Understanding on Climate Resilient Practices for Rainfed Rice-A Review

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ABSTRACT

Rice is one of the major staples feeding around 3.5 billion people in the world. Rainfed rice area account for 33% of the total world rice production. Its cultivation is vulnerable to changes in temperature and rainfall. Due to global climate changes, it is essential to analyze and characterize the weather parameters like rainfall, temperature, solar radiation etc., over a region for identifying location specific sowing time. A scientific approach based on appropriate understanding of weather resources and its application for efficient crop management can help in achieving higher productivity. Various studies revealed that changes in microclimate by altering sowing dates has great role to play during vegetative and reproductive stages of the crop and also nutrient content and its uptake which ultimately affects the yield potential. Studies also showed that delayed sowing and transplanting time can significantly affect on the infestation of pest and diseases.

Key words: Climate resilient, Meteorological indices, Microclimate, Rainfed rice.

The most significant impacts of climate change are likely to be borne by small-holder rain-fed farmers who constitute the majority of farmers in the country and possess low financial and technical capacity to adapt to climate variability and change. Farmers can adapt to climate change to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations. Many researchers have shown that changing the planting date of rice from present practice could be a very good solution to improve rice yield under the impacts of climate change (Tripathy et al., 2009).

Rice is one of the most important food crops and feeds more than 60 per cent population of India. In India it occupies an area of 43.79 million ha with a production of 116.42 million tones and productivity of 2659 kg/ha (Anonymous 2019). It is grown under diverse soil and climatic conditions. It is one of the major crops grown and consumed in rainfed areas and rainfed cultivation accounts for about 25% of global rice production. The rainfed rice area constitutes 12.9 m ha in Eastern India including the states of Odisha, West Bengal, Jharkhand, Assam, Chhattisgarh and Bihar. Due to its dependence on climate, rainfed rice cultivation is vulnerable to changes in temperature and rainfall. The productivity level of rice is low compared to the productivity levels of many countries in the world. About 90 per cent of the cultivated land belongs to marginal, small and medium farmers which are another constrain in increasing the productivity of rice in the country. Therefore, there is ample scope to increase the productivity of rice in the country. There are improved technologies and various interventions which could be adapted to increase the productivity in the country. Cultivation of hybrid rice has potential to increase the productivity and needs to be promoted.

Sowing time significantly affect on the infestation of different pest and diseases in rice. Hong-xing et al. (2017) reported that the sowing time of rice has significant effects on the occurrence of virus diseases (rice stripe virus disease and black streaked dwarf virus disease) transmitted by the small brown plant hopper. The occurrence of small brown plant hopper (SBPH) and the virus diseases transmitted by them are significantly reduced by postponing the sowing time to late May or early June with no significant difference in the grain yield (Sun et al., 2008). Delayed sowing and transplanting time significantly reduced the density and damage of SBPH in transplanted and directly seeded rice fields (Zhu et al., 2011). Early planted rice had lower pests and natural enemy’s population than later-transplanted rice (Magunmder et al., 2013).

Generation of information regarding the influence of microclimatic regimes on the productivity of the crops is important to the farmers. The literature on effect of microclimatic regimes on performance of the rice-based cropping system as a whole in particular is very meager. However, research information generated elsewhere on the...
Effect of microclimatic regime on rice regarding growth, yield and their relationship with agro-meteorological parameters have been illustrated in this review.

Effect of microclimatic regimes on growth of rice

It is well known fact that crop performance is the result of combined effect of genetic traits which it inherits and the environment to which it is exposed. Proper planting time influences crop growth and ultimately lead to better yield. Environmental condition acts as a factor, affecting yield related properties of rice in different planting dates. Various studies have revealed that delayed sowing affect various physiological as well as yield related parameters which ultimately lead to the poor production of the grain yield. Pillai (1958) reported that if planting is delayed beyond a known critical planting period, the yield is very much affected. The proportion of decrease in yield, increase progressively with the delay in planting and very late planted crop gives less than half of its normal yield. Ali and Rahman (1992) reported that planting date affects the genetic efficiency of rice in environmental resources consumption, the selection of appropriate planting date is of high importance for optimum rice production. Benefits of choosing optimum planting dates in rice was reported by different workers viz., Habibullah et al. (2007); Saffdar et al., (2013); and Laborte et al., (2012). They reported that sowing dates provides differential growth conditions such as temperature, precipitation and growth periods, yet out of these; temperature is the key factor which affects the sowing dates and time in medium grain rice. Difference in sowing time or date effects on plant growth parameters was reported by different workers. Ghosh and Singh (1998) stated that leaf area index at flowering showed yield variation of 79 per cent in delayed planting by 15 days which drastically affected leaf area index of rice. Farrell et al. (2003) also reported thermal and photoperiodic conditions significantly affect the vegetative and reproductive development of the crop. Nayak et al. (2003) reported that early planting on 16 July exhibited the maximum total and effective tillers/clump, LAI and dry matter accumulation compared to planting on 31 July and 16 August. One month delay in planting from 16 July reduced total tillers number, leaf area index and dry matter accumulation by 38, 13 and 18 per cent, respectively. Dixit et al. (2004) also observed that rice crop planting on 25 June showed significantly more number of leaves at 60 days after sowing (DAS) than that of crop planting on 5, 10 and 15 June. El-Khoby (2004) showed that delaying sowing date sharply decreased the leaf area index, dry matter production and chlorophyll content. In addition, delaying sowing date up to June 15th significantly reduced days to heading. Abou Khalifa (2005) found that number of days from sowing up to maximum tillering, panicle initiation and heading date was significantly affected by different sowing dates and was recorded higher under early sowing (April 20th) and gradually decreased with delaying sowing (up to May 20th). Rai and Kushwaha (2008) reported that plant height reduced significantly due to delay in planting from 15th June to 15th July during both the years of 1997 and 1998. This reduction might be due to decrease in photoperiod available at active growth phases. Similar results were also reported by Khalifa and El-Rewainy (2012). They found that number of days from sowing up to maximum tillering, panicle initiation and flowering stage were gradually decreased by delaying of sowing dates from April 1st up to May 10th. They also showed that April 1st date of sowing gave the highest value of roots length (cm), leaf area index, no. of tillers/hill at panicle initiation stage, except light penetration at heading which was the lowest value and the root length and leaf area index were gradually decreased by delaying of sowing dates from April 10th up to May 10th. Khalil et al. (2013) found that under delayed dates of sowing the leaf area index and leaf area duration decreased gradually. Moradpour et al. (2013) observed that in June 9th transplanting higher leaf area index was obtained after 50 to 55 days of planting and low leaf area index was produced after 50 days of planting when the crop was transplanted on May 30th. Dawadi and Chaudhary (2013) observed that rice crop sown on June 13 produced significantly higher plant height, higher number of tiller/m², leaves/tiller, leaf area index and total dry matter as compared to the sowing of crop on the later dates.

Gu Lang et al. (2014) studied the effects of sowing date on the yield and production characteristics of hybrid japonica rice Chunyou 84 and found that along with the delaying of sowing dates, the growth process of rice variety Chunyou 84 was correspondingly delayed and growth stages were significantly shortened. They also reported that the yield of Chunyou 84 was highest when the sowing date was on May 10th, the decreasing range of yield increased with the delaying of sowing date. The dry matter distribution in panicles significantly declined as sowing is delayed. Haque et al. (2015) reported that early planting of hybrid rice caused rapid expansion of leaf area resulted in higher leaf area index just after the heading stage. Tiwari et al. (2015) reported that earliest sowing produced significantly higher growth characters of rice as compared to the sowing of crop on the later dates. Early or timely sowing of photo-sensitive crop variety provided more photoperiod to complete its vegetative phase which was responsible for production of photosynthates for increased crop growth. Vishwakarma et al. (2016) observed higher growth parameters, viz., plant height, tillers/hill, leaf area index and dry matter accumulation/hill on 27 June transplanting as compared to 7 July and 17 July dates of planting, respectively. Difference in sowing date was also reported to affect the yield.

Effect of microclimatic regimes on yield performance of rice

For direct seeding rice, precise sowing date or time plays a vital role in improving growth and yield of the crop. As the precise date or time of seedling ensures that the vegetative growth of the crop occurs at a period of satisfactory temperatures and high levels of solar radiation and also in
return which will have a direct effect on the yield attributing characters of the crop. On the other hand, late sowing of rice reduces the maturity period and also the yield attributing characters. Elemon and Mabbayad (1980) reported that late sowing of rice reduced the maturity period, plant height, straw yield, panicle/m² and filled grains/panicle whereas per cent unfilled grains increased. Pandey and Agarwal (1991) also indicated that different sowing dates had significant effect on number of fertile tillers/m². Khade et al. (1997) noted that yield decreased with the delayed sowing mainly due to delayed heading, decrease plant height and yield components and shortened growth duration. Tashiro et al. (1999) reported that sowing date also has a direct impact on the rate of establishment of rice seedling. Sharief et al. (2000) found that early sowing dates (May 10th) had marked effect on number of panicles/m², number of filled grains/panicle, 1000-grain weight, grain and straw yields/ha. Ehsanullah et al. (2001) reported that duration of growing season and average temperature during different growth stages have significant effects on rice yield; therefore, planting date plays a substantial role in rice production. The role of microclimatic regime on plant yield attributing characters was given by many workers. Soomro et al. (2001) reported that early planted (May 16) rice crop had taken more number of days to heading (110.4 days) and maturity (136.0 days). Dwivedi et al. (2001) also 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 15th August. The reduction in grain yield of rice was significant when planting was delayed to 25th July as compared to 15th July.

Subba Rao et al. (2002) reported that the grain yield was significantly higher in 1st June planting over the later planting. The reduction in yield was on the range of 10 per cent and 22 per cent due to 15 and 30 days delayed sowing over 1st June planting. Hayat et al. (2003) reported lower number of panicles/m² and spikelets/panicle and ultimately lower yield with delayed sowing. Nayak et al. (2003) studied the response of hybrid rice variety PA 6201 to different dates of planting i.e., 16th June, 31st July and 16th August during 1999 and 2000. They reported that a fortnight delay in planting from 16th June to 31st July reduced the grain yield by 7.6 per cent in the first year and 4.5 per cent in the second year. They also observed that one month delay in planting from 16th June to 16th August reduced the grain yield by 24.3 per cent. Similar findings were also reported by Upadhyay et al. (2004). They reported that higher numbers of tillers, panicles, spikelets/panicle and panicles weight were obtained from the early planting (6th June) as compared to 22nd June and 16th July planting for all varieties of rice. Rakesh and Sharma (2004) opined that delays in planting resulted in significant decrease in number of productive tillers/m² and ultimately yield of paddy. Sreenivas et al. (2005) reported that significantly higher grain yield was obtained when crop was planted on 15th July and progressive decrease in growth and yield was recorded with delay in planting. Khakwani et al. (2006) explained that grain yield was significantly influenced by sowing time. They found that effect of planting date was significant on the number of fertile tillers, number of grains, 1000-grain weight and grain yield. Khalifa (2009) concluded that early date of sowing is the appropriate time for gaining important properties such as the maximum tillers, number of tillers/m², plant height, 1000-grain weight and grain yield. The number of kernel/panicle showed a better response with early sowing because late sowing shortened the growth period of the plant and therefore reduced the leaf area, length of panicle and number of kernels/panicle. Mahajan et al. (2009) also revealed that June 15th transplanted crop experienced mean temperature between 31°C and 33°C during tillering stage resulted more production of tillers/m² as compared to June 25 and July 5 transplanted crop. Akbar et al. (2010) reported that total number of productive tillers gradually decreased as the sowing was done before 20th June or delayed after 20th June. This increase in number of productive tillers/m² at 20th June sowing was attributed due to the favourable environmental conditions which enabled the plant to improve its growth and development as compared to other sowing dates. Bashir et al. (2010) observed the effect of different sowing dates on yield and yield components of direct seeded coarse rice. They reported that the number of kernel/panicle showed better response in early sowing compared to late sowing. Late sowing shortened the growth period of the plant which reduced the leaf area, length of panicle and number of kernels/panicle than early sown crop. They also reported that a thousand grain weight decreased gradually with delay in planting time. Yao Yi et al. (2011) found that the delayed sowing date decreased the yields of three types of rice cultivars. The decrease in yield was caused by the decline of spikelets/panicle and filled grain percentage, panicles and 1000-grain weight. Khalifa and El-Rewainy (2012) indicated that sowing date at April 1st gave the highest value on number of days from sowing up to maximum tillering, panicle initiation and flowering dates and also root length (cm), leaf area index, number of tillers at PL, chlorophyll content at heading (H.D), number of tillers/m² at maturity stage, panicle length (cm), number of grains/panicle, 1000-grain weight (g) and grain yield/ha as compared to the sowing date at May 10th. Sartori et al. (2013) found that the sowing date affected grain yield with yields of 13 and 24 per cent more in the beginning of the sowing season compared to the end of the sowing date, respectively. So sowing early during the recommended period provides greater yield and more water use efficiency. Early sowing dates resulted in the maximum number of panicle/m², total florets/panicle, 1000-grain weight and paddy yield, while delay in sowing dates after 25th June reduced the yield gradually (Dahiya et al., 2017).

Effect of microclimatic regimes on nutrient content and their uptake

Climate has direct role on nutrient content and uptake in rice. Here, genotype also plays an important role.
Verma et al. (2004) investigated the effect of planting date (20 July, 5 and 20 August) on leaf growth, chlorophyll, nitrogen content and grain yield of hybrid rice and revealed that early planting (20 July and 5 August) increased N content significantly in the third leaf, compared to 20 August (late) planting. Pandey et al. (2008) conducted an experiment to find out nitrogen concentration in the third leaf and nitrogen uptake by hybrid rice under four different planting dates (July 5, July 20, August 5 and August 20). They reported that delayed planting on August 5 or 20 significantly reduced N concentration and uptake by grain and straw. The planting of hybrid rice on July 5 or 20 found to be equally effective for N concentration and uptake in grain and straw due to increased concentration and dry matter production. Mandal et al. (2011) found that the N, P and K concentrations in grain and straw do not appear to be a function of dates of sowing of direct seeded rice. Kumar et al. (2013) studied the effect of dates of transplanting (6, 16 and 28 July) on yield and yield parameters of aromatic rice in lowland condition during kharif seasons at Umiam, Meghalