi irrigated (10.84) and rainfed (9.28) conditions while at 60-75 DAS under irrigated condition maximum CGR was measured (20.46) significantly followed by semi irrigated (17.53) and rainfed (15.70) conditions while at 75-90 DAS under irrigated condition maximum CGR was measured (24.55) significantly followed by semi irrigated (22.02) and rainfed (20.12) conditions while at 90-105 DAS under irrigated condition maximum CGR was found (19.94) significantly followed by semi irrigated (18.03) and rainfed (17.00) conditions and at 105-120 DAS under irrigated condition maximum CGR was measured (17.43) significantly followed by semi irrigated (15.31) and rainfed (14.62) conditions.

The rice varieties also differed significantly variation among themselves in relation to their CGR at crop growth stages. Variety V₅ recorded maximum CGR (7.14) significantly followed by varieties V₃ (6.53) and V₈ (6.17) at 30-45 DAS. Similar trend was obtained at 45-60 DAS variety V₅ (18.23) measured significantly maximum CGR followed by varieties V₈ (14.78) and V₉ (12.81) and at 60-75 DAS V₅ (22.81) observed significantly maximum CGR followed by varieties V₈ (21.96) and V₃ (20.15) and at 75-90 DAS variety V₅ (27.42) measured significantly maximum CGR followed by varieties V₃ (24.81) and V₈ (24.77) and at 90-105 DAS variety V₉ (21.17) noted significantly maximum CGR followed by varieties V₃ (21.12) and V₅ (20.47) and 105-120 DAS variety V₉ (18.38) expressed significantly followed by varieties V₈ (18.05) and V₅ (17.26).

The interaction of irrigation factors and paddy varieties also influenced CGR significantly at crop growth stages. At 30-45 DAS variety V₅ under irrigated condition (7.86) exhibited significantly maximum CGR and minimum in variety V₂ under rainfed condition (3.83) while at 45-60 DAS variety V₅ (19.97) noted maximum CGR under irrigated condition and minimum obtained variety V₇ (6.24) under rainfed conditions while at 60-75 DAS variety V₅

(26.71) noted maximum CGR under irrigated condition and minimum obtained in variety V₆ (11.11) under rainfed conditions while at 75 -90 DAS variety V₅ (29.92) noted maximum CGR under irrigated condition and minimum noted in variety V₆ (16.89) under rainfed conditions while at 90-105 DAS variety V₃ (22.84) noted maximum CGR under irrigated condition and minimum obtained in variety V₆ (13.44) under rainfed conditions and at 105-120 DAS variety V₈ (21.41) noted maximum CGR under irrigated condition and minimum obtained in variety V₆ (11.06) under rainfed conditions.

Table 4.8 Impact of staggered irrigation factors and varieties on CGR (g/cm²/day)

	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	105-120 DAS
Main treatment Irrigation factors						
Irrigated	5.89	12.57	20.46	24.55	19.94	17.43
Semi irrigated	5.48	10.84	17.53	22.02	18.03	15.31
Rainfed	5.10	9.28	15.70	20.12	17.00	14.62
SEm±	0.056	0.080	0.195	0.168	0.295	0.285
CD 5%	0.550	0.781	1.916	1.645	2.893	2.803
Sub treatment variety (V)						
V ₁ (JGL-3844)	5.30	8.32	16.21	19.00	17.32	14.76
V ₂ (WGL-32100)	4.46	8.76	15.10	20.09	15.67	13.86
V ₃ (IR-36)	6.53	10.63	20.15	24.81	21.12	17.02
V ₄ (IR-64)	5.04	9.83	18.19	21.77	18.82	16.31
V ₅ (Kranti)	7.14	18.23	22.81	27.42	20.47	17.26
V ₆ (PS-4)	4.42	7.65	12.53	19.04	14.45	12.42
V ₇ (PS-5)	4.49	7.08	16.08	19.39	16.12	14.01
V ₈ (MR-219)	6.17	14.78	21.96	24.77	19.80	18.05
V ₉ (Mahamaya)	5.88	12.81	18.02	23.74	21.17	18.38
SEm±	0.205	0.409	0.469	0.505	0.589	0.502
CD 5%	0.752	1.497	1.720	1.850	2.157	1.840
Interaction						
V ₁ x Irrigated	5.75	8.80	18.43	21.65	18.64	16.73
V ₁ x Semi irrigated	5.63	8.47	15.90	18.26	16.87	13.73
V ₁ x Rainfed	4.52	7.70	14.30	17.08	16.44	13.83
V ₂ x Irrigated	4.93	10.21	17.89	21.88	17.39	16.15
V ₂ x Semi irrigated	4.62	8.60	14.45	20.43	15.43	13.53
V ₂ x Rainfed	3.83	7.46	12.96	17.97	14.17	11.90
V ₃ x Irrigated	6.28	11.21	23.24	27.76	22.84	18.30
V ₃ x Semi irrigated	6.82	10.82	19.81	24.50	20.55	15.48
V ₃ x Rainfed	6.49	9.85	17.41	22.19	19.95	17.29
V ₄ x Irrigated	5.15	11.57	20.62	24.22	21.08	18.24
V ₄ x Semi irrigated	5.01	9.36	18.55	21.89	18.32	16.20
V ₄ x Rainfed	4.95	8.56	15.41	19.21	17.07	14.48
V ₅ x Irrigated	7.86	19.97	26.71	29.92	22.18	17.75
V ₅ x Semi irrigated	6.95	18.75	21.60	27.59	20.60	17.62
V ₅ x Rainfed	6.61	15.95	20.12	24.76	18.64	16.42
V ₆ x Irrigated	4.60	9.01	14.34	20.35	15.58	14.28
V ₆ x Semi irrigated	4.35	7.41	12.14	19.89	14.32	11.91

V ₆ x Rainfed	4.31	6.53	11.11	16.89	13.44	11.06
V ₇ x Irrigated	4.72	8.26	17.42	22.16	17.44	16.56
V ₇ x Semi irrigated	4.41	6.74	15.68	18.56	16.59	13.34
V ₇ x Rainfed	4.32	6.24	15.12	17.46	14.33	12.14
V ₈ x Irrigated	7.26	18.59	25.31	27.84	22.70	21.41
V ₈ x Semi irrigated	5.92	15.05	21.01	23.82	19.22	17.34
V ₈ x Rainfed	5.33	10.69	19.58	22.66	17.48	15.40
V ₉ x Irrigated	6.42	15.54	20.15	25.16	21.62	17.46
V ₉ x Semi irrigated	5.65	12.34	18.60	23.21	20.38	18.66
V ₉ x Rainfed	5.56	10.56	15.32	22.86	21.51	19.02
SEm±	0.160	0.360	0.411	0.438	0.432	0.496
CD 5%	0.405	0.910	1.039	1.105	1.091	1.253

4.2.6 Relative Growth Rate (RGR) (g/g/day)

Table 4.9 and Figure 12 revealed that the RGR was significantly affected by irrigation factors and varieties as well as by their interaction during crop growth period. The RGR ranged between 0.030 to 0.062 (30-45 DAS), 0.027 to 0.054 (45-60 DAS), 0.021 to 0.035 (60-75 DAS), 0.014 to 0.024 (75-90 DAS), 0.021 to 0.033 (90-105 DAS) and 0.022 to 0.035 (105-120 DAS).

The irrigation factors significantly affected RGR at all stages of rice varieties. At 30-45 DAS maximum RGR was noted under irrigated and semi irrigated condition (0.045) significantly followed by rainfed (0.044) conditions while at 45-60 DAS under semi irrigated condition maximum RGR was measured (0.037) significantly followed by irrigated (0.035) and rainfed (0.034) conditions while at 60-75 DAS under semi irrigated condition maximum RGR was measured (0.030) significantly followed by rainfed (0.027) and irrigated (0.026) conditions while at 75-90 DAS under irrigated and semi irrigated condition maximum RGR was measured (0.019) significantly followed by rainfed (0.018) conditions while at 90-105 DAS under rainfed condition maximum RGR was found (0.026) significantly followed by semi irrigated (0.025) and irrigated (0.023) conditions and at 105-120 DAS under rainfed condition maximum RGR was measured (0.031) significantly followed by semi irrigated (0.030) and irrigated (0.027) conditions.

The rice varieties also differed significantly variation among themselves in relation to their RGR at crop growth stages. Variety V₁ recorded maximum RGR (0.050) significantly followed by varieties V₃ (0.049) and V₅ (0.048) at 30-45 DAS. Similar trend was obtained at 45-60 DAS variety V₅ (0.041) measured significantly maximum RGR followed by varieties V₁, V₃, V₈ and V₉

(0.037) and at 60-75 DAS variety V₇ (0.034) observed significantly maximum LAD followed by varieties V₅ (0.030) and V₃, V₈, V₉ (0.028) and at 75-90 DAS variety V₅ (0.021) measured significantly maximum RGR followed by varieties V₉ (0.020) and V₂, V₃ (0.019) and at 90-105 DAS variety V₆ (0.026) noted significantly maximum RGR followed by varieties V₂, V₃, and V₅ (0.025) and at 105-120 DAS V₁, and V₆ (0.032) expressed significantly followed by variety V₅ (0.031).

**Table 4.9 Impact of staggered irrigation factors and varieties on RGR
(g/g/day)**

	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	105-120 DAS
Main treatment Irrigation factors						
Irrigated	0.045	0.035	0.026	0.019	0.023	0.027
Semi irrigated	0.045	0.037	0.030	0.019	0.025	0.030
Rainfed	0.044	0.034	0.027	0.018	0.026	0.031
SEm±	0.00022	0.00030	0.00036	0.00047	0.00038	0.00012
CD 5%	0.00213	0.00297	0.00356	0.00465	0.00377	0.00114
Sub treatment variety (V)						
V ₁ (JGL-3844)	0.050	0.037	0.026	0.018	0.024	0.032
V ₂ (WGL-32100)	0.038	0.029	0.023	0.019	0.025	0.030
V ₃ (IR-36)	0.049	0.037	0.028	0.019	0.025	0.029
V ₄ (IR-64)	0.041	0.032	0.024	0.018	0.023	0.028
V ₅ (Kranti)	0.048	0.041	0.030	0.021	0.025	0.031
V ₆ (PS-4)	0.044	0.035	0.026	0.018	0.026	0.032
V ₇ (PS-5)	0.042	0.033	0.034	0.015	0.024	0.029
V ₈ (MR-219)	0.044	0.037	0.028	0.018	0.023	0.027
V ₉ (Mahamaya)	0.044	0.037	0.028	0.020	0.024	0.028
SEm±	0.00050	0.00060	0.00060	0.00081	0.00035	0.00035
CD 5%	0.00181	0.00219	0.00219	0.00297	0.00129	0.00128
Interaction						
V ₁ x Irrigated	0.044	0.027	0.023	0.019	0.023	0.030
V ₁ x Semi irrigated	0.062	0.054	0.033	0.017	0.022	0.032
V ₁ x Rainfed	0.045	0.031	0.024	0.017	0.027	0.033
V ₂ x Irrigated	0.040	0.031	0.024	0.021	0.026	0.029
V ₂ x Semi irrigated	0.045	0.031	0.024	0.019	0.026	0.030
V ₂ x Rainfed	0.030	0.024	0.021	0.016	0.024	0.031
V ₃ x Irrigated	0.047	0.034	0.024	0.019	0.022	0.024
V ₃ x Semi irrigated	0.048	0.034	0.026	0.022	0.029	0.033
V ₃ x Rainfed	0.054	0.042	0.034	0.015	0.023	0.031
V ₄ x Irrigated	0.040	0.032	0.025	0.018	0.022	0.026
V ₄ x Semi irrigated	0.039	0.030	0.023	0.019	0.025	0.027
V ₄ x Rainfed	0.045	0.034	0.025	0.018	0.023	0.029
V ₅ x Irrigated	0.058	0.049	0.035	0.024	0.027	0.032
V ₅ x Semi irrigated	0.046	0.040	0.028	0.020	0.025	0.032
V ₅ x Rainfed	0.041	0.033	0.026	0.018	0.023	0.027
V ₆ x Irrigated	0.045	0.037	0.024	0.014	0.024	0.029
V ₆ x Semi irrigated	0.042	0.033	0.026	0.017	0.022	0.031
V ₆ x Rainfed	0.045	0.034	0.027	0.023	0.033	0.035
V ₇ x Irrigated	0.038	0.029	0.024	0.016	0.021	0.024
V ₇ x Semi irrigated	0.044	0.033	0.047	0.015	0.024	0.030
V ₇ x Rainfed	0.045	0.038	0.032	0.016	0.029	0.032
V ₈ x Irrigated	0.047	0.041	0.032	0.018	0.021	0.022
V ₈ x Semi irrigated	0.041	0.039	0.030	0.021	0.027	0.031
V ₈ x Rainfed	0.044	0.030	0.023	0.016	0.022	0.027
V ₉ x Irrigated	0.044	0.038	0.027	0.020	0.022	0.026
V ₉ x Semi irrigated	0.040	0.036	0.031	0.018	0.021	0.026
V ₉ x Rainfed	0.046	0.038	0.027	0.023	0.028	0.032
SEm±	0.00051	0.00070	0.00086	0.00110	0.00069	0.00040
CD 5%	0.00128	0.00178	0.00216	0.00277	0.00175	0.00101

The interaction of irrigation factors and paddy varieties also influenced RGR significantly at crop growth stages. At 30-45 DAS variety V_1 under semi irrigated condition (0.062) exhibited significantly maximum RGR and minimum in variety V_2 under rainfed condition (0.030) while at 45-60 DAS variety V_1 (0.054) noted maximum RGR under semi irrigated condition and minimum obtained variety V_1 (0.027) under irrigated conditions while at 60-75 DAS variety V_5 (0.035) noted maximum RGR under irrigated condition and minimum obtained in variety V_2 (0.021) under rainfed conditions while at 75-90 DAS variety V_5 (0.024) noted maximum RGR under irrigated condition and minimum obtained in variety V_6 (0.014) under irrigated conditions while at 90-105 DAS variety V_6 (0.033) noted maximum RGR under rainfed condition and minimum obtained in varieties V_7 , V_8 (0.021) and V_9 (0.021) under semi irrigated conditions and at 105-120 DAS variety V_8 (0.035) noted maximum RGR under irrigated condition and minimum obtained in variety V_7 (0.022) under rainfed conditions.

4.3 Physiological attributes

4.3.1 Leaf chlorophyll index (g/m^2)

Table 4.10 and Figure 13 revealed that the leaf chlorophyll index (g/m^2) was significantly affected by irrigation factors and varieties as well as by their interaction.

The leaf chlorophyll index (g/m^2) was expressed significantly due to the irrigation factors and varieties as well as by their interaction. The leaf chlorophyll index (g/m^2) ranged between 41.10 to 48.01 at tillering and 16.58 to 28.31 in flowering stages.

The irrigation factors significantly affected leaf chlorophyll index at both stages of rice varieties. At tillering stage maximum leaf chlorophyll index (g/m^2) was obtained under irrigated condition (43.71) significantly followed by semi irrigated (42.78) and rainfed (42.69) conditions while at flowering stage under irrigated conditions maximum leaf chlorophyll index was measured (23.21) significantly followed by semi irrigated (21.25) and rainfed (21.11) conditions.

The rice varieties also differed significantly among themselves in relation to their leaf chlorophyll index at tillering as well as at flowering stage.

Variety V₉ recorded maximum leaf chlorophyll index (g/m²) (46.39) significantly followed by varieties V₅ (43.82) and V₃ (43.79) at tillering stage. Similar trend was also maintained at flowering stage as variety V₉ (25.41) measured significantly maximum leaf chlorophyll index (g/m²) followed by varieties V₅ (24.95) and V₈ (24.23).

The interaction of irrigation factors and paddy varieties also influenced leaf chlorophyll index (g/m²) significantly at tillering and at flowering stage. At tillering stage variety V₉ under irrigated condition (48.01) exhibited significantly maximum leaf chlorophyll index and minimum in variety V₉ under semi irrigated conditions (41.10) while at flowering stage variety V₉ (28.31) exhibited maximum leaf chlorophyll index (g/m²) under irrigated condition and short statured obtained in variety V₁ (16.58) under rainfed conditions.

4.3.2 Relative leaf water content (RLWC) (%)

Table 4.10 and Figure 13 showed that the RLWC (%) was significantly affected by irrigation factors and varieties as well as by their interaction.

The RLWC (%) was expressed significantly due to the irrigation factors and varieties as well as by their interaction. The RLWC ranged between 76.78% to 91.73% at tillering and 47.18% to 81.19% in flowering stages.

The irrigation factors significantly affected RLWC at both stages of rice varieties. At tillering stage maximum RLWC was obtained under semi irrigated condition (83.84%) significantly followed by irrigated (83.75%) and rainfed (81.35%) conditions while at flowering stage under irrigated condition maximum RLWC was measured (70.06%) significantly followed by semi irrigated (63.20%) and rainfed (57.35%) conditions.

The rice varieties also differed significantly among themselves in relation to their RLWC at tillering as well as at flowering stage. Variety V₅ recorded maximum RLWC (87.74%) significantly followed by varieties V₃ (87.36%) and V₁ (83.67%) at tillering stage. Similar trend was also maintained at flowering stage as variety V₄ (70.21%) measured significantly maximum RLWC followed by varieties V₅ (68.10%) and V₃ (69.81%).

The interaction of irrigation factors and paddy varieties also influenced RLWC significantly at tillering and at flowering stage. At tillering stage variety V₅ under semi irrigated condition (91.73%) expressed significantly maximum RLWC and minimum in variety V₆ under rainfed condition (76.78%) while at flowering stage variety V₃ (81.19%) noted maximum RLWC under irrigated condition and minimum obtained in variety V₆ (47.18) under rainfed conditions.

4.3.3. Water Saturation Deficit (WSD) (%)

Table 4.10 and Figure 13 showed that the WSD was significantly affected by irrigation factors and varieties as well as by their interaction.

The WSD was observed significantly due to the irrigation factors and varieties as well as by their interaction. The WSD ranged between 8.27% to 23.22% at tillering and 18.81% to 52.82% in flowering stages.

The irrigation factors significantly affected WSD at both stages of rice varieties. At tillering stage maximum WSD was obtained under rainfed condition (18.65) significantly followed by irrigated (16.24) and semi irrigated (16.16) conditions while at flowering stage under rainfed condition maximum WSD was measured (42.65) significantly followed by semi irrigated (36.79) and irrigated (29.94) conditions.

The rice varieties also differed significantly among themselves in relation to their WSD at tillering as well as at flowering stage. Variety V₆ recorded maximum WSD (21.80) significantly followed by varieties V₂ (21.63) and V₇ (17.79) at tillering stage. Similar trend was also maintained at flowering stage as variety V₆ (47.90) measured significantly maximum WSD followed by varieties V₂ (43.12) and V₇ (42.29).

The interaction of irrigation factors and paddy varieties also influenced WSD significantly at tillering and at flowering stage. At tillering stage variety V₆ under rainfed condition (23.22) exhibited significantly maximum WSD and minimum in variety V₅ under semi irrigated condition (8.27) while at flowering stage variety V₆ (52.82) noted maximum WSD under rainfed condition and minimum obtained in variety V₃ (18.81) under irrigated conditions.

4.3.4. Drought Susceptibility Index (DSI)

Table 4.10 and Figure 13 revealed that the DSI was significantly affected by irrigation factors and varieties as well as by their interaction.

The DSI was differed significantly due to the irrigation factors and varieties as well as by their interaction. The DSI ranged between 0.087 to 1.91.

The irrigation factors significantly affected DSI of the rice varieties. Significantly maximum DSI (0.923) was recorded under semi irrigated condition followed by rainfed (0.406) and irrigated (0.329) conditions.

The rice varieties also obtained significantly among themselves in their DSI. Variety V₅ recorded maximum DSI (1.168) significantly followed by varieties V₁ (1.128) and V₇ (1.023).

The interaction of irrigation factors and paddy varieties also influenced DSI significantly variety V₁ (1.910) under semi irrigated conditions exhibited significantly maximum DSI and minimum in variety V₄ (0.087) under rainfed conditions.

Table 4.10 Impact of staggered irrigation factors and varieties on Leaf Chlorophyll Index (LCI), Relative Leaf Water Content (RLWC), Water Saturation Deficit (WSD) and Drought Susceptibility Index (DSI).

	LCI (g/m ²)		RLWC (%)		WSD (%)		DSI
	Tillering stage	Flower. stage	Tillering stage	Flower. stage	Tillering stage	Flower. stage	
Main treatments (Irrigation factors)							
Irrigated	43.710	23.216	83.751	70.06	16.24	29.94	0.329
Semi irrigated	42.780	21.322	83.837	63.20	16.16	36.79	0.923
Rainfed	42.690	21.114	81.354	57.35	18.65	42.65	0.406
SEm±	0.280	0.268	0.140	0.066	0.140	0.066	0.020
CD (5%)	2.75	2.63	1.37	0.653	1.375	0.653	0.196
Sub treatments (Varieties)							
V ₁ (JGL3844)	42.220	18.199	83.672	62.75	16.328	37.243	1.128
V ₂ (WGL32100)	42.973	17.851	78.368	56.87	21.632	43.124	0.484
V ₃ (IR-36)	43.793	24.073	87.359	69.81	12.641	30.188	0.145

V ₄ (IR-64)	42.302	21.677	83.318	70.21	16.682	29.784	0.112
V ₅ (Kranti)	43.829	24.952	87.736	68.10	12.264	31.896	1.168
V ₆ (PS-4)	41.304	19.832	78.197	52.10	21.803	47.900	0.394
V ₇ (PS-5)	42.622	20.720	82.208	57.71	17.792	42.290	1.023
V ₈ (MR-219)	42.101	24.239	83.292	67.83	16.708	32.164	0.379
V ₉ (Mahamaya)	46.392	25.411	82.680	66.42	17.320	33.578	0.140
SEm±	0.351	0.330	0.210	0.267	0.210	0.267	0.047
CD (5%)	1.286	1.210	0.768	0.979	0.768	0.979	0.173
Interactions							
V ₁ x Irrigated	42.08	20.26	83.71	69.17	16.29	30.83	0.689
V ₁ x Semi irrigated	42.38	17.76	84.66	62.80	15.34	37.20	1.910
V ₁ x Rainfed	42.20	16.58	82.65	56.30	17.35	43.70	0.784
V ₂ x Irrigated	43.55	18.22	77.03	62.85	22.97	37.15	0.475
V ₂ x Semi irrigated	42.70	17.59	81.24	56.72	18.76	43.28	0.765
V ₂ x Rainfed	42.68	17.74	76.83	51.06	23.17	48.94	0.214
V ₃ x Irrigated	44.62	25.49	89.03	81.19	10.97	18.81	0.105
V ₃ x Semi irrigated	43.69	22.52	85.23	68.27	14.77	31.73	0.226
V ₃ x Rainfed	43.07	24.21	87.82	59.98	12.18	40.02	0.105
V ₄ x Irrigated	43.07	22.39	85.99	74.02	14.01	25.98	0.108
V ₄ x Semi irrigated	41.47	21.82	84.24	69.86	15.76	30.14	0.172
V ₄ x Rainfed	42.37	20.82	79.72	66.76	20.28	33.24	0.087
V ₅ x Irrigated	44.68	27.25	86.28	73.29	13.72	26.71	0.261
V ₅ x Semi irrigated	43.35	24.11	91.73	68.99	8.27	31.01	1.871
V ₅ x Rainfed	43.45	23.50	85.20	62.04	14.80	37.96	1.373
V ₆ x Irrigated	41.31	20.43	79.19	58.41	20.81	41.59	0.195
V ₆ x Semi irrigated	41.10	19.70	78.62	50.71	21.38	49.29	0.661
V ₆ x Rainfed	41.51	19.37	76.78	47.18	23.22	52.82	0.325
V ₇ x Irrigated	42.98	21.62	84.92	66.11	15.08	33.89	0.555
V ₇ x Semi irrigated	42.21	19.51	81.73	58.21	18.27	41.79	1.889
V ₇ x Rainfed	42.67	21.03	79.97	48.81	20.03	51.19	0.627
V ₈ x Irrigated	43.08	24.96	84.60	75.50	15.40	24.50	0.449
V ₈ x Semi irrigated	41.14	24.49	84.12	67.07	15.88	32.93	0.571
V ₈ x Rainfed	42.08	23.26	81.16	60.94	18.84	39.06	0.118
V ₉ x Irrigated	48.01	28.31	83.01	70.00	16.99	30.00	0.162
V ₉ x Semi irrigated	46.98	24.40	82.95	66.21	17.05	33.79	0.239
V ₉ x Rainfed	44.18	23.52	82.07	63.06	17.93	36.94	0.118
SEm±	0.393	0.393	0.320	0.255	0.320	0.255	0.040
CD (5%)	0.992	0.993	0.808	0.643	0.808	0.643	0.102

4.3.5 Photosynthetically Active Radiation (PAR) ($\mu\text{mol}/\text{m}^2/\text{s}$)

Table 4.11 and Figure 14 showed that the PAR absorption was significantly affected by irrigation factors and varieties as well as by their interaction.

The PAR absorption was differed significantly due to the irrigation factors and varieties as well as by their interaction. The PAR absorption ranged between 1199.00 to 1201.00.

The irrigation factors significantly affected PAR absorption at panicle stage. Significantly maximum PAR absorption (1200.07) was obtained under rainfed conditions followed by irrigated (1200.04) and semi irrigated (1200.04) conditions.

The rice varieties also exhibited significantly among themselves in their PAR absorption at panicle stage. Variety V_9 recorded maximum PAR absorption (1200.56) significantly followed by varieties V_6 (1200.22) and V_1 , V_4 and V_7 (1200.11).

The interaction of irrigation factors and paddy varieties also PAR absorption significantly obtained in variety V_7 (1201.00) under semi irrigated conditions exhibited significantly maximum PAR absorption and minimum in variety V_5 (1199.00) under semi irrigated conditions at panicle stage.

4.3.6 Net Photosynthesis ($\mu\text{mol}/\text{m}^2/\text{s}$)

Table 4.11 and Figure 14 showed that the net photosynthesis was significantly affected by irrigation factors and varieties as well as by their interaction.

The net photosynthesis was differed significantly due to the irrigation factors and varieties as well as by their interaction. The net photosynthesis ranged between 34.33 to 55.47.

The irrigation factors significantly affected net photosynthesis at panicle stage. Significantly maximum net photosynthesis (45.93) was obtained under semi irrigated condition followed by irrigated (43.94) and rainfed (41.69) conditions.

The rice varieties also exhibited significantly among themselves in their net photosynthesis at panicle stage. Variety V_9 recorded maximum net

photosynthesis (48.82) significantly followed by varieties V₈ (47.11) and V₇ (45.14).

The interaction of irrigation factors and paddy varieties also net photosynthesis significantly obtained in variety V₉ (55.47) under irrigated conditions exhibited significantly maximum net photosynthesis and minimum in variety V₂ (34.33) under rainfed conditions at panicle stage.

4.3.7 Transpiration Rate (mmol/m²/s)

Table 4.11 and Figure 14 showed that the transpiration rate was significantly affected by irrigation factors and varieties as well as by their interaction.

The transpiration rate was differed significantly due to the irrigation factors and varieties as well as by their interaction. The transpiration rate ranged between 2.35 to 9.34.

The irrigation factors significantly affected transpiration rate at panicle stage. Significantly maximum transpiration rate (5.57) was obtained under rainfed condition followed by irrigated (4.20) and semi irrigated (3.75) conditions.

The rice varieties also exhibited significantly among themselves in their transpiration rate at panicle stage. Variety V₉ recorded maximum transpiration rate (6.01) significantly followed by varieties V₃ (5.88) and V₇ (5.07).

The interaction of irrigation factors and paddy varieties also transpiration rate significantly obtained in variety V₃ (9.34) under rainfed conditions exhibited significantly maximum transpiration rate and minimum in variety V₄ (2.35) under semi irrigated conditions at panicle stage.

4.3.8 Stomatal Conductance (mmol/m²/s)

Table 4.11 and Figure 14 showed that the stomatal conductance was significantly affected by irrigation factors and varieties as well as by their interaction.

The stomatal conductance was differed significantly due to the irrigation factors and varieties as well as by their interaction. The stomatal conductance ranged between 0.36 to 1.10.

The irrigation factors significantly affected stomatal conductance at panicle stage. Significantly maximum stomatal conductance (0.726) was obtained under rainfed condition followed by irrigated (0.532) and semi irrigated (0.467) conditions.

Table 4.11 Impact of staggered irrigation factors and varieties on PAR absorption ($\mu\text{mol}/\text{m}^2/\text{s}$), net photosynthesis ($\mu\text{mol}/\text{m}^2/\text{s}$), transpiration rate ($\text{mmol}/\text{m}^2/\text{s}$), stomatal conductance ($\text{mmol}/\text{m}^2/\text{s}$)

	PAR absorption ($\mu\text{mol}/\text{m}^2/\text{s}$)	Net photosynthesis ($\mu\text{mol}/\text{m}^2/\text{s}$)	Transpiration rate ($\text{mmol}/\text{m}^2/\text{s}$)	Stomatal conductance ($\text{mmol}/\text{m}^2/\text{s}$)
Main treatments (Irrigation factors)				
Irrigated	1200.04	43.94	4.20	0.532
Semi irrigated	1200.04	45.93	3.75	0.467
Rainfed	1200.07	41.69	5.57	0.726
SEm$\pm$	0.252	0.039	0.080	0.004
CD 5%	2.476	0.385	0.789	0.043
Sub treatments (Varieties)				
V ₁ (JGL-3844)	1200.11	44.86	4.48	0.629
V ₂ (WGL-32100)	1199.89	39.12	2.77	0.400
V ₃ (IR-36)	1199.78	40.82	5.88	0.594
V ₄ (IR-64)	1200.11	44.61	3.22	0.501
V ₅ (Kranti)	1199.67	44.76	3.72	0.506
V ₆ (PS-4)	1200.22	39.42	4.40	0.674
V ₇ (PS-5)	1200.11	45.14	5.07	0.579
V ₈ (MR-219)	1200.00	47.11	5.01	0.616
V ₉ (Mahamaya)	1200.56	48.82	6.01	0.676
SEm$\pm$	0.175	0.251	0.119	0.013
CD 5%	0.642	0.921	0.438	0.047
Interactions				
V ₁ x Irrigated	1200.33	45.97	4.13	0.54
V ₁ x Semi irrigated	1200.00	46.93	4.54	0.50
V ₁ x Rainfed	1200.00	41.67	4.78	0.84
V ₂ x Irrigated	1200.00	35.73	2.60	0.38
V ₂ x Semi irrigated	1200.33	47.30	3.11	0.44
V ₂ x Rainfed	1199.33	34.33	2.61	0.38
V ₃ x Irrigated	1199.33	43.17	4.67	0.58
V ₃ x Semi irrigated	1200.33	42.43	3.62	0.49
V ₃ x Rainfed	1199.67	36.87	9.34	0.71
V ₄ x Irrigated	1200.33	37.43	3.08	0.36
V ₄ x Semi irrigated	1199.67	48.17	2.35	0.52
V ₄ x Rainfed	1200.33	48.23	4.23	0.62
V ₅ x Irrigated	1200.00	41.03	4.13	0.53
V ₅ x Semi irrigated	1199.00	46.53	3.38	0.46
V ₅ x Rainfed	1200.00	46.70	3.64	0.53
V ₆ x Irrigated	1200.33	40.53	3.55	0.44
V ₆ x Semi irrigated	1199.67	39.87	4.24	0.49
V ₆ x Rainfed	1200.67	37.87	5.42	1.10
V ₇ x Irrigated	1199.33	45.47	4.58	0.57
V ₇ x Semi irrigated	1201.00	47.83	4.59	0.38
V ₇ x Rainfed	1200.00	42.13	6.05	0.79
V ₈ x Irrigated	1199.67	50.63	4.79	0.55

V ₈ x Semi irrigated	1200.33	47.17	3.64	0.45
V ₈ x Rainfed	1200.00	43.53	6.59	0.85
V ₉ x Irrigated	1201.00	55.47	6.24	0.84
V ₉ x Semi irrigated	1200.00	47.17	4.31	0.48
V ₉ x Rainfed	1200.67	43.83	7.47	0.71
SEm±	0.350	0.317	0.189	0.013
CD 5%	0.883	0.802	0.477	0.032

The rice varieties also exhibited significantly among themselves in their stomatal conductance at panicle stage. Variety V₉ recorded maximum stomatal conductance (0.676) significantly followed by varieties V₆ (0.674) and V₁ (0.629).

The interaction of irrigation factors and paddy varieties also stomatal conductance significantly obtained in variety V₆ (1.10) under rainfed condition exhibited significantly maximum stomatal conductance and minimum in variety V₄ (0.36) under irrigated conditions at panicle stage.

4.4 Other physiological traits

4.4.1 Intercellular CO₂ Concentration (Ci) (μmmol CO₂ mol⁻¹)

Table 4.12 and Figure 15 showed that the Ci was significantly affected by irrigation factors and varieties as well as by their interaction.

The Ci was differed significantly due to the irrigation factors and varieties as well as by their interaction. The Ci ranged between 49.40 to 94.67.

The irrigation factors significantly affected Ci at panicle stage. Significantly maximum Ci (84.69) was obtained under semi irrigated condition followed by irrigated (73.09) and rainfed (63.80) conditions.

The rice varieties also exhibited significantly among themselves in their Ci at panicle stage. V₁ recorded maximum Ci (81.86) significantly followed by varieties V₅ (79.51) and V₉ (74.87).

The interaction of irrigation factors and paddy varieties also Ci significantly obtained in variety V₅ (94.67) under semi irrigated condition exhibited significantly maximum Ci and minimum in variety V₂ (49.40) under rainfed conditions at panicle stage.

4.4.2 Water Use Efficiency (WUE) ($\llcorner\text{mol/mol}$)

Table 4.12 and Figure 15 showed that the WUE was significantly affected by irrigation factors and varieties as well as by their interaction.

The WUE was differed significantly due to the irrigation factors and varieties as well as by their interaction. The WUE ranged between 6.70 to 20.53.

The irrigation factors significantly affected WUE at panicle stage. Significantly maximum WUE (13.00) was obtained under semi irrigated condition followed by irrigated (11.24) and rainfed (8.65) conditions.

The rice varieties also exhibited significantly among themselves in their WUE at panicle stage. Variety V_4 recorded maximum WUE (15.61) significantly followed by varieties V_2 (13.85) and V_5 (11.37).

The interaction of irrigation factors and paddy varieties also WUE significantly obtained in variety V_4 (20.53) under semi irrigated condition exhibited significantly maximum WUE and minimum in variety V_8 (6.70) under rainfed conditions at panicle stage.

4.4.3 Carboxylation Efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1}$)/($\mu\text{mol mol}^{-1}$)

Table 4.12 and Figure 15 showed that the carboxylation efficiency was significantly affected by irrigation factors and varieties as well as by their interaction.

The carboxylation efficiency was differed significantly due to the irrigation factors and varieties as well as by their interaction. The carboxylation efficiency ranged between 0.431 to 0.813.

The irrigation factors significantly affected carboxylation efficiency at panicle stage. Significantly maximum carboxylation efficiency (0.667) was obtained under rainfed condition followed by irrigated (0.608) and semi irrigated (0.546) conditions.

The rice varieties also exhibited significantly among themselves in their carboxylation efficiency at panicle stage. Variety V_7 recorded maximum carboxylation efficiency (0.694) significantly followed by varieties V_9 (0.663) and V_8 (0.642).

The interaction of irrigation factors and paddy varieties also carboxylation efficiency significantly obtained in variety V₇ (0.813) under rainfed condition exhibited significantly maximum carboxylation efficiency and minimum in variety V₂ (0.431) under irrigated condition at panicle stage.

4.4.4 Quantum Use Efficiency (QUE) ($\mu\text{mol m}^{-2} \text{s}^{-1}$)/($\mu\text{mol mol}^{-1}$)

Table 4.12 and Figure 15 showed that the quantum efficiency was significantly affected by irrigation factors and varieties as well as by their interaction.

The quantum efficiency was differed significantly due to the irrigation factors and varieties as well as by their interaction. The quantum efficiency ranged between 0.029 to 0.046.

The irrigation factors significantly affected quantum efficiency at panicle stage. Significantly maximum quantum efficiency (0.038) was obtained under semi irrigated condition followed by irrigated (0.037) and rainfed (0.035) conditions.

The rice varieties also exhibited significantly among themselves in their quantum efficiency at panicle stage. Variety V₉ recorded maximum quantum efficiency (0.041) significantly followed by varieties V₈ (0.039) and V₇ (0.038).

The interaction of irrigation factors and paddy varieties also quantum efficiency significantly obtained in variety V₉ (0.046) under irrigated condition exhibited significantly maximum quantum efficiency and minimum in variety V₂ (0.029) under rainfed conditions at panicle stage.

Table 4.12 Impact of staggered irrigation factors and varieties on Inter cellular CO₂ concentration (Ci), Water Use Efficiency (WUE), Carboxylation Efficiency, Quantum Use Efficiency (QUE).

	Ci (μ mmol CO ₂ mol ⁻¹)	WUE («mol/mol)	Carboxylation Efficiency	QUE
			(μmol m ⁻² s ⁻¹) / (μmol mol ⁻¹)	
Main treatments (Irrigation factors)				
Irrigated	73.09	11.24	0.608	0.037

Semi irrigated	84.69	13.00	0.546	0.038
Rainfed	63.80	8.65	0.667	0.035
SEm±	0.319	0.197	0.0012	0.00004
CD 5%	3.135	1.938	0.0115	0.00039
Sub treatments (Varieties)				
V ₁ (JGL-3844)	81.86	9.95	0.550	0.037
V ₂ (WGL-32100)	73.10	13.85	0.557	0.033
V ₃ (IR-36)	69.92	8.49	0.590	0.034
V ₄ (IR-64)	73.23	15.61	0.625	0.037
V ₅ (Kranti)	79.51	11.37	0.572	0.037
V ₆ (PS-4)	71.39	9.96	0.569	0.033
V ₇ (PS-5)	66.63	9.11	0.694	0.038
V ₈ (MR-219)	74.23	10.94	0.642	0.039
V ₉ (Mahamaya)	74.87	9.39	0.663	0.041
SEm±	0.431	0.277	0.0023	0.00021
CD 5%	1.580	1.014	0.0086	0.00077
Interactions				
V ₁ x Irrigated	75.73	11.18	0.607	0.038
V ₁ x Semi irrigated	87.23	10.37	0.538	0.039
V ₁ x Rainfed	82.60	8.30	0.505	0.035
V ₂ x Irrigated	82.87	13.84	0.431	0.030
V ₂ x Semi irrigated	87.03	14.56	0.544	0.039
V ₂ x Rainfed	49.40	13.15	0.695	0.029
V ₃ x Irrigated	60.87	9.29	0.703	0.036
V ₃ x Semi irrigated	81.23	12.15	0.522	0.035
V ₃ x Rainfed	67.67	4.02	0.545	0.031
V ₄ x Irrigated	84.67	14.83	0.442	0.031
V ₄ x Semi irrigated	72.03	20.53	0.669	0.040
V ₄ x Rainfed	63.00	11.47	0.766	0.040
V ₅ x Irrigated	64.93	9.93	0.632	0.034
V ₅ x Semi irrigated	94.67	13.79	0.492	0.039
V ₅ x Rainfed	78.93	10.38	0.592	0.039
V ₆ x Irrigated	71.57	11.97	0.567	0.034
V ₆ x Semi irrigated	87.10	9.49	0.458	0.033
V ₆ x Rainfed	55.50	8.41	0.682	0.032
V ₇ x Irrigated	67.87	9.93	0.670	0.038
V ₇ x Semi irrigated	80.23	10.45	0.598	0.040
V ₇ x Rainfed	51.80	6.96	0.813	0.035
V ₈ x Irrigated	69.43	11.45	0.726	0.042
V ₈ x Semi irrigated	87.50	14.66	0.539	0.039
V ₈ x Rainfed	65.77	6.70	0.662	0.036

V ₉ x Irrigated	79.90	8.77	0.695	0.046
V ₉ x Semi irrigated	85.17	10.99	0.554	0.039
V ₉ x Rainfed	59.53	8.41	0.740	0.037
SEm±	0.627	0.467	0.0032	0.00026
CD 5%	1.583	1.180	0.0080	0.00067

4.5 Biochemical attributes

4.5.1 Seed nitrogen content (%)

Table 4.13 and Figure 16 revealed that the nitrogen (%) was significantly affected by irrigation factors and varieties as well as by their interaction.

The nitrogen (%) was differed significantly due to the irrigation factors and varieties as well as by their interaction. The nitrogen ranged between 0.437% to 1.29%.

The irrigation factors significantly affected nitrogen (%) of the rice varieties. Significantly maximum nitrogen (0.923%) was recorded under irrigated condition followed by semi irrigated (0.802%) and rainfed (0.696%) conditions.

The rice varieties also obtained significantly among themselves in their nitrogen (%) of the rice crop. Variety V₅ recorded maximum nitrogen (0.958%) significantly followed by varieties V₉ (0.917%) and V₇ (0.913%).

The interaction of irrigation factors and paddy varieties also influenced nitrogen significantly variety V₅ (1.29%) under irrigated conditions exhibited significantly maximum nitrogen and minimum in variety V₁ (0.437%) under rainfed conditions.

4.5.2 Seed protein (%)

Table 4.13 and Figure 16 revealed that the seed protein (%) was significantly affected by irrigation factors and varieties as well as by their interaction.

The seed protein (%) was differed significantly due to the irrigation factors and varieties as well as by their interaction. The seed protein ranged between 2.73% to 7.25%.

The irrigation factors significantly affected seed protein (%) of the rice varieties. Significantly maximum seed protein (6.02%) was recorded under irrigated condition followed by semi irrigated (5.01%) and rainfed (4.35%) conditions.

The rice varieties also obtained significantly among themselves in their seed protein (%) of the rice crop. Variety V₅ recorded maximum seed protein (5.99%) significantly followed by varieties V₉ (5.73%) and V₇ (5.71%).

The interaction of irrigation factors and paddy varieties also influenced seed protein significantly variety V₇ (7.25%) under semi irrigated and variety V₉ (7.25%) under irrigated conditions exhibited significantly maximum seed protein and minimum in variety V₁ (2.73%) under rainfed conditions.

4.5.3 Seed carbohydrate (%)

Table 4.13 and Figure 16 revealed that the seed carbohydrate (%) was significantly affected by irrigation factors and varieties as well as by their interaction.

The seed carbohydrate (%) was differed significantly due to the irrigation factors and varieties as well as by their interaction. The seed carbohydrate ranged between 54.26% to 65.72%.

The irrigation factors significantly affected seed carbohydrate (%) of the rice varieties. Significantly maximum seed carbohydrate (63.67%) was recorded under semi irrigated condition followed by rainfed (62.72%) and irrigated (60.23%) conditions.

The paddy varieties also obtained significantly among themselves in their seed carbohydrate (%) of the rice varieties. V₇, V₈ and V₂ recorded maximum seed carbohydrate (63.67%) significantly followed by varieties V₁, V₃ and V₆ (62.72%).

The interaction of irrigation factors and paddy varieties also influenced seed carbohydrate significantly variety V₉ (65.72%) under irrigated conditions

exhibited significantly maximum seed carbohydrate and minimum in variety V₃ (54.26%) under irrigated conditions.

4.5.4 Leaf proline content (µmol/g)

Table 4.13 and Figure 16 revealed that the leaf proline was significantly affected by irrigation factors and varieties as well as by their interaction.

Table 4.13 Impact of irrigation factors and varieties on Seed nitrogen, Seed protein, Seed carbohydrate and Leaf proline content.

	Nitrogen (%)	Seed protein (%)	Seed Carbohydrate (%)	Leaf proline content (µmol/g)
Main treatments (Irrigation factors)				
Irrigated	0.963	6.02	60.23	0.307
Semi irrigated	0.802	5.01	63.67	0.322
Rainfed	0.696	4.35	62.72	0.343
SEm±	0.002	0.016	0.087	0.067
CD 5%	0.016	0.169	0.851	0.660
Sub treatments (Varieties)				
V ₁ (JGL-3844)	0.578	3.61	62.72	0.491
V ₂ (WGL-32100)	0.740	4.63	63.67	0.447
V ₃ (IR-36)	0.912	5.70	62.72	0.143
V ₄ (IR-64)	0.670	4.19	60.23	0.256
V ₅ (Kranti)	0.958	5.99	60.23	0.480
V ₆ (PS-4)	0.868	5.42	62.72	0.141
V ₇ (PS-5)	0.913	5.71	63.67	0.381
V ₈ (MR-219)	0.824	5.15	63.67	0.360
V ₉ (Mahamaya)	0.917	5.73	60.23	0.218
SEm±	0.003	0.018	0.151	0.077
CD 5%	0.011	0.065	0.553	0.283
Interactions				
V ₁ x Irrigated	0.720	4.50	56.52	0.727
V ₁ x Semi irrigated	0.577	3.60	65.44	0.365
V ₁ x Rainfed	0.437	2.73	61.97	0.379
V ₂ x Irrigated	1.13	7.08	61.64	0.195
V ₂ x Semi irrigated	0.583	3.65	64.17	0.493
V ₂ x Rainfed	0.503	3.15	61.70	0.653
V ₃ x Irrigated	1.01	6.31	54.26	0.136
V ₃ x Semi irrigated	0.863	5.40	61.27	0.181
V ₃ x Rainfed	0.863	5.40	62.21	0.113
V ₄ x Irrigated	0.863	5.40	59.94	0.295
V ₄ x Semi irrigated	0.573	3.58	64.60	0.201
V ₄ x Rainfed	0.573	3.58	64.43	0.271
V ₅ x Irrigated	1.29	8.10	64.45	0.242
V ₅ x Semi irrigated	0.853	5.33	65.40	0.633
V ₅ x Rainfed	0.723	4.52	60.18	0.566
V ₆ x Irrigated	0.740	4.63	54.66	0.107
V ₆ x Semi irrigated	1.01	6.27	65.63	0.174
V ₆ x Rainfed	0.860	5.38	65.40	0.141
V ₇ x Irrigated	0.727	4.54	59.31	0.663
V ₇ x Semi irrigated	1.16	7.25	61.33	0.139

V ₇ x Rainfed	0.853	5.33	61.12	0.341
V ₈ x Irrigated	1.01	6.33	65.56	0.279
V ₈ x Semi irrigated	0.737	4.60	63.44	0.341
V ₈ x Rainfed	0.723	4.52	65.17	0.459
V ₉ x Irrigated	1.16	7.25	65.72	0.117
V ₉ x Semi irrigated	0.867	5.42	61.72	0.372
V ₉ x Rainfed	0.723	4.52	62.26	0.166
SEm±	0.004	0.024	0.191	0.108
CD 5%	0.11	0.061	0.483	0.272

The leaf proline was differed significantly due to the irrigation factors and varieties as well as by their interaction. The leaf proline ranged between (0.107) to (0.727).

The irrigation factors significantly affected leaf proline of the rice varieties. Significantly maximum leaf proline (0.343) was recorded under rainfed condition followed by semi irrigated (0.322) and irrigated (0.307) conditions.

The rice varieties also obtained significantly among themselves in their leaf proline of the rice varieties. V₁ recorded maximum leaf proline (0.491) significantly followed by variety V₅ (0.480) and V₂ (0.447).

The interaction of irrigation factors and paddy varieties also influenced leaf proline significantly variety V₁ (0.727) under irrigated conditions exhibited significantly maximum leaf proline and minimum in variety V₆ (0.107) under irrigated conditions.

4.6 Phenological phases (days after sowing)

4.6.1 Days to tiller initiation

Table 4.14 and Figure 17 revealed that the days to tiller initiation was significantly affected by irrigation factors and varieties as well as by their interaction. The days to tiller initiation ranged between 34.67 to 39.00.

The irrigation factors significantly affected days to tiller initiation of the rice varieties. Significantly maximum days to tiller initiation (36.52) was recorded under irrigated condition followed by rainfed (36.37) and semi irrigated (36.07) conditions.

The rice varieties also obtained significantly among themselves in their days to tiller initiation of the rice varieties. V₆ recorded maximum days to tiller initiation (38.78) significantly followed by varieties V₇ (38.22) and V₁ (37.00).

The interaction of irrigation factors and paddy varieties also influenced days to tiller initiation significantly variety V₆ (39.00) under irrigated, semi irrigated and variety V₇ (39.00) under rainfed conditions exhibited significantly maximum days to tiller initiation and minimum in variety V₄ (34.67) under semi irrigated conditions.

4.6.2 Days to panicle initiation

Table 4.14 and Figure 17 revealed that the days to panicle initiation was significantly affected by irrigation factors and varieties as well as by their interaction. The days to panicle initiation ranged between 55.00 to 74.67.

The irrigation factors significantly affected days to panicle initiation of the rice varieties. A maximum day to panicle initiation (65.70) was recorded under irrigated condition followed by semi irrigated (62.67) and rainfed (61.74) conditions.

The rice varieties also obtained significantly among themselves in their days to panicle initiation of the rice varieties. Variety V₈ recorded maximum days to panicle initiation (74.22) significantly followed by varieties V₉ (67.22) and V₆ (66.78).

The interaction of irrigation factors and paddy varieties also influenced days to panicle initiation variety V₈ (74.67) under irrigated conditions exhibited significantly maximum days to panicle initiation and minimum in variety V₅ (55.00) under rainfed conditions.

4.6.3 Days to 50% panicle

Table 4.14 and Figure 17 revealed that the days to 50% panicles was significantly affected by irrigation factors and varieties as well as by their interaction. The days to 50% panicles ranged between 68.33 to 80.67.

The irrigation factors significantly affected days to 50% panicles of the rice varieties. A maximum days to 50% panicles (75.11) was recorded under

irrigated condition followed by semi irrigated (72.78) and rainfed (72.41) conditions.

The rice varieties also obtained significantly among themselves in their days to 50% panicles of the rice varieties. Variety V₈ recorded maximum days to 50% panicles (77.11) significantly followed by varieties V₁ (75.44) and V₄ (75.11). The interaction of irrigation factors and paddy varieties also influenced days to 50% panicles variety V₈ (80.67) under irrigated conditions exhibited significantly maximum days to 50% panicles and minimum in variety V₂ (68.33) under irrigated conditions.

4.6.4 Days to flower initiation

Table 4.14 and Figure 17 revealed that the days to flower initiation was significantly affected by irrigation factors and varieties as well as by their interaction. The days to flower initiation ranged between 75.00 to 87.00.

The irrigation factors significantly affected days to flower initiation of the rice varieties. A maximum days to flower initiation (82.96) was recorded under irrigated condition followed by semi irrigated (81.11) and rainfed (79.89) conditions.

The rice varieties also obtained significantly among themselves in their days to flower initiation of the rice varieties. Variety V₁ recorded maximum days to flower initiation (85.44) significantly followed by varieties V₇, V₈ (83.22) and V₄ (83.11).

The interaction of irrigation factors and paddy varieties also influenced days to flower initiation variety V₁ (87.00) under irrigated conditions exhibited significantly maximum days to flower initiation and minimum in variety V₃ (75.00) under semi irrigated and rainfed conditions.

4.6.5 Days to 50% flowering

Table 4.14 and Figure 17 revealed that the days to 50% flowering was significantly affected by irrigation factors and varieties as well as by their interaction. The days to 50% flowering ranged between 81.67 to 97.00.

The irrigation factors significantly affected days to 50% flowering of the rice varieties. A maximum days to 50% flowering (91.67) was recorded under

irrigated condition followed by semi irrigated (89.15) and rainfed (87.22) conditions.

The rice varieties also obtained significantly among themselves in their days to 50% flowering of the rice varieties. Variety V_2 recorded maximum days to 50% flowering (93.67) significantly followed by V_1 (93.33) and V_5 (92.22).

The interaction of irrigation factors and paddy varieties also influenced days to 50% flowering variety V_2 (97.00) under irrigated conditions exhibited significantly maximum days to 50% flowering and minimum in variety V_3 (81.67) under rainfed conditions.

4.6.6 Days to physiological maturity

Table 4.14 and Figure 17 revealed that the days to physiological maturity was significantly affected by irrigation factors and varieties as well as by their interaction. The days to physiological maturity ranged between 100.67 to 118.33.

The irrigation factors significantly affected days to physiological maturity of the rice varieties. A maximum days to physiological maturity (112.85) was recorded under irrigated condition followed by semi irrigated (109.30) and rainfed (106.85) conditions.

The rice varieties also obtained significantly among themselves in their days to physiological maturity of the rice varieties. V_7 recorded maximum days to physiological maturity (114.56) significantly followed by varieties V_2 (114.22) and V_9 (112.56).

The interaction of irrigation factors and paddy varieties also influenced days to physiological maturity variety V_2 (118.33) under irrigated conditions exhibited significantly maximum days to 50% flowering and minimum in variety V_3 (100.67) under rainfed conditions.

Table 4.14 Impact of staggered irrigation factors and varieties on phenological phases (days after sowing).

	Days to	Days to	Days to	Days to	Days to	Days to
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	tiller Initiation	panicle initiation	50% Panicle	Flower initiation	50% Flowering	physio. maturity
Main treatments (Irrigation factors)						
Irrigated	36.52	65.70	75.11	82.96	91.67	112.85
Semi irrigated	36.07	62.67	72.78	81.11	89.15	109.30
Rainfed	36.37	61.74	72.41	79.89	87.22	106.85
SEm±	0.206	0.052	0.100	0.145	0.229	0.225
CD 5%	2.020	0.514	0.985	1.424	2.252	2.212
Sub treatments (Varieties)						
V ₁ (JGL-3844)	37.00	64.67	75.44	85.44	93.33	109.00
V ₂ (WGL32100)	35.78	59.22	69.00	81.22	93.67	114.22
V ₃ (IR-36)	35.33	59.11	71.00	75.22	83.33	104.56
V ₄ (IR-64)	35.22	56.67	75.11	83.11	91.11	111.56
V ₅ (Kranti)	35.22	59.22	74.89	81.78	92.22	110.22
V ₆ (PS-4)	38.78	66.78	72.78	80.22	85.89	108.11
V ₇ (PS-5)	38.22	63.22	72.44	83.22	88.89	114.56
V ₈ (MR-219)	35.33	74.22	77.11	83.22	90.33	102.22
V ₉ (Mahamaya)	36.00	67.22	73.11	78.44	85.33	112.56
SEm±	0.214	0.268	0.293	0.286	0.373	0.376
CD 5%	0.783	0.983	1.073	1.047	1.367	1.378
Interactions						
V ₁ x Irrigated	38.00	68.00	78.00	87.00	95.33	111.00
V ₁ x Semi irri.	35.67	64.00	74.67	86.33	94.00	108.00
V ₁ x Rainfed	37.33	62.00	73.67	83.00	90.67	108.00
V ₂ x Irrigated	35.67	60.00	68.33	83.67	97.00	118.33
V ₂ x Semi irri.	36.00	59.00	69.00	81.00	93.67	113.00
V ₂ x Rainfed	35.67	58.67	69.67	79.00	90.33	111.33
V ₃ x Irrigated	35.67	63.00	71.00	75.67	85.33	109.00
V ₃ x Semi irri.	35.00	59.00	71.00	75.00	83.00	104.00
V ₃ x Rainfed	35.33	55.33	71.00	75.00	81.67	100.67
V ₄ x Irrigated	35.00	57.67	77.00	84.33	94.00	116.00
V ₄ x Semi irri.	34.67	56.00	74.67	84.00	90.67	111.67
V ₄ x Rainfed	36.00	56.33	73.67	81.00	88.67	107.00
V ₅ x Irrigated	35.00	65.67	77.00	83.33	94.00	112.33
V ₅ x Semi irri.	35.67	57.00	74.00	81.33	92.00	110.33
V ₅ x Rainfed	35.00	55.00	73.67	80.67	90.67	108.00
V ₆ x Irrigated	39.00	68.33	75.33	81.00	86.67	110.33
V ₆ x Semi irri.	39.00	66.00	71.33	80.33	86.67	109.00
V ₆ x Rainfed	38.33	66.00	71.67	79.33	84.33	105.00

V ₇ x irrigated	38.33	66.00	73.67	84.67	91.33	117.33
V ₇ x Semi irri.	37.33	62.33	71.67	83.33	89.33	114.00
V ₇ x Rainfed	39.00	61.33	72.00	81.67	86.00	112.33
V ₈ x Irrigated	35.67	74.67	80.67	86.33	95.00	104.00
V ₈ x Semi irri.	35.33	73.67	76.67	81.33	88.00	101.67
V ₈ x Rainfed	35.00	74.33	74.00	82.00	88.00	101.00
V ₉ x Irrigated	36.33	68.00	75.00	80.67	86.33	117.33
V ₉ x Semi irri.	36.00	67.00	72.00	77.33	85.00	112.00
V ₉ x Rainfed	35.67	66.67	72.33	77.33	84.67	108.33
SEm±	0.359	0.328	0.405	0.348	0.407	0.531
CD 5%	0.906	0.828	1.022	0.880	1.027	1.340

Chapter-V

DISCUSSION

Agriculture researches are mainly aimed to enhance the crop yields. The crop yields are mainly governed by genetic and environmental factors. Genetic factors include the performance of crop varieties, but crop variety alone is seldom responsible to step-up the yield of crops. The another factor i.e. environmental factors have great concern for the growth and yield of crop. The environmental factor consists with soil, climate and management.

Climate is one of the major controlling factors for the well-being of the residents of the world. Global climate has been changing due to natural forcing as well as anthropogenic activities, especially emissions of greenhouse gases and aerosols, and land use changes in recent decades. Climatic factors such as temperature, rainfall, atmospheric carbon dioxide, solar radiation etc. are closely link with agriculture production. Therefore, rice production would be major concern in recent years due to changing climatic conditions, because there is a significant amount of rice yield may hamper for only fluctuations of those climatic parameters.

Rice crop is influenced by genotypic, phenotypic, environmental and physiological interactions. It was important to investigate the morphological and physiological behavior of rice varieties in relation to their productivity and economic net return. The desired data were generated through the observations recorded in the field experiment. The results based on these data are described in pervious chapter along with appropriate tables and illustrations. Some of the result have focused most valuable finding of academic and applied importance. Such significant findings are discussed in this chapter with the support of the data, established scientific facts and relevant findings of other researchers. Keeping these points in view, the present investigation entitled **“Differential response of climate variability on morpho-physiological parameters and yield of late sown direct seeded rice varieties”** was conducted during *Kharif* season of 2011 at Research Farm, Deptt. of Physics and Agro-meteorology, College of Agril. Engineering JNKVV, Jabalpur (M. P.).

An examination of the data recorded for various aspects of crop studies reveals several points of interest which, it is felt, can be discussed in conjunction with the findings of other workers. It may be noted that the yield was to a considerably extent correlated with the supplementary observations taken on growth and yield attributing characters of crop, and it is realized that the assessment of the experimental treatments by such supplementary data has been reasonably justified.

The results of the present investigation have been interpreted and discussed under following aspects:

1. Morphological and yield attributing characters of direct seeded rice varieties under irrigated, semi irrigated and rainfed conditions.
2. Growth analytical characters of direct seeded rice varieties under irrigated, semi irrigated and rainfed conditions.
3. Effect on physiological traits of direct seeded rice varieties under irrigated, semi irrigated and rainfed conditions.
4. Effect on other physiological traits of direct seeded rice varieties under irrigated, semi irrigated and rainfed conditions.
5. Effect on different treatments on biochemical determination by the rice varieties under different irrigation regimes.
6. Phenological phases of different direct seeded rice varieties under different irrigation regimes.

5.1 Performance of varieties

All the varieties tested under the irrigated, semi irrigated, and rainfed conditions and after that found the variation among the all treatment combination. Variety V₅ (Kranti) was significantly higher in parameters viz., plant height, no. of spikelets, no. of seeds per panicle, seed yield, RWC, seed nitrogen content, seed protein, LAI etc. and the variety V₉ (Mahamaya) was significantly higher in parameters viz., spikelets dry weight per panicle, seed index, leaf chlorophyll index, PAR absorption, net photosynthesis, transpiration rate, stomatal conductance and quantum use efficiency etc. and the variety V₁ (JGL-3844) was significantly higher in parameters viz., leaf

proline content, inter CO₂ concentration, days to flower initiation etc. and the variety V₇ (PS-5) was significantly higher in parameters viz., no. of productive tillers, seed carbohydrate, carboxylation efficiency, days to physiological maturity etc. and the variety V₂ (WGL-32100) was significantly higher in parameters viz., seed carbohydrate, days to 50% flowering etc. Similar results, significant difference in grains yield between mid and low land situation was observed under rainfed, life saving irrigation and full irrigation conditions respectively. One additional irrigation was required in mid land due to quick disappearance of water mainly because of seepage and other losses. (Singh and Bhargava, 2012; Yang Xiao *et al.*, 2005; Pandey *et al.*, 2001).

5.2 Irrigation performance

All the varieties revealed under the irrigated, semi irrigated, and rainfed conditions and after that found the variation among the all treatment combination. The parameters was higher significantly viz., plant height, no. of productive tillers per m², no. of panicle per plant, no. of spikelets, no. of seeds per panicle, spikelets dry weight, seed index, seed yield, biological yield, chlorophyll index, RWC, LAI, CGR, seed nitrogen, seed protein and phenophases under irrigated condition than semi irrigated and rainfed conditions. The parameters was higher significantly viz., harvest index, seed carbohydrate, drought susceptibility index, SLW, RGR, net photosynthesis, inter CO₂ concentration, WUE, QUE etc. under semi irrigated condition than irrigated and rainfed conditions. The parameters was higher significantly viz., WSD, leaf proline content, SLA, SLW, PAR absorption, transpiration rate, stomatal conductance, carboxylation efficiency etc. under rainfed condition than irrigated and semi irrigated conditions. Similar result, There is thus more flexibility in the timing of irrigated rice operations, since these are not dependent on rainfall. (Shapiro, B. I., 2002) and indicating thereby that plant growth period from booting to grain fill (reproductive stage) was the more sensitive to water deficit. (Singh *et al.*, 2002; Das *et al.* 2001; Rai and Kushwaha, 2005; Manjappa and Prasad kumar 2002).

5.3 Morphological and yield attributes parameters affected by varieties & irrigation

All the varieties revealed under the irrigation, semi irrigation, and rainfed conditions and after that found the variation among the all treatment combination. The parameters were higher significantly following:

5.3.1 Plant height (cm)

Plant height was higher significantly at tillering and at maturity stages. The plant height was higher under irrigated condition than semi irrigated and rainfed conditions. Similar result, the effects of different water management on rice plant height (Polon *et al.*, 2004). Significantly plant height was higher found in variety V₅ (Kranti) respectively 65.09 cm, 107.66 cm then other rice varieties at all the stages of plant growth and the treatment combination higher was V₅ (Kranti) x rainfed (67.10 cm) at tillering and V₅ (Kranti) x irrigated (116.33 cm) at maturity stage. Similar results were reported by Singh and Tripathi (2007) observed that higher plant height, irrespective of source, leaves and LAI accumulated higher amount of dry matter almost at all the stages of crop growth, supporting the well-established fact that water sufficiency resulted into vigorous growth of the foliage. Plant height of rice was significantly affected by level of foliage as well as varieties and their effects were found to be significant. These findings are in conformation with those of Gevrek *et al.*, (2008).

Each plant process through the vegetative as well as reproductive phases of growth to complete its life cycle. Yield can be considered to be the final expression of the physiological and metabolic activities of plants and is governed by various factors. These yield attributing factors viz., number of effective tillers per m², no. of panicle per plant, no. of spikelets per panicle, number of seeds per panicle, spikelets dry weight per panicle, seed yield, biological yield, harvest index and seed index etc. plays an important role in ameliorating the yield of rice.

5.3.2 Number of productive tillers per plant

In the present investigation treatments (different direct seeded rice varieties under different irrigation regimes) was showed significant differences

for the number of effective tillers per m² at maturity stage. Significant the higher number of productive tillers per m² was found in irrigated condition than semi irrigated and rainfed conditions. Similar result, the total number of productive tiller per plant, number of productive tillers per plant did not alter between alternate wetting (AWD) and normal irrigated condition (Rao *et al.*, 2011; Anonymous, 2004). Variety V₇ (PS-5) respectively produced more number of tillers (343.78) per m² at maturity as compared with other varieties. Interaction V₇ (PS-5) x irrigated significantly increase the number of productive tillers (422.71) per m² respectively over other treatment combinations. These results are in close conformity with the findings of several workers (Sabir *et al.*, 2007; Longshithung *et al.*, 2005; Gill *et al.*, 2006; Anonymous, 2004).

5.3.3 Number of panicles per plant

Significant the higher number of panicles/plant was found in irrigated and semi irrigated conditions than rainfed condition. Similar result, Angadi *et al.* (2004) evaluated the response of direct sown rainfed lowland rice the number of tillers did not differ among the different treatments. Variety V₆ (PS-4) produced more number of panicles/plant respectively 4.37 at maturity as compared with other varieties. Interaction V₄ (IR-64) x semi irrigated significantly increase the number of panicles per plant respectively 845.30 over other treatment combinations similar that the result, Ghille (1995) reported that rice cultivar IET 9219 produced more number of panicles per plant as compared to other cultivars in rainfed upland.

5.3.4 Number of spikelets per plant

Significant the higher number of spikelets per m² was found in irrigated condition than semi irrigated and rainfed conditions. Variety V₅ (Kranti) produced more number of spikelets (775.67) per m² respectively at maturity as compared with other varieties. Interaction V₈ (MR-219) x irrigated significantly increase the number of spikelets (845.30) per m² respectively over other treatment combinations conformed result, higher grain yield of rice-cultivar Govinda coupled with more number of spikelets per panicle under transplanting in puddled field. (Panda *et al.*, 1994; Saiedzadeh *et al.*, 2010; Navendu Shekhar and Mahindra Nath Upadhyaya, 2011; Angadi *et al.*, 2004).

5.3.5 Number of seeds per panicle

Significant the higher number of seeds per panicle was found in irrigated condition. Variety V₅ (Kranti) produced more number of seeds (133.59) per panicle respectively at maturity as compared with other varieties. Interaction V₅ (Kranti) x irrigated significantly increase the number of seeds (144.77) per panicle respectively over other treatment combinations. Similar result, that upland local rice variety Leikhumo recorded significantly higher number of filled grains per panicle as compared to other varieties (Longshithung *et al.*, 2005; Kapre *et al.*, 1996).

5.3.6 Spikelets dry weight (g) per panicle

Significant the higher spikelets dry weight (g) per panicle was found in irrigated condition. Variety V₉ (Mahamaya) respectively produced more spikelets dry weight (8.47) per panicle at maturity as compared with other varieties. Interaction V₉ (Mahamaya) x irrigated significantly increase the spikelets dry weight (10.94) per panicle respectively over other treatment combinations (Krishnan and Rao, 2005; Sheehy, 2007).

5.3.7 Seed yield (kg/ha)

Grain yield is the product of several physio-bio and morphological characters and it has got a higher degree of complexity. The increase in grain yield was associated with the increasing developmental characters like number of tillers per m², number of grains per panicle and 1000 grain weight. Marked increase in yield attribute might have resulted due to adequate availability and translocations of nitrogen during reproductive and grain filling stages. Enhancement in yield attributing traits due to better availability and translocation of nutrients and photosynthetic from source to sink.

The significant highest seed yield (kg/ha) was recorded in irrigated condition than semi irrigated and rainfed conditions. Similar result, Sharma and Piri (2006) revealed that application of two irrigation at 45 DAS and 90 DAS significantly increased Seed yield increased significantly with increasing levels of irrigation. Variety V₅ (Kranti) respectively produced higher seed yield (2759.68) as compared with other varieties. Interaction V₅ (Kranti) x irrigated significantly increase the seed yield (3108.16) respectively over other treatment combinations. These results are in close conformity with the

findings of several workers, Dubey, (1993); Roy and Pradhan, (1996); Reddy and Krishna, (1998); Arshad *et al.*, (2003); Haque *et al.*, (2011).

5.3.8 Biological yield (kg/ha)

The biological yield is also influenced by several components viz., plant height, number of tillers, number of leaves etc. The biological yield of upland rice was also enhanced significantly by the varieties under irrigated condition than other irrigation treatments. Variety V₈ (MR-219) recorded significantly highest biological yield respectively (9841.27) as compared with other varieties. Interaction V₅ (Kranti) x irrigated significantly increase the biological yield 11020.41 (kg/ha) respectively over other treatment combinations. (Gautam, 1990; Kapre *et al.*, 1996; Lar *et al.*, 2007; Singh *et al.*, 1997).

5.3.9 Harvest index (%)

Harvest index is available criterion for an improved plant type the morphological framework of the plant must be constructed so that total dry matter produced is efficiently partitioned between grains and vegetative parts. Harvest index under semi irrigated condition in upland rice was found significantly higher due to the other treatments. Variety V₃ (IR-36) showed highly significant effect for harvest index (35.18) over remaining varieties. Interaction V₃ (IR-36) x rainfed significantly increase the harvest index (41.20) respectively over other treatment combinations. Similar result, that rice cultivar IET 9219 produced highest grain and straw yield as compared to other cultivars in rainfed upland conditions (Ghille, 1995; Swain *et al.*, 2006; Haque *et al.*, 2011).

5.3.10 Seed index (1000 sees weight) (g)

Significant the seed index higher was found in irrigated condition than semi irrigated and rainfed conditions. Variety V₉ (Mahamaya) respectively produced more seed index (29.78) as compared with other varieties. Interaction V₉ (Mahamaya) x irrigated significantly increase the seed index (31.09) respectively as compare to other treatment combinations. These results are in close conformity with the findings of several workers, Gautam, (1990); Ghille, (1995); Singh *et al.*, (1995); Kapre *et al.*, (1996); Ojha *et al.*, (2000).

5.4 Functional attributes (growth analysis) affected by varieties & irrigation regimes

To account for yield variation in terms of growth and development is very complex, since it involves the effect of external factors on all the physiological processes of plants. The inter relation between different processes and their dependence on internal factors is determined by the genetic constitution of the plant. Various empirical relationships such as CGR, RGR, LAD, SLW and SLA described the connection between the end point of a long chain of interdependent processes in the environment and plant (Watson, 1952).

5.4.1 Leaf Area Index (LAI)

The upland rice plants which contributed towards enhanced meristematic activity of roots and cell division thereby increasing the leaf surface area and sink potential by more nutrients. The more leaf surface area resulted into more photosynthesis. LAI revealed the following facts :-

The present investigation, treatments (different direct seeded rice varieties under different irrigation regimes) showed significantly maximum the LAI at all stages of crop growth in irrigated condition than semi irrigated and rainfed conditions. While Khapke *et al.*, (2011) observed the number of leaves and leaf area decreased with increasing water stress at seedling and anthesis stage of crop.

A pattern of linear increase in LAI was exhibited under all circumstances, from at 30-45 DAS and it continued up to at 75-90 DAS and there after it reduced sharply. Variety V₅ (Kranti) and V₉ (Mahamaya) attained significantly maximum LAI after this at all stages of crop growth as compared with other varieties. Interaction V₈ (MR-219) x irrigated significantly increase respectively as compare to other treatment combinations. Similar result that 3 to 4 LAI was needed for higher productivity. Further increased in LAI caused lodging and reduction in yield. (Nichiporovich, 1970) and Conformed, Dinghkuhn *et al.*, (1991) observed a negative relationship between LAI at flowering and grain yield. Gill *et al.*, (2005) observed the maximum dry matter accumulation (leaf area index 4.37 – 4.97 and 5.24 – 6.06) under direct seeding.

5.4.2 Leaf Area Duration (LAD) (m². day)

The leaf area duration is a measure of the ability of the plant to produce and maintained leaf area and its whole opportunity for assimilation during growing season (Watson, 1947). It is an useful physiological parameter to asses the final productivity and is also called as photosynthetic potential of a crop (Kvet, 1978). It is mainly depends on the development and product of rate of initiation and size of assimilatory surface area and is closely connected with yield. The physiological processes are affected by genetic as well as environmental factors.

A progressive pattern of increase in leaf area duration was obtained with advancement in crop growth up to at 75-90 DAS behind that it decline sharply under different irrigation regimes. LAD was higher under irrigated condition than semi irrigated and rainfed conditions. V₅ (Kranti) and V₉ (Mahamaya) attained significantly maximum LAD after this at all stages of crop growth as compared with other varieties. Interaction V₈ (MR-219) x irrigated significantly increase respectively as compare to other treatment combinations. Welbank *et al.*, (1988) reported that the ratio of grain yield to LAD increased with increase in daily radiation during grain filling. Conformed, Chauhan *et al.*, (1999) reported that the LAD and LAI measured at 30-45 days after sowing (DAS) had positive and significant association with dry accumulation at 50% flowering. Conformed, Sahoo and Guru (1998) observed the positive association of LAD with grain yield.

5.4.3 Specific Leaf Area (SLA) (cm²/g)

The specific leaf area represents the leafiness and indicates the interrelationship between leaf areas in relation to leaf dry weight (Asalatha *et al.* 1999). SLA increased at 30-45 DAS to at 75-90 DAS and thereafter it declined sharply during 90-105 DAS to 105 DAS to maturity.

A differential pattern of SLA was noted under different irrigation regimes. Significantly maximum the SLA at all stages of crop growth under irrigated and rainfed conditions than semi irrigated condition. Significantly maximum SLA under variety V₂ (WGL-32100) at 30-45 DAS, variety V₁ (JGL-3844) under both stages 45-60 DAS and 60-75 DAS, variety V₆ (PS-4)

maximum under both stages 75-90 DAS and 90-105 DAS and variety V₁ (JGL-3844) at 90-105 DAS was recorded maximum value of SLA as compare to other varieties of rice. While the interaction diminishing trend of SLA was noted under variety V₂ (WGL-32100) x irrigate at 30-45 DAS, variety V₁ (JGL-3844) x rainfed at 45-60 DAS, variety V₂ (WGL-32100) x rainfed at 60-75 DAS and at 75-90 DAS, variety V₆ (PS-4) x semi irrigated at 90-105 DAS and variety V₁ (JGL-3844) x semi irrigated at 105 DAS to maturity were superior in maintaining maximum value of SLA during various stages of crop growth. Sahoo and Guru (1998) observed the positive association of SLA with grain yield.

5.4.4 Specific Leaf Weight (SLW) (g/cm²)

Specific leaf weight gives idea about the thickness of the leaves. A differential response of SLW was observed under different irrigation conditions. There was no specific trend in SLW was noted among various cultivars and after that found the variation among the all treatment combination. Significantly maximum value of SLW under semi irrigated and rainfed conditions than irrigated condition at almost all the crop growth stages.

A differential pattern of SLW was increased at 30-45 DAS and thereafter it declined sharply during both stages 45-60, 60-75 DAS and again increased during at 75-90 DAS to maturity.

Variety V₉ (Mahamaya) showed higher SLW at 30-45 DAS, V₅ (Kranti) at 45-60 DAS, V₂ (WGL-32100) at 60-75 DAS and at 75-90 DAS, and V₆ (PS-4) at 90-105 DAS and V₅ (Kranti) at 105 DAS to maturity recorded maximum value of SLW. While the interaction diminishing trend of SLW was noted under V₇ (PS-5) x irrigate at 30-45 DAS, V₅ (Kranti) x semi irrigated at 45-60 DAS, V₅ (Kranti) x irrigated at 60-75 DAS, V₂ (WGL-32100) x irrigated at 75-90 DAS, V₆ (PS-4) x semi irrigated at 90-105 DAS and V₇ (PS-5) x rainfed at 105 DAS to maturity were superior in maintaining maximum value of SLW during various stages of crop growth. Similar that, Haloi and Dey (2003) recorded the IET 10664 maintained stable rate of specific leaf weight during its inundation period. The cultivar produced a significant higher quantum of stem reserve mobilization (17.7%) as compared to other cultivars.

5.4.5 Crop Growth Rate (CGR) (g/cm² ground area/day)

The assessment of crop productivity per unit land area is important parameter of crop growth and computation of CGR is always more appropriate as it is simple and important index of agricultural productivity as rate of dry matter production. Huijie *et al.* (2001) found in rice that the highest production rate exhibited by the cultivars during the middle and late growth stages. During these stages, the yield increased with the increase in net dry matter accumulation, and the crop growth rate (CGR) was significantly and positively correlated with the yield.

There was linear impact of all the varieties revealed under the irrigated, semi irrigated and rainfed conditions and after that found the variation among the all treatment combination on crop growth rate. Significantly higher was CGR under irrigated condition than semi irrigated and rainfed conditions. Variety V₅ (Kranti) and V₉ (Mahamaya) attained significantly maximum CGR after this at all stages of crop growth as compared with other varieties. Interaction V₈ (MR-219) x irrigated significantly increase respectively as compare to other treatment combinations. Similar that the value of CGR was normally low during early vegetative stages and becomes higher during start of reproductive phase and attained maximum during both panicle and flowering stage and there after it reduced sharply. (Singh *et al.*, 2007; Deka and Baruah, 2000; Gill *et al.*, 2006). Conformed, Turner *et al.* (1986) observed no difference among cultivars were observed in either the rates of dry matter production or water use during the period of differential irrigation.

5.4.6 Relative Growth Rate (RGR) (g g⁻¹day⁻¹)

The increase in total dry matter of plant per unit plant material per unit time is called as relative growth rate (RGR) (Redford 1967). The RGR was generally higher during early vegetative growth stage and decrease with advancement in crop age. A differential pattern of increase in RGR was noted during different growth intervals under all circumstances.

An increase in RGR was noted upto at 30-45 DAS thereafter it decreased during at 75-90 DAS and further again increased during at 90-105 DAS under different conditions. Similar that the influence of the differential water treatments on the relative growth rate during the period of stress development. (Turner *et al.*, 1986).

Significantly the RGR at maximum stages of crop growth under semi irrigated condition than irrigated and rainfed conditions. Variety V₁ (JGL-3844) attained maximum RGR during at 30-45 DAS, V₅ (Kranti) during at 45-60 DAS, V₇ (PS-5) during at 60-75 DAS, V₅ (Kranti) during at 75-90 DAS, V₆ (PS-4) during at 90-105 DAS and V₁ (JGL-3844) and V₆ (PS-4) intervals respectively were superior varieties in relation to maximum RGR in respective stages of crop growth. Treatment combination V₁ (JGL-3844) x semi irrigated significantly maximum under both stages 30-45 DAS and 45-60 DAS, V₅ (Kranti) x irrigated significantly maximum under both stages 60-75 DAS and 75-90 DAS and the treatment combination V₆ x rainfed significantly maximum under both stages 90-105 DAS and 105-maturity. (Turner *et al.*, 1986) show the RGR decreased by about the same amount in all cultivars with the reduction in water applied both leaf and stem growth were equally affected.

5.5 Studies on Physiological Aspects for drought tolerance

All the varieties revealed under the irrigated, semi irrigated and rainfed conditions and after that found the variation among the all treatment combination. The parameters was higher significantly viz.,

5.5.1 Chlorophyll Index (g/m²)

Water stress may also cause damage to photosynthetic apparatus such as increased photooxidation of chlorophyll and inhibition of chlorophyll biosynthesis and damage in lamellar membrane of chloroplast (Gyler *et al.* 1974) stress induced loss of solutes mainly potassium from guard cells results in selective reduction in guard cell turgor. Moreover there is significant decreased in the chlorophyll index along with photosynthetic rate. Stability indices of cell membrane and chlorophyll are affected under heat stress. Lower per cent reduction in nitrate reductase activity and chlorophyll index in tolerant variety C-306 was observed earlier.

Leaf chlorophyll content in all the varieties planted under different irrigation regimes at tillering and flowering stage with a significant the chlorophyll content higher was found under irrigated condition than semi irrigated and rainfed conditions. While conformed, Baruah *et al.* (1998) observed the high chlorophyll content during stress in high yielding variety.

Variety V₉ (Mahamaya) respectively 46.39 and 25.41 produced high chlorophyll content as compared with other varieties. Interaction V₉ (Mahamaya) x irrigated significantly increase the chlorophyll content (48.01 and 28.31) respectively as compare to other treatment combinations. Choudhary *et al.* (1994) emphasized that the grain development was accompanied by decreases in chlorophyll percent of the leaf as a result of ageing. Pradhan and Singh (2011) noted the total chlorophyll content was less in Jal lahri than Pant Dhan-11 of submergence rice cultivar. Ghosh *et al.* (2000) reported a positive and significance of chlorophyll content with yield, which confirmed its rate in sink development.

5.5.2 Relative leaf water content (RLWC) (%)

Environment stresses such as drought, heat, cold, water logging and salinity are major constants of yield potential. The plant water stress decides the rate of various physiological processes related to growth and development of the plant. The relative leaf water content (RLWC) is the relation of water in the leaves under moisture stress condition is a major indication of drought tolerance. It is the ratio of water content of a tissue to that of the same when the tissue is fully turgid expressed as percentage and indicates the water status of tissues. Significant the RLWC higher was found in semi irrigated condition at tillering and decrease in irrigated condition at flowering stage. Similar that, Deivanai *et al.*, (2010) reported that drought symptom was noticed by wilting of leaves and sharp decline in RLWC (%) in water deficit condition.

Variety V₅ (Kranti) respectively 87.74 produced high as compared with other varieties at tillering stage and V₄ (IR-64) respectively 70.21 produced high RLWC as compared with other varieties at flowering stage. Combination V₅ (Kranti) x semi irrigated significantly decrease RLWC (91.73) respectively as compare to other treatments at tillering stage and combination V₃ (IR-36) x irrigated significantly decrease RLWC (81.19) respectively as compare to other treatment combinations at flowering stage. Similar result, Haque *et al.*, (2011) identified as best suited varieties for water limited condition having grain yield with high RLWC. While Baruah, (1998) observed the high RLWC during stress in high yielding variety. Ranjan Das and Kalita (2010) observed the highest reduction in RLWC in the cultivars IR-50, Nilanjee and Guni in stress condition.

5.5.3 Water Saturation Deficit (WSD) (%)

WSD in all the varieties planted under different irrigation regimes at tillering and flowering stage with a significant the WSD maximum was found in rainfed condition than irrigated and semi irrigated conditions. Variety V₆ (PS-4) respectively 21.80 and 47.90 observed high WSD as compared with other varieties. Interaction V₆ (PS-4) x rainfed significantly increase the WSD (23.22 and 52.82) respectively as compare to other treatment combinations.

5.5.4 Drought Susceptibility Index (DSI)

Significant the DSI higher was found in semi irrigated condition. Treatment V₅ (Kranti) respectively 1.17 induced more DSI as compared with other treatments. Interaction V₁ (JGL-3844) x semi irrigated significantly increase the DSI (1.91) respectively as compare to other treatment combinations conform that, Saxena *et al.* (1996).

5.6 Other physiological aspects for drought tolerance

Light is one of the most important factors which plays a major role in development and yield of crop. The biochemical processes leading to growth of plant and chlorophyll formation are depends upon the amount of radiation received. The yield or dry matter production of a crop is partially the reflection of efficiency of the conversion of light energy into chemical energy through photosynthesis. The conversion efficiency is affected by the amount and intensity of photosynthetically active radiation (PAR) intercepted and the photosynthetic efficiency of the leaves of the crop. (Anwar *et al.* 2001)

The present investigation, different treatments, direct seeded rice varieties under different irrigation regimes. Results revealed that the parameters viz., net photosynthetic rate, PAR, transpiration rate, stomatal conductance, intercellular CO₂ concentration, water use efficiency, carboxylation efficiency and quantum use efficiency etc. significantly affected by the sunshine condition and water stress considerably increase under semi irrigated and rainfed than irrigated circumstances (Leport *et al.*, 1998).

5.6.1 Photosynthetically active radiation (PAR) ($\mu \text{ mol/m}^2/\text{s}$)

The morphological features as characterized by the geometrical structure of plant communities, PAR interception and its utilization have a great influence on the productivity which is an interaction between plants and environment through the modification and interception of fluxes of radiation, heat, CO_2 etc. The PAR interception by the whole canopy was maximum in the morning and afternoon during fruit development stage of the crops (Mukherjee *et al.*, 2003).

The data regarding photosynthetically active radiation (PAR) revealed that the increase under rainfed than irrigated and semi irrigated circumstances. Similar that, Haloi and Dey, (2000) noted the variation in productive efficiency between rice cultivars and plant population stress under a given set of environment depends on the rate at which a closed canopy develops leading to better use of incoming solar radiation.

Variety V_9 (Mahamaya) had absorbed maximum PAR (1200.56) and with high yielding variety in relation to seed yield per plant and the interaction V_7 (PS-5) x semi irrigated (1201.00) of rice respectively. Conformed, Monteith and Elston, (1983) show the analysis of crop growth should consider total dry matter as a product of the amount of PAR intercepted by the crop multiply by efficiency factor.

5.6.2 Net photosynthesis (P_n) ($\mu \text{ mol/m}^2/\text{s}$)

Singh *et al.* (1997) concluded that the rate of photosynthesis was positively correlated with stomatal conductance, rate of transpiration, leaf temperature and grain yield.

The net photosynthetic (P_n) significantly increase under semi irrigated and rainfed than irrigated circumstances. Variety V_9 (Mahamaya) showed maximum rate of net photosynthesis (48.82) and the interaction V_9 (Mahamaya) x irrigated (55.47) of rice. Similar that, Kalpana *et al.*, (2003) noted that the genotypes produced higher seed yield also showed higher value for net photosynthesis. While Rajeswari *et al.* (2011) recorded higher photosynthetic rate, transpiration rate and stomatal conductance ratio, but were found to be low grain yielders because of low harvest index, more

number of ill filled grains per plant under rainfed upland conditions. Conformed, Richards (2000) noted that total photosynthesis has increased as a result of an increase in leaf area.

5.6.3 Transpiration rate ($\text{m mol/m}^2/\text{s}$)

The physiological attributes under different light intensities in rainfed, semi-arid conditions, rate of photosynthesis (P_n) and stomatal conductance decreased with decreasing light intensity and reached the minimum level under high shading (25%), light intensity, transpiration rate of 25% light intensity was half than that in full sunlight as reported by Bhatt *et al.*, (2006).

The transpiration rate was significantly increased under rainfed condition than irrigated and semi irrigated regimes. Similar that, Rajeswari *et al.*, (2011) recorded higher photosynthetic rate, transpiration rate and stomatal conductance ratio, but were found to be low grain yielders because of low harvest index, more number of ill filled grains per plant under rainfed upland conditions.

Variety V_9 (Mahamaya) had absorbed maximum transpiration rate (6.01) and the interaction V_3 (IR-36) x rainfed (9.34) respectively. This might be ascribed to that the photosynthetic rates of both grain and subtending leaves decreased with age, but the rate of transpiration of the grains increased with age. (Matsui *et al.*, 2001).

5.6.4 Stomatal conductance ($\text{mmol/m}^2/\text{s}$)

Fisher *et al.* (1998) found an increase in photosynthetic rate and stomatal conductance in modern varieties.

The stomatal conductance was significantly increased under rainfed condition than irrigated and semi irrigated regimes. Similar result, Rao *et al.*, (2011) showed that the reduction in stomatal conductance, while the varieties were less affected than hybrids under alternate wetting and drying (AWD) situation. Variety V_9 (Mahamaya) had absorbed maximum transpiration rate (0.676) and the interaction V_6 (PS-4) x rainfed (1.10) respectively. While Zhao *et al.*, (2007) suggested that the reduction in transpiration rate and stomatal conductance and suggested that both stomatal and non stomatal factors were involved in the reduction of photosynthesis.

5.6.5 Intercellular CO₂ concentration (Ci) ($\mu\text{mol CO}_2 \text{ mol}^{-1}$)

Gupta *et al.* (2012) suggested the drought stress led to a significant decrease in photosynthetic rate and stomatal conductance and concomitant increase in intercellular CO₂ concentration. The Ci significantly increases under semi irrigated than irrigated and rainfed circumstances. Variety V₁ (JGL-3844) showed maximum rate of Ci (81.86) and the interaction V₅ (kranti) x semi irrigated (94.67) of rice. Zhao *et al.*, (2007) suggested that the increase in intercellular CO₂ concentration suggested that both stomatal and non stomatal factors were involved in the reduction of photosynthesis.

5.6.6 Water Use Efficiency (WUE) ($\ll \text{mol/mol}$)

Singh *et al.* (2008) noted that the water use efficiency (WUE) ability of the plant to produce dry matter per unit of water is a genotypic character and two important physiological traits that determine the variability in WUE are photosynthetic rate (Pn) and transpiration rate (Tr) are basically the function of leaf.

The WUE significantly increase under semi irrigated than irrigated and rainfed circumstances. Variety V₄ (IR-64) showed maximum rate of WUE (15.61) and the interaction V₄ (IR-64) x semi irrigated (20.53) of rice. Similar that, Dingkuhn, (1991) determine WUE, we formed the quotient (net photosynthesis transpiration⁻¹) in both rices, WUE was low under well watered conditions and extreme water stress, but it was relatively high at intermediate degree of stress.

5.6.7 Carboxylation Efficiency ($\mu\text{mol m}^{-2} \text{ s}^{-1}/(\mu\text{mol mol}^{-1})$)

The carboxylation efficiency significantly increases under rainfed than irrigated and semi irrigated circumstances. Variety V₇ (PS-5) showed maximum rate of carboxylation efficiency (0.694) and the interaction V₇ (PS-5) x rainfed (0.813) of rice.

5.6.8 Quantum Use Efficiency (QUE) ($\mu\text{mol m}^{-2} \text{ s}^{-1}/(\mu\text{mol mol}^{-1})$)

The QUE significantly increase under semi irrigated than irrigated and rainfed circumstances. Variety V₉ (Mahamaya) showed maximum rate of QUE (0.041) and the interaction V₉ (Mahamaya) x irrigated (0.046) of rice. Similar that, Haloi and Dey (2003) recorded the IET 10664 maintained stable rate of specific leaf weight during its inundation period. The cultivar produced a

significant higher quantum of stem reserve mobilization (17.7%) as compared to other cultivars.

5.7 Biochemical estimation affected by varieties & irrigation

Sumesh *et al.* (2008) reported that the proline, amino acids, proteins and sugars are some of the common metabolites that accumulate under stress conditions.

5.7.1 Seed nitrogen content (%) and Seed Protein (%)

Nitrogen and protein percentage were significantly higher in the irrigated condition than semi irrigated and rainfed conditions. Pawar *et al.* (1992) reported that nitrogen and seed protein content was the highest with three irrigations (23.75%) and lowest with no irrigation (22.00%).

The biochemical parameters varied significant due to varieties amongst variety V₅ (Kranti) had highest nitrogen (0.958) and protein (5.99) percentage respectively as compare to other varieties. The interaction almost all the biochemical parameters like nitrogen percentage (1.29) had the higher significant in V₅ (Kranti) x irrigated and protein percentage (7.25) under V₇ x semi irrigated and V₉ (Mahamaya) x irrigated respectively as compare to other treatment combinations.

Similar result, Ryo Matsuda *et al.* (2004) suggested that the increase in total N content of leaves induced by supplemental blue light enhanced both light-saturated and light-limited photosynthesis. Conformed, Namita and Koundal (2000) studied that the total protein in mature seeds was found to be 22% (dry weight basis). The major storage protein, globulin synthesized actively between 9 days after flowering (DAF) until 29 DAF and was 66% on a total protein basis in the mature seeds.

5.7.2 Seed carbohydrate (%)

Seed carbohydrate significantly maximum under semi irrigated condition than irrigated and rainfed conditions. Similar that indicates the complete submergence of rice led to low concentration of carbohydrate and reduced growth partly due to low rate of photosynthesis associated. (Setter *et al.*, 1989).

Variety V₂ (WGL-32100) was observed higher carbohydrate percentage respectively 63.67 than other varieties. Interaction V₉ (Mahamaya) x irrigated significantly increase the carbohydrate percentage (65.72) respectively as compare to other treatment combinations. Turner and Begg (1981) and Turner (1977) concluded that loss is compensated partially by the mobilization of carbohydrates stored in the vegetative plant parts which contributed up to 30% of the final grain yield when water deficits develop during grain filling

5.7.3 Leaf proline content («mol/g)

Khapke *et al.* (2011) identified the concentration of proline increased significantly with an increase in the degree of water stress and proline may possibly play an important role in the osmoregulation under moisture stress condition. Choudhary *et al.* (2005); kale, (2006); Pawar *et al.* (2011) clearly show that proteins and proline protect the cell from osmotic damage due to low water content.

Leaf proline content significantly increases in rainfed condition than irrigated and semi irrigated conditions. proline content observed higher under variety V₁ (JGL-3844) respectively 0.491(μmol/g) than other varieties. Interaction V₁ (JGL-3844) x irrigated significantly increase the proline content (0.727) respectively as compare to other treatment combinations. Similar that, Baruah *et al.*, (1998) observed the high proline accumulation during stress in high yielding variety.

5.8 Staggered of phenophases (Day's from sowing) affected by varieties & irrigation in rice crop

Phenology largely determines the adaptability of a cereal crop to a certain range of environmental conditions and may also strongly affect yield potential (Slafer *et al.*, 2001). Development traits in cereals are particularly significant in water limiting condition of Mediterranean environments, where available water becomes increasingly scares towards the end of the growing season (Richards *et al.*, 1991; Slafer *et al.*, 1994; Royo *et al.*, 1995; Passioura *et al.*, 1996; Bort *et al.*, 1998; Gonzanz *et al.*, 1999).

The better adapted cultivars develop reaching anthesis earlier thus minimizing the exposure to terminal drought stress. Almost all phenological stages viz., tiller initiation, panicle initiation, 50% panicles, flower initiation,

50% flowering and physiological maturity were significantly higher in the irrigated condition than semi irrigated and rainfed conditions.

The results revealed a significant variation among different varieties in relation to days required for their phenological developments. Tiller initiation was ranged between 34.67 to 39.00 DAS. Maximum was noted in variety V₆ (PS-4) 38.78 DAS respectively. Panicle emergence ranged between 55.00 to 74.67 DAS and maximum was noted under variety V₈ (MR-219) 74.22 DAS. Fifty percent panicle emergence ranged between 68.33 to 80.67 DAS and maximum was noted under variety V₈ (MR-219) 77.11 DAS. Flowered initiation in a range of 75.00 to 87.00 DAS and maximum was noted under variety V₁ (JGL-3844) 85.44 DAS. Similarly, all varieties 50% flowered in a range of 81.67 to 97.00 DAS and maximum was noted under variety V₂ (WGL-32100) 93.67 DAS. The days of physiological maturity among rice varieties was attained range between 112-120 DAS and highest was noted in variety V₇ (PS-5) at 114.56 DAS was reported. Similar result, There was no difference noticed among varieties if applied with more irrigation. In rice, the time to flowering is strongly affected by photoperiod. In general, a short photoperiod accelerates and a long photoperiod delays flowering under rice plants, however, do not respond to photoperiod during the entire vegetative period from sowing to flowering (Vergara and Chang, 1985). Goswami (1991), Kalita (1996) conform the low soil moisture during germination, intermittent moisture stress during seedling and panicle initiation are the major factor that contribute to lower production. Zacharias *et al.* (2010) indicate the stress was given either throughout crop growth period or at of the three growth phases viz., seedling to panicle initiation, panicle initiation to flowering and flowering to maturity result indicate that the warmer temperature hasten crop development, shortens the growth period and thus finally lower the grain yield in both crops wheat and rice.

Chapter-VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

Summary

The present investigation entitled Differential response of climate variability on morpho-physiological parameters and yield of late sown rice varieties." was conducted at the Research Farm, Deptt. of Physics and Agro-meteorology, College of Agril. Engineering JNKVV, Jabalpur (M.P.) during Kharif season of 2011. The experimental material consisting of 27 treatments (3 Irrigation conditions and 9 varieties) of rice were transplanted on plot size of 4.0 x 4.0 m in a strip plot design with three replications. The row and plant spacing was maintained at 22 cm and 10 cm respectively. The observations were recorded replication wise by selecting 5 random plants for investigation for the morphological and yield parameters, growth analytical attributes, physiological traits, biochemical estimations and phenological development phases. The pooled data was statistically analysed through strip plot design. (Dr S.R.S.Chandel - A Hand book of agricultural statistics).

The important findings obtained from the present investigation are summarized below:

Morphological and Yield attributing characters

The rice seed yield and its attributing components viz., plant height, number of productive tillers per m², number of panicles per plant, number of spikelets per m², number of seeds per panicle, spikelets dry weight (g) per panicle, seed yield and biological yield (kg/ha), harvest index (%) and seed index (g) etc. given the good performance in irrigated situations. Among all conditions significantly superior variety Kranti observed maximum plant height under irrigated

conditions at all the stages, while JGL-3844 had minimum plant height under rainfed conditions during tillering and maturity stages. Significantly maximum number of productive tillers m^{-2} noted in variety PS-5 under irrigated situations, while the number of panicles per plant observed in variety PS-4 under irrigated and semi irrigated conditions. Significantly maximum number of spikelets m^{-2} and number of seeds per panicle obtained in variety Kranti under irrigated conditions. While the spikelets dry weight (g) per panicle higher in variety Mahamaya under irrigated conditions.

Among irrigated treatment better performed in seed yield. Significantly superior varieties Kranti, IR-64, Mahamaya, and MR-219 good performance than JGL-3844, PS-4, PS-5, WGL-32100. No significance differences observed between semi irrigated and rainfed in biomass yield. However, semi irrigated produced significantly grain yield than rainfed treatments. The highest biomass yield noted in varieties Kranti and MR-219 under irrigated circumstances. The harvest index was similar in irrigated and semi irrigated situations. While, it was recorded 21.38% in rainfed conditions significantly higher HI in variety IR-36 under semi irrigated situations and the seed index maximum in variety Mahamaya under irrigated conditions.

Growth analytical characters

A linear pattern of LAI accumulation was attained with advancement of crop age and maximum LAI measured at 90-105 DAS under irrigated situations and thereafter sharply declined. Maximum LAI noted in Kranti under irrigated regimes. While LAD also higher at 90-105 DAS and thereafter sharply declined. Maximum LAD observed in variety Kranti under irrigated conditions. SLA had a linear decreased while SLW showed a stable trend during crop growth period. Significantly maximum SLA noted at 75-90 DAS thereafter it decreased sharply during 90 DAS to maturity stage. Maximum SLA noticed in variety PS-4 under rainfed situations. A differential pattern of SLW was increased upto 30-45 DAS and thereafter declined sharply during 45-60

DAS, 60-75 DAS and again increased during 75 DAS to maturity stage. Maximum SLW obtained by variety WGL-32100 under irrigated situations. CGR exhibited an increasing trend upto 75-90 DAS and thereafter sharply declined. Maximum CGR observed in variety Kranti under irrigated conditions as compared to other treatments. An increase in RGR was noted upto 30-45 DAS thereafter it decreased during 75-90 DAS and further again increased during 90-105 DAS under conditions. Maximum RGR expressed in variety JGL-3844 under semi irrigated conditions.

Physiological aspects for drought tolerance

PAR, net photosynthesis, transpiration rate and stomatal conductance, C_i , WUE, QUE, carboxylation efficiency etc. significantly reduced under irrigated conditions and its increased in rainfed situations but were found to be low grain yielders because of low harvest index, more number of ill filled grains per plant under rainfed upland conditions. While PAR, net photosynthesis, transpiration rate and stomatal conductance in variety Mahamaya maintained higher value under semi irrigated and rainfed situations and C_i , WUE, QUE, carboxylation efficiency etc. maximum in varieties JGL-3844, Kranti, PS-5 and Mahayama under semi irrigated and rainfed situations. These traits are important indicators for drought tolerance.

The photosynthetic pigment content in rice leaves differed significantly during tillering and flowering stages. At physiological maturity stage, chlorophyll content decreases from content at flowering stage with a range 16.58 to 28.31 except Mahamaya planted under different irrigation regimes. Significantly higher chlorophyll content was measured in variety Mahamaya at tillering stage under irrigated situations. Which also higher reduce chlorophyll content under drought conditions.

The physiological parameters viz., RLWC, WSD, DSI etc. also indicates for drought tolerance. The relative leaf water content varied significantly among rice varieties under different irrigation regimes. At tillering

stage varieties Kranti maintained higher RLWC under irrigated conditions and thereafter decreased in variety IR-64 maximum obtained higher RLWC under irrigated conditions at flowering stage. This important trait showed that maintained higher cell water content under different irrigation regimes. Water saturation deficit was higher in variety PS-4 under rainfed situations at tillering and flowering stage. The DSI significantly higher in variety Kranti under semi irrigated conditions.

Biochemical estimation

Seed quality parameters were significantly influenced by drought during seed development stage. Variety Kranti had higher seed nitrogen content and seed protein percent was estimated under irrigated regimes and leaf proline content influence expect JGL-3844 under rainfed circumstances. Whereas maximum carbohydrates were estimated in variety WGL-32100, PS-5 and MR-219 under semi irrigated conditions as carbohydrate metabolism play an important role in tolerance to stress.

Phenological development phases

In general, a short photoperiod accelerates and a long photoperiod delays flowering under rice plants. However, do not respond to photoperiod during the vegetative period from sowing to flowering. Among irrigated conditions had maximum days for maturity but rainfed regimes indicate minimum days for maturity. The tiller initiation had maximum days required in variety PS-4 under irrigated and minimum in IR-64 and Kranti under rainfed situations. Panicle initiation and 50% panicles observed maximum days required in variety MR-219 under irrigated conditions and minimum days required in IR-64 and WGL-32100 under semi irrigated and rainfed circumstances. The flower initiation and 50% flowered exhibited maximum days required in varieties JGL-3844 and WGL-32100 under irrigated conditions than minimum in variety IR-36 under rainfed situations. The physiological maturity had maximum days to required in variety PS-5 under irrigated than minimum in variety MR-219 under rainfed situations.

Conclusion

It may be concluded from this investigation that the different irrigation regimes has an additive effect on all phenological development, physiological, biochemical as well as morphological yield attributing parameters and seed yield of rice varieties. The irrigated treatment had good performed in all parameters than semi irrigated and rainfed treatments.

Varieties kranti and Mahamaya higher tolerance capacity among the cultivars studied and this could be attributed to higher accumulation of proline.

The cultivars like PS-4, PS-5, JGL-3844 and WGL-32100 were susceptible to low moisture level.

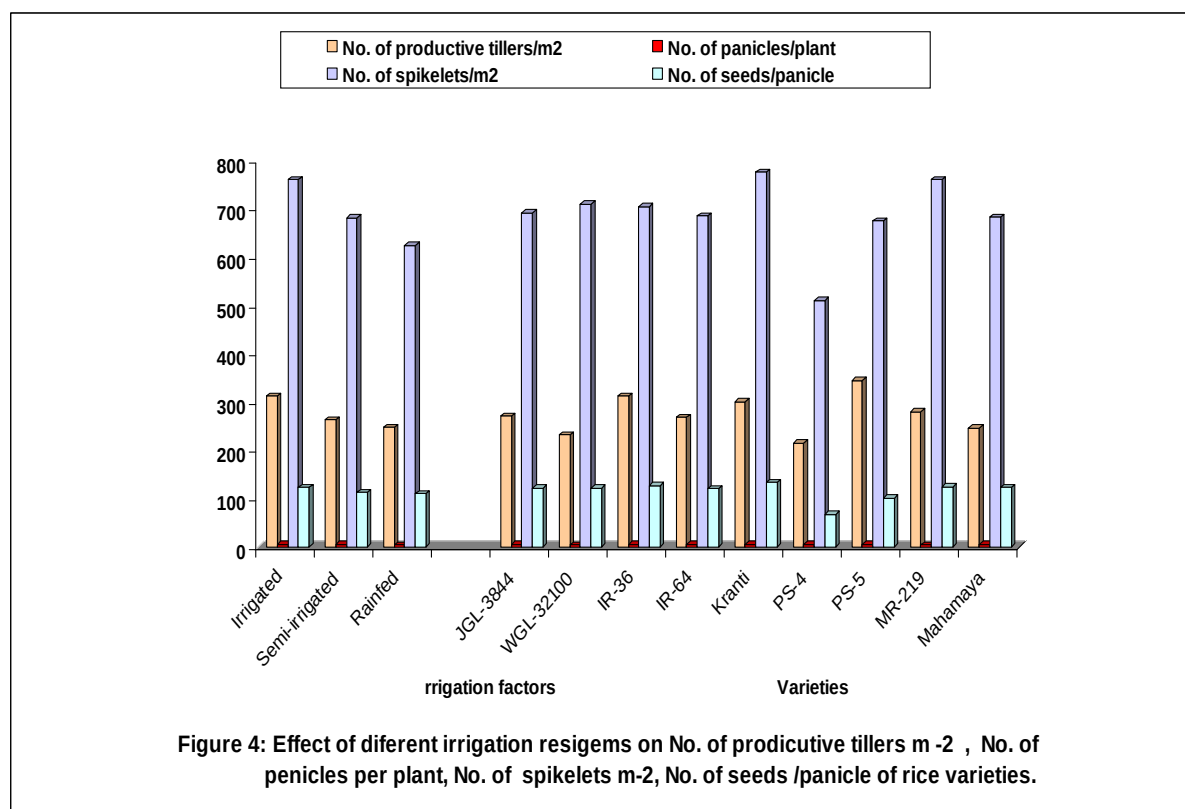
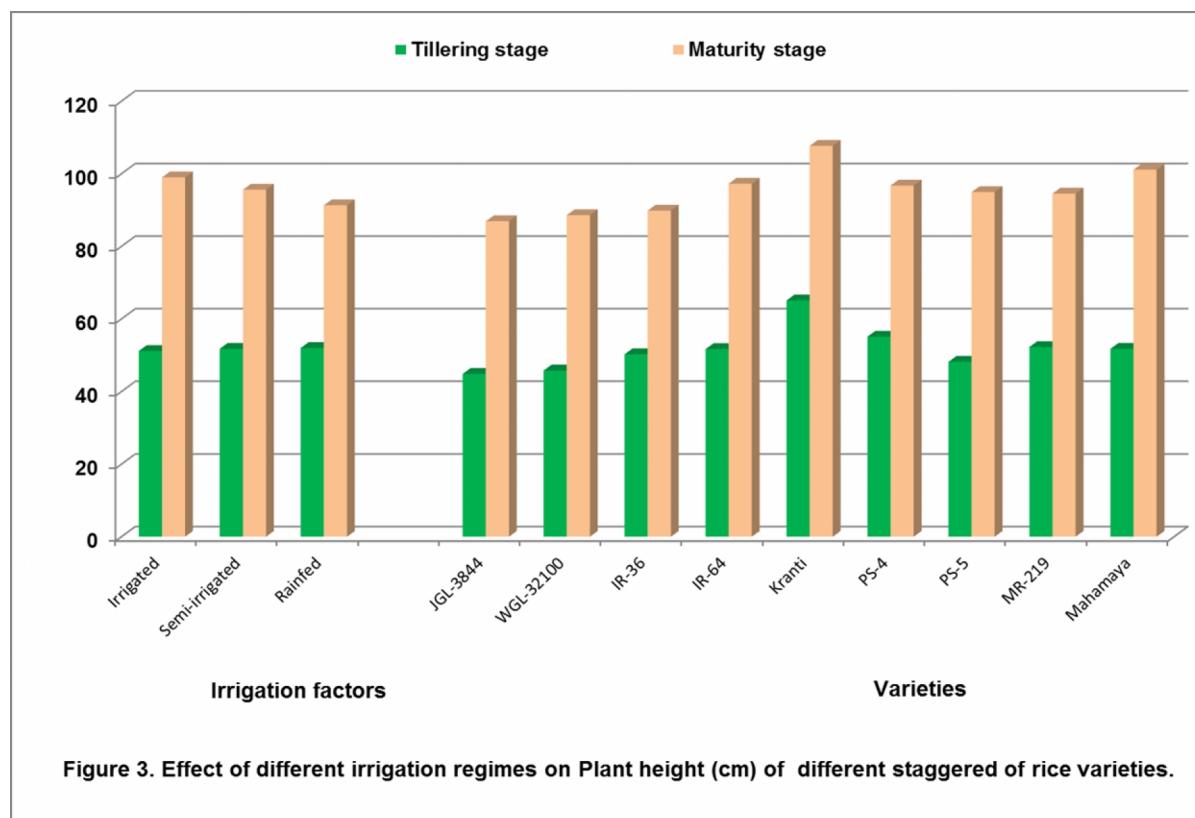
The susceptible cultivars invariably reflected less favorable plant water status; more metabolic de-arrangement in terms of chlorophyll and carbohydrate loss and depressed level of RLWC and increased level of WSD, DSI, Transpiration rate, Stomatal conductance. Therefore reduced seed yield of rice varieties.

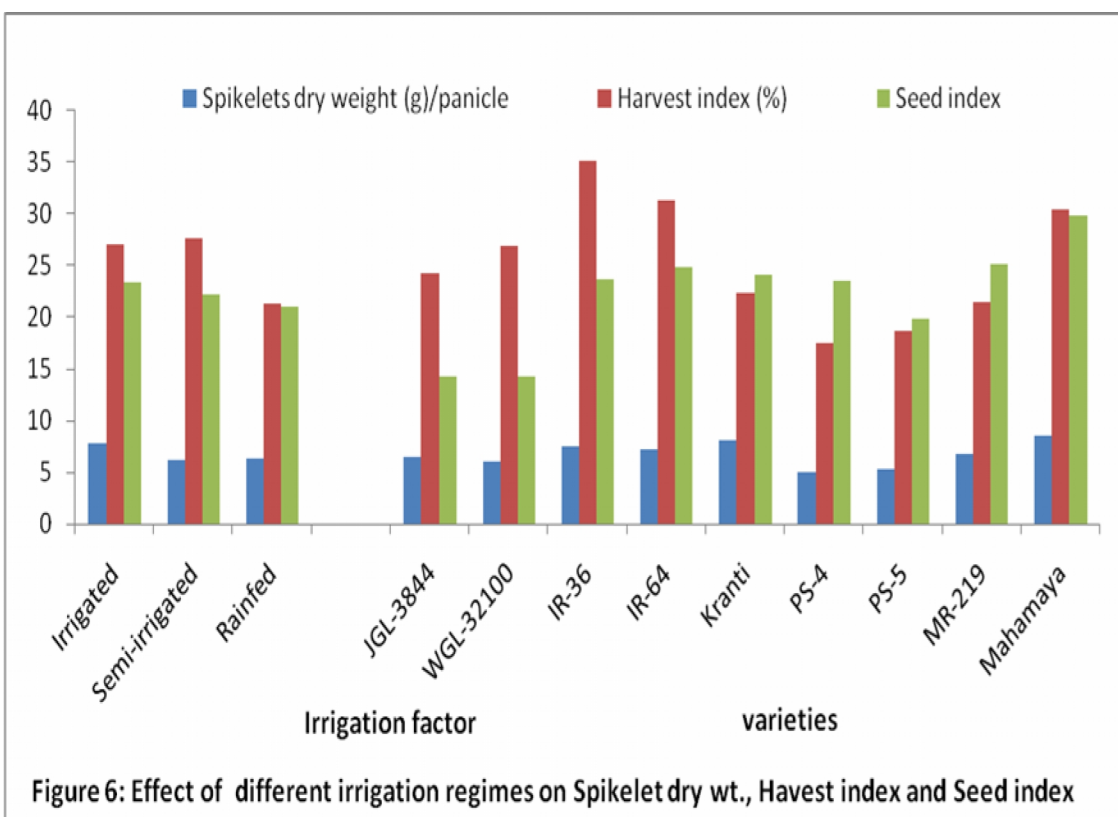
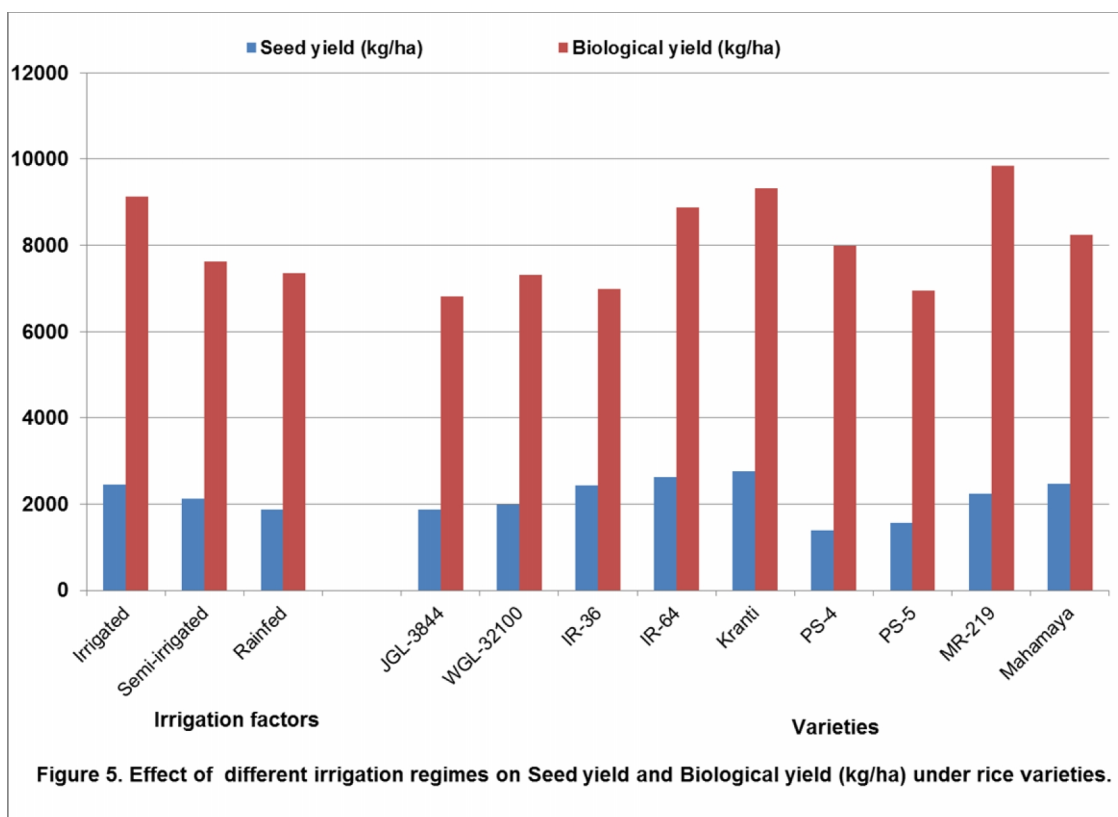
The capacity to sustain plant function at low plant water status is a rare occurrence in crops.

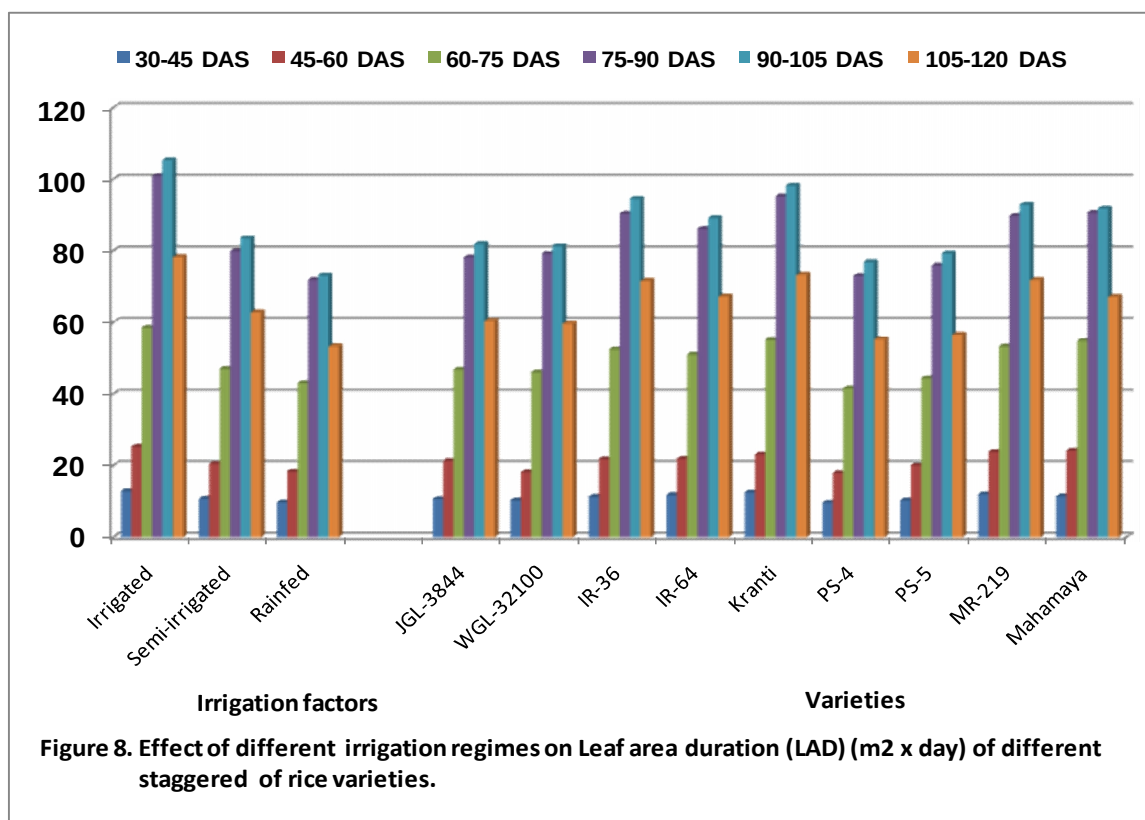
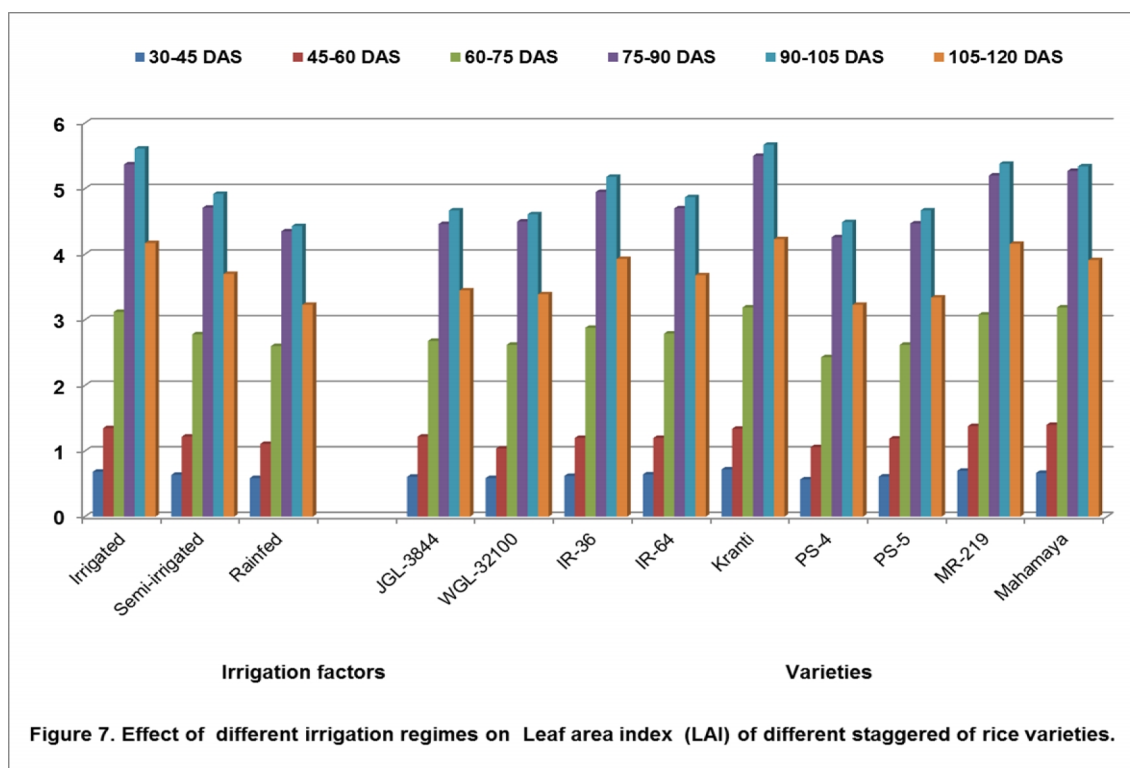
Therefore, varietal differences in plant function under moisture stress can be utilized for enhancing seed quality and plant productivity.

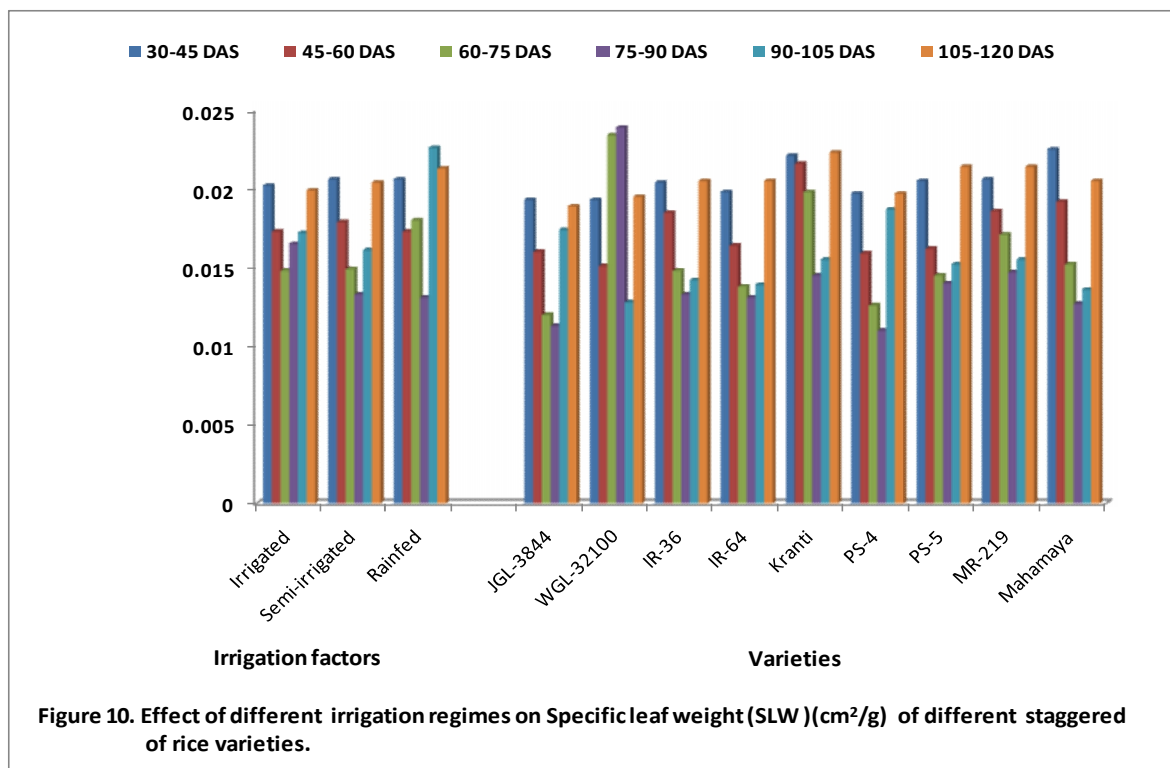
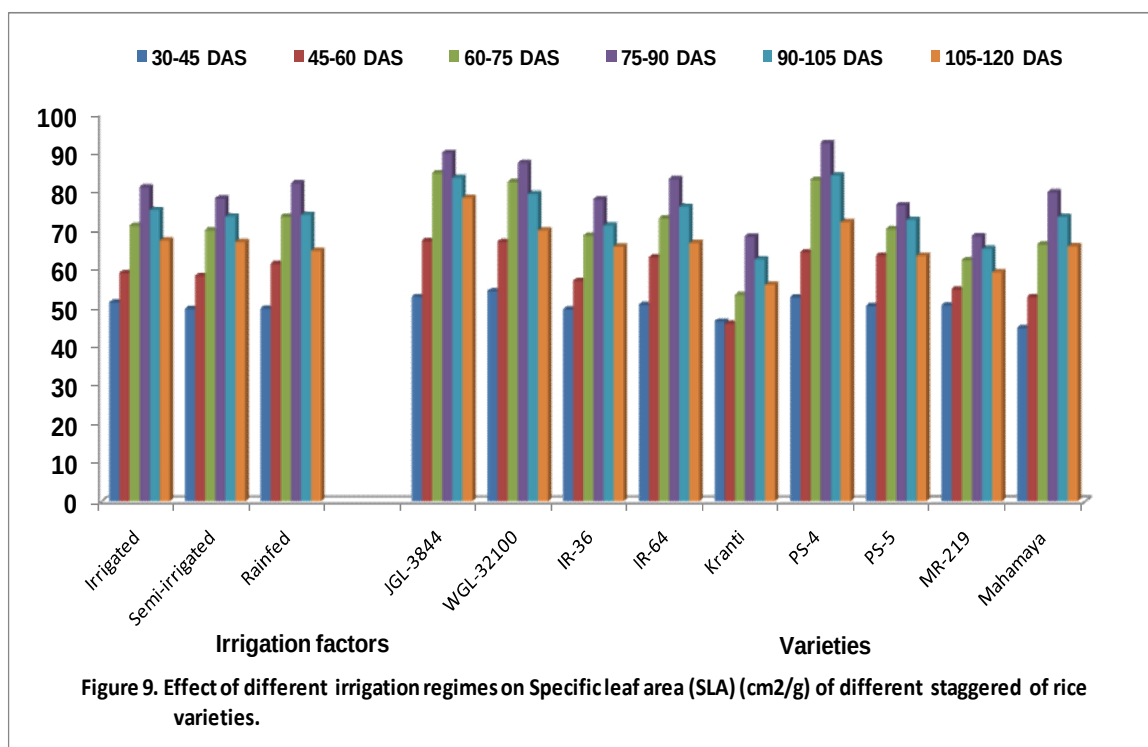
Suggestion for further research work in future

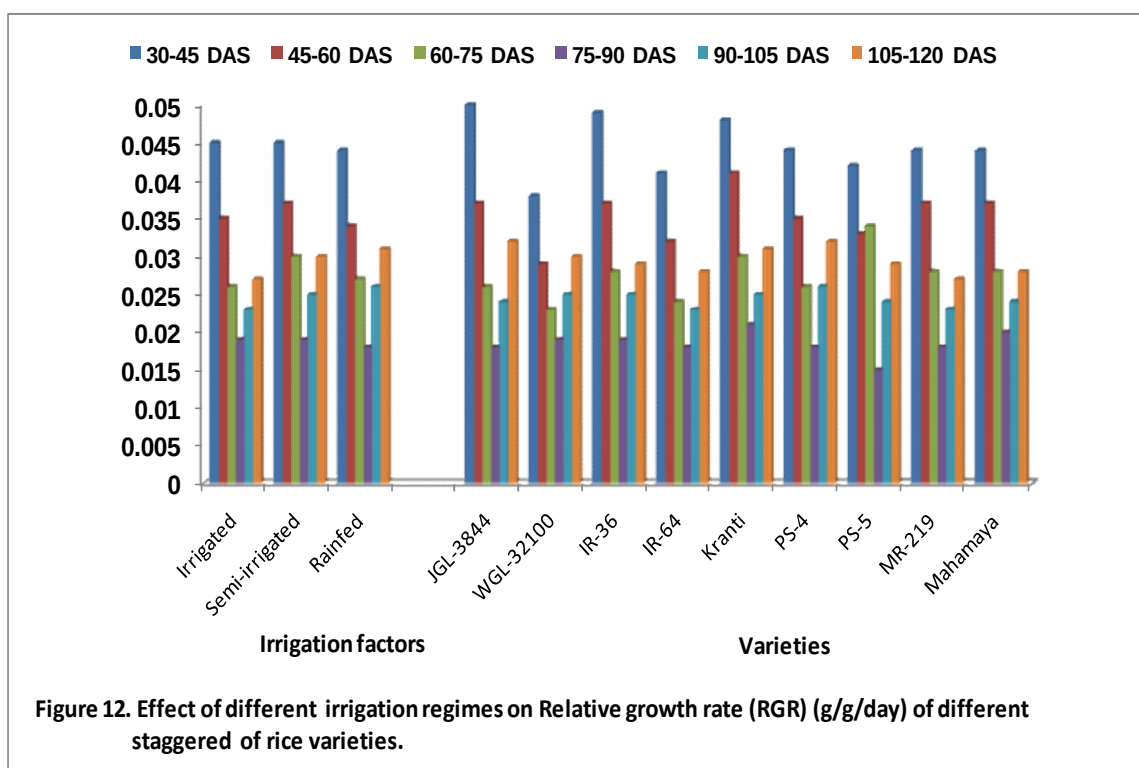
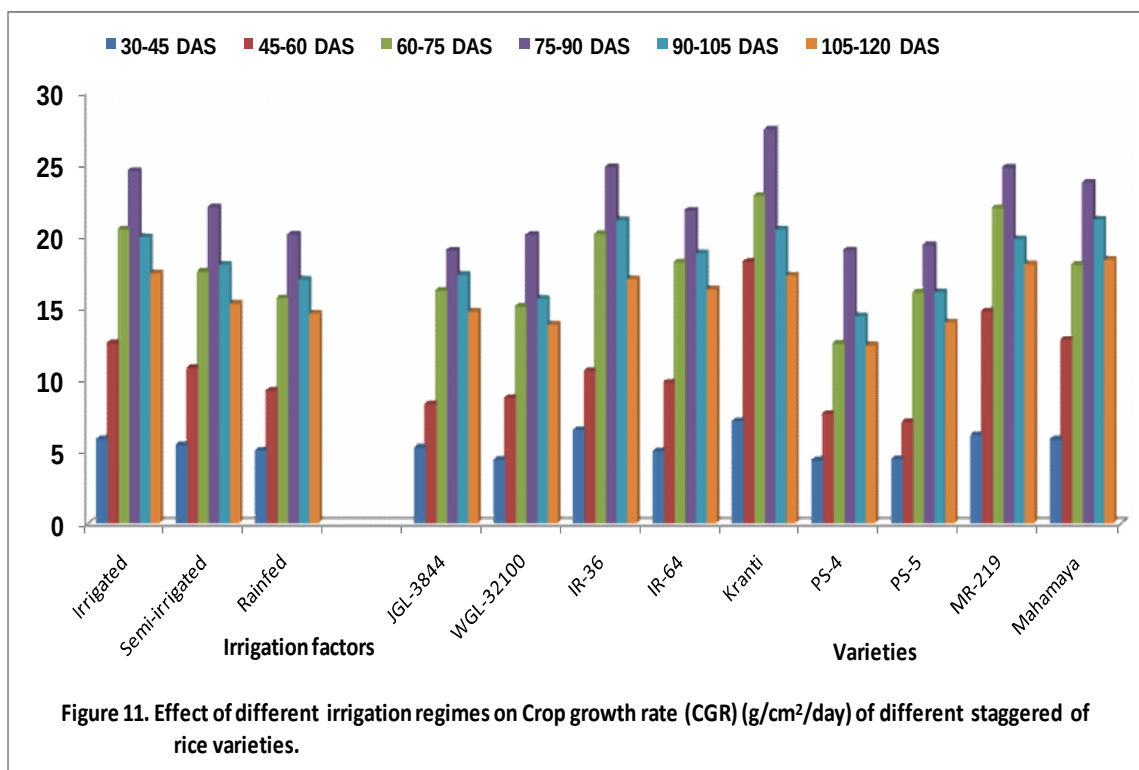
1. To confirm the results under rainfed upland condition in the changing climatic conditions, the experiment should be repeated for a few more years.
2. To exploit the full potential of rice more varieties should be tested.

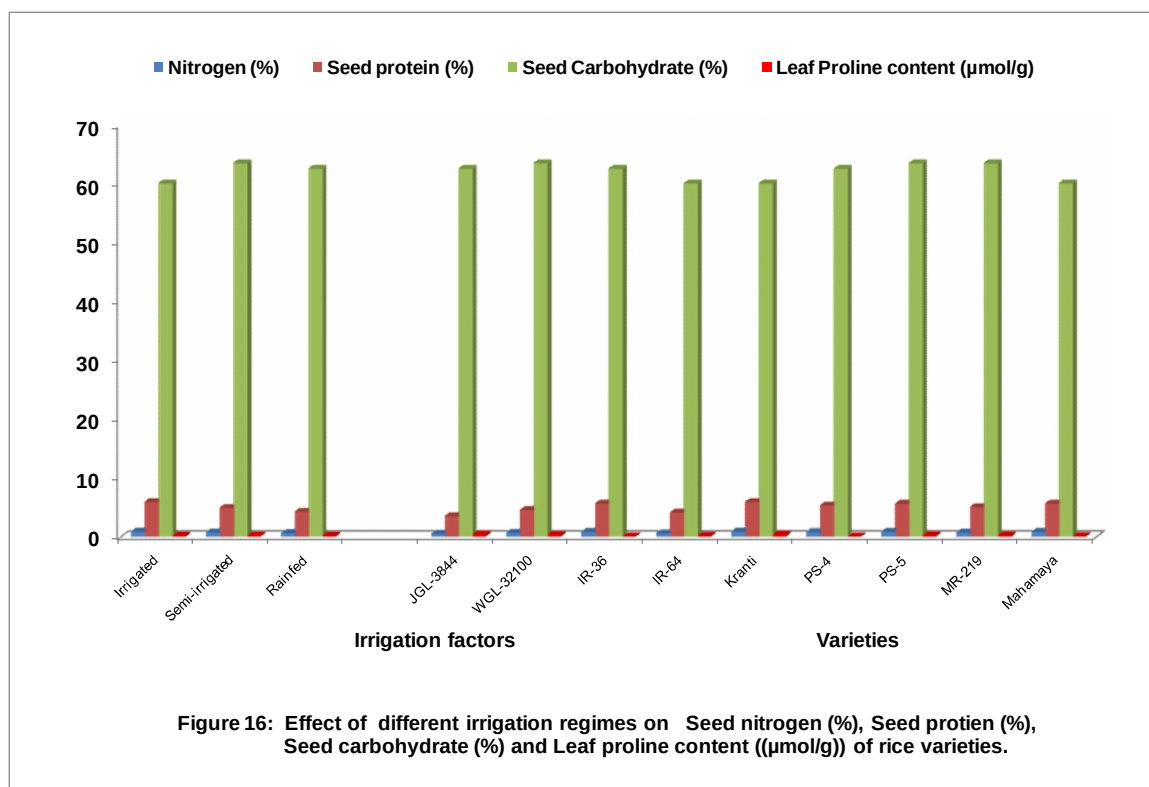
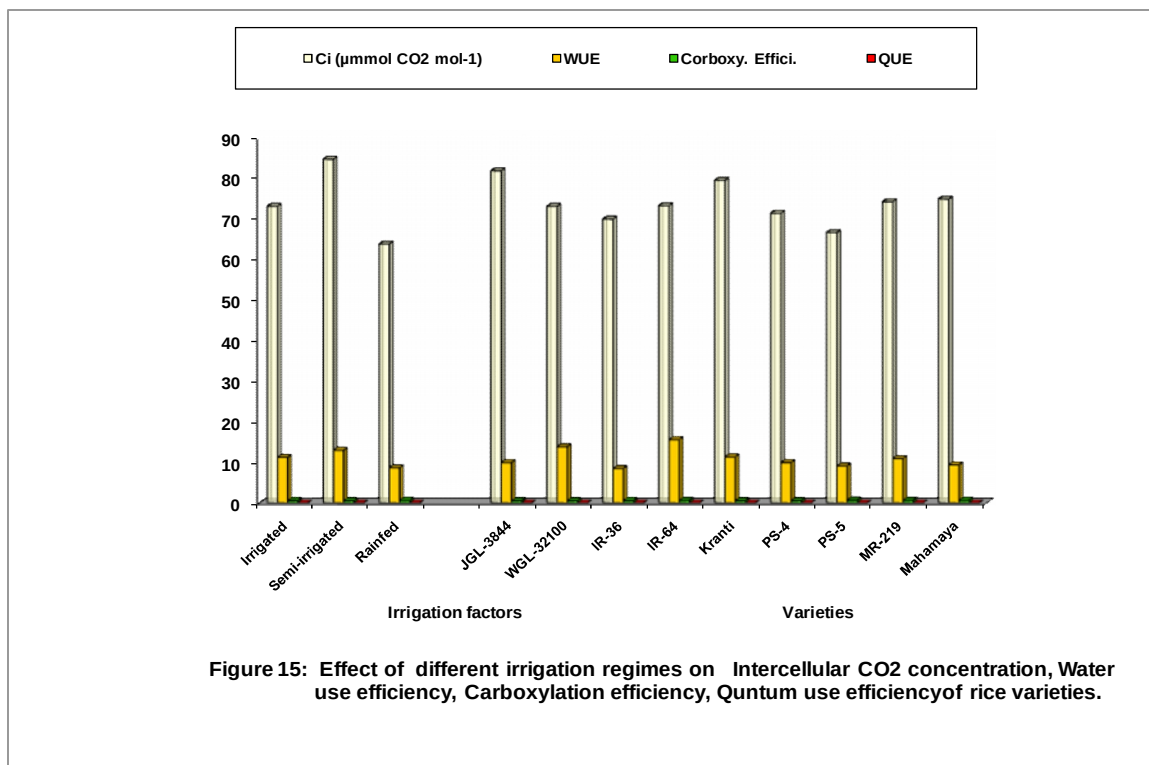


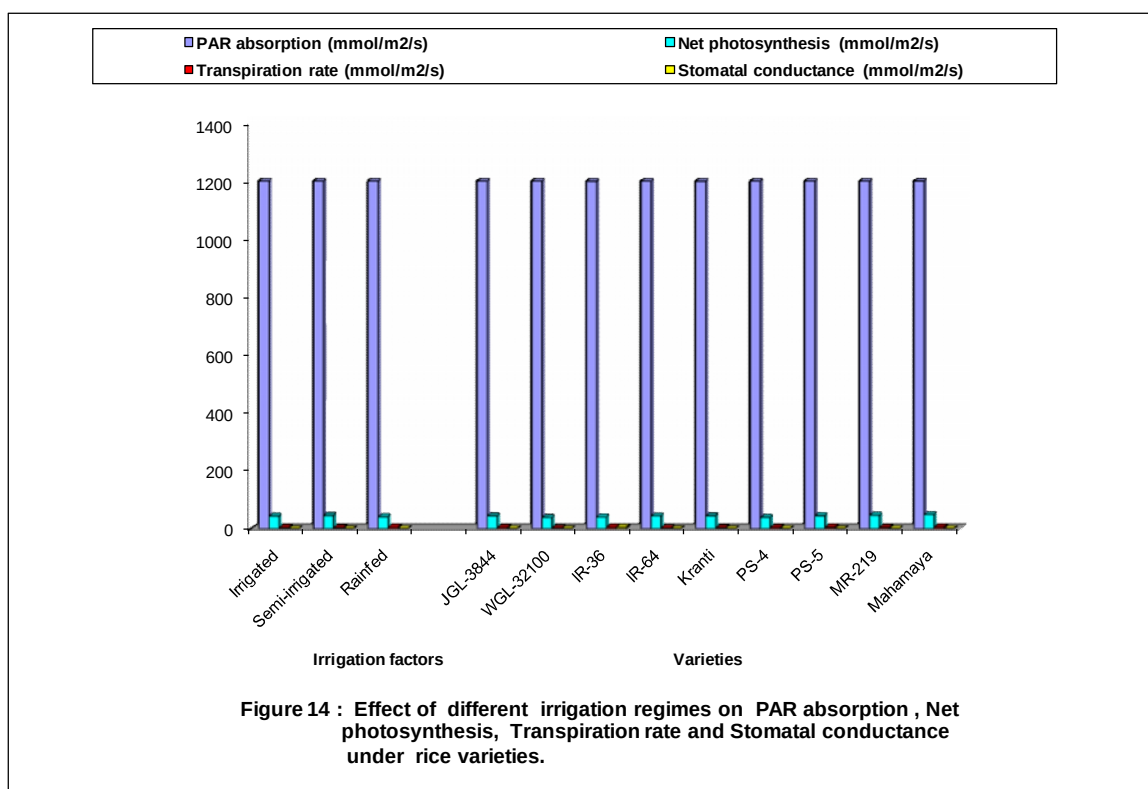
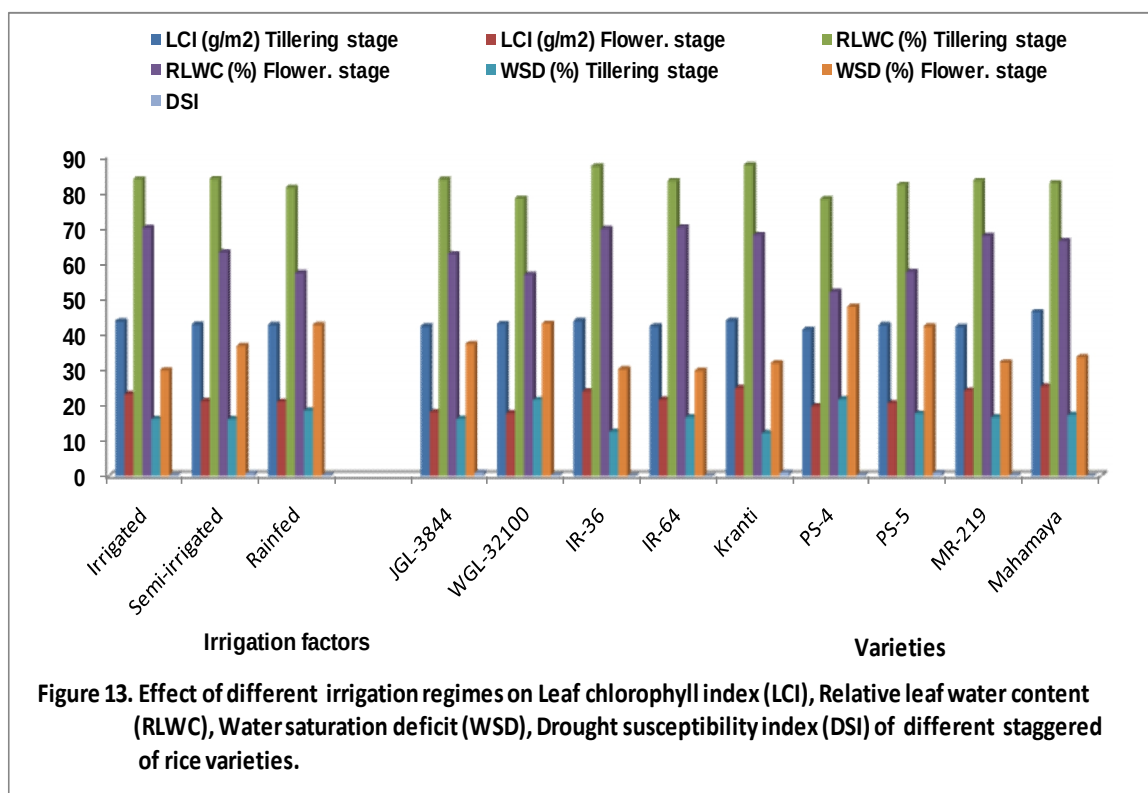












■ Days to tiller Initiation
 ■ Days to panicle initiation
 ■ Days to 50% Panicle
■ Days to Flower initiation
 ■ Days to 50% Flowering
 ■ Days to physio. maturity

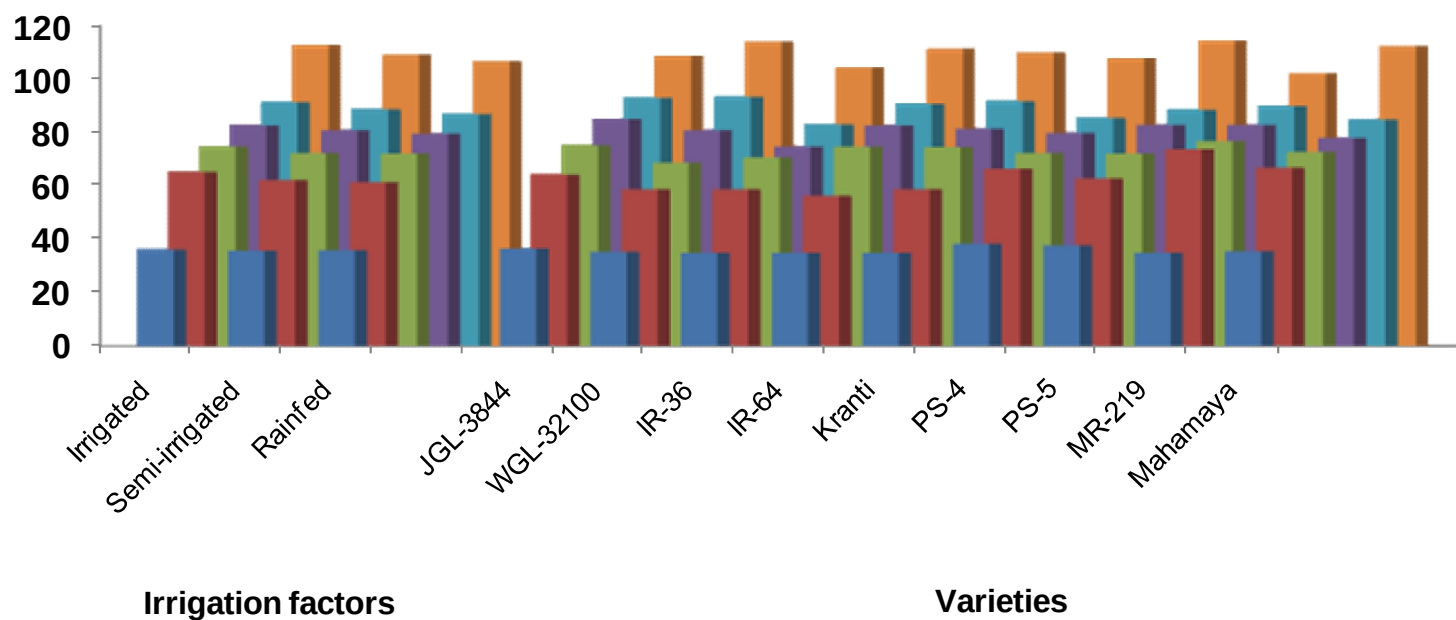


Figure 17: Effect of different irrigation regimes on Phenophases development of rice varieties.

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APPENDICES

1. Morphological Parameters

Source of variation	d.f.	Plant height at 60 DAS	Plant height at maturity	No. of producti. tillers/m ²	No. of panicle/ pl.	No. of spikelets/ m ²	No. of seeds/ panicle
Replicaion	2	4.87	0.26	364.51	3.35	3560.38	2.93
MP1	2	4.88	398.83	30910.91	1.88	126968.28	1298.30
Error A	4	10.10	0.75	129.26	2.95	2652.05	1.05
MP2	8	323.83	381.08	14800.53	0.46	51408.32	3640.45
Error B	16	19.33	1.31	155.54	0.86	1279.30	1.43
Intereaction	16	17.98	36.54	854.68	0.61	870.10	135.81
Error C	72	3.95	0.39	67.53	0.37	641.80	1.09

2. Yield Attributing Parameters

Source of variation	d.f.	Spikelets dry weight (g)/panicle	Seed index/ 1000 seed weight	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Replicaion	2	0.14	0.55	2960.33	1280713.66	0.95
MP1	2	9.45	37.35	2374485.04	24293082.13	319.21
Error A	4	0.21	1.04	6452.54	611676.69	2.29
MP2	8	12.54	238.46	2037999.09	11197567.37	328.79
Error B	16	0.10	0.65	15395.07	201310.43	2.14
Intereaction	16	0.47	2.51	128080.34	1382367.57	64.86
Error C	72	0.05	0.38	3948.82	114869.75	1.11

3. Biochemical Parameters

Source of variation	d.f.	Nitrogen (%)	Seed protein (%)	Seed Carbohydrate (%)	Leaf Proline content (μmol/g)
Replicaion	2	0.012	0.63	0.560	0.137
MP1	2	0.503	19.06	85.113	0.009
Error A	4	0.000	0.01	0.203	0.122
MP2	8	0.153	5.95	24.372	0.173
Error B	16	0.000	0.00	0.205	0.054
Intereaction	16	0.088	3.57	27.764	0.089
Error C	72	0.000	0.00	0.098	0.024

4. Functional attributes (growth analysis)

LAI

Source of variation	d.f.	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	Physio. maturity
Replicaion	2	0.00063	0.0029	0.011	0.0116	0.02	0.031
MP1	2	0.06106	0.3737	1.846	7.2788	9.59	6.038
Error A	4	0.00022	0.0003	0.001	0.0032	0.01	0.006
MP2	8	0.02355	0.1527	0.665	1.7003	1.56	1.240
Error B	16	0.00039	0.0013	0.004	0.0069	0.01	0.007
Intereaction	16	0.00500	0.0312	0.154	0.3788	0.38	0.161
Error C	72	0.00020	0.0009	0.002	0.0035	0.01	0.003

LAD (m².day)

Source of variation	d.f.	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	Physio. maturity
Replicaion	2	0.29	1.46	3.78	8.02	11.46	15.76
MP1	2	67.44	335.70	1735.66	6038.09	7280.83	4285.07
Error A	4	0.14	0.57	3.42	8.81	5.93	2.28
MP2	8	7.76	46.16	218.69	554.50	523.37	432.09
Error B	16	0.26	0.76	4.78	13.43	13.66	7.30
Intereaction	16	1.23	9.02	37.45	82.18	77.17	32.14
Error C	72	0.13	0.64	1.96	4.70	5.50	2.56

SLA (cm²/g)

Source of variation	d.f.	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	Physio. maturity
Replicaion	2	0.58	1.13	0.82	0.39	2.07	1.00
MP1	2	23.89	71.59	88.17	108.51	21.31	55.76
Error A	4	1.11	0.50	1.69	1.49	5.23	2.52
MP2	8	83.34	479.56	994.77	681.04	502.50	404.91
Error B	16	1.32	1.07	2.77	1.72	1.41	1.99
Intereaction	16	69.26	53.70	85.75	99.06	93.52	63.53
Error C	72	0.43	0.74	0.46	0.88	0.58	0.62

SLW (g/cm²)

Source of variation	d.f.	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	Physio. maturity
Replicaion	2	0.000002	0.000002	0.000100	0.000162	0.001326	0.000002
MP1	2	0.000001	0.000013	0.000091	0.000103	0.000543	0.000013
Error A	4	0.000002	0.000001	0.000130	0.000150	0.000390	0.000001
MP2	8	0.000012	0.000040	0.000120	0.000133	0.003570	0.000010
Error B	16	0.000001	0.000002	0.000133	0.000141	0.001200	0.000001
Intereaction	16	0.000010	0.000005	0.000106	0.000149	0.000256	0.000002
Error C	72	0.000001	0.000011	0.000052	0.000065	0.000103	0.000001

CGR (g/cm²/day)

Source of variation	d.f.	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	Physio. maturity
Replicaion	2	0.01	1.91	1.69	0.83	0.22	3.72
MP1	2	4.14	73.19	155.24	133.48	59.94	58.07
Error A	4	0.08	0.17	1.03	0.76	2.34	2.20
MP2	8	8.85	123.73	99.76	85.27	57.27	39.47
Error B	16	0.38	1.50	1.98	2.29	3.12	2.27
Intereaction	16	0.44	3.64	2.07	1.65	1.86	4.63
Error C	72	0.08	0.42	0.44	0.55	0.34	0.56

RGR (g/g/day)

Source of variation	d.f.	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90-105 DAS	Physio. maturity
Replicaion	2	0.000001	0.000001	0.000002	0.000007	0.000003	0.000002
MP1	2	0.000012	0.000053	0.000095	0.000005	0.000062	0.000128
Error A	4	0.000001	0.000002	0.000004	0.000006	0.000004	0.000001
MP2	8	0.000143	0.000109	0.000101	0.000021	0.000010	0.000030
Error B	16	0.000002	0.000003	0.000003	0.000006	0.000001	0.000001
Intereaction	16	0.000109	0.000133	0.000083	0.000024	0.000034	0.000021
Error C	72	0.000001	0.000001	0.000002	0.000003	0.000001	0.000001

5. Physiological Parameters

SOURCE	d.f.	Chloro. 45-60 DAS	Chloro. 90-105 DAS	RWC 45-60	RWC 90-105	WSD 45-60 DAS	WSD 90-105 DAS	DSI
Replicaion	2	0.71	2.31	0.27	0.21	0.27	0.21	0.02
MP1	2	8.61	36.20	53.62	1093.36	53.62	1093.36	2.81
Error A	4	2.12	1.94	0.53	0.12	0.53	0.12	0.01
MP2	8	19.93	76.10	98.23	384.06	98.23	384.06	1.71
Error B	16	1.11	0.98	0.40	0.64	0.40	0.64	0.02
Intereaction	16	1.60	2.72	10.30	16.91	10.30	16.91	0.37
Error C	72	0.26	0.28	0.28	0.20	0.28	0.20	0.00

6. Physiological traits

Source of variation	d.f.	PAR	Net Photosynthesis	Transpiration rate	Stomatal conductance
Replicaion	2	2.57	0.37	0.16	0.00
MP1	2	0.01	121.96	24.24	0.49
Error A	4	1.72	0.04	0.17	0.00
MP2	8	0.61	101.89	11.24	0.07
Error B	16	0.28	0.57	0.13	0.00
Intereaction	16	0.89	51.52	3.29	0.06
Error C	72	0.20	0.33	0.10	0.00

7. Other physiological traits

Source of variation	d.f.	Intercellular CO ₂ concn. (μmmol CO ₂ mol ⁻¹)	WUE	Corboxy. efficiency	Quantum efficiency
Replicaion	2	0.51	1.30	0.0002	0.0000003
MP1	2	2957.27	129.52	0.0984	0.0000848
Error A	4	2.75	1.05	0.0022	0.000008
MP2	8	193.30	49.64	0.0237	0.0000706
Error B	16	1.67	0.69	0.00010	0.0000004
Intereaction	16	259.54	10.05	0.0274	0.0000357
Error C	72	0.98	0.61	0.0006	0.0000002

8. Phenological development

Source of variation	d.f.	Days to tiller Initiation	Days to panicle initiation	Days to 50% Panicle	Days to Flower initiation	Days to 50% Flowering	Days to physio. maturity
Replicaion	2	1.94	1.93	0.60	0.46	0.75	0.04
MP1	2	1.38	116.04	58.01	64.68	134.12	245.78
Error A	4	1.14	0.07	0.27	0.57	1.42	1.37
MP2	8	16.73	273.83	55.79	83.62	125.26	158.94
Error B	16	0.41	0.65	0.77	0.73	1.25	1.27
Intereaction	16	1.06	10.26	4.72	3.00	4.46	5.31
Error C	72	0.29	0.35	0.52	0.34	0.38	0.78

VITA

The author of this thesis Mr. Dharmendra Patidar is the youngest among the four childrens of Shri Hansraj Patidar and Smt. Suman Patidar. Dharmendra was born on 6th June 1986 at Sundrel, District Dhar. Dharmendra passed his High School examination in the year 2002 with 68.7 percent in Boys Higher Secondary School Sundrel and Higher Secondary School examination in the year 2004 with 67.51 percent from Boys Government Higher Secondary School Dhamnod, District Dhar, Madhya Pradesh.

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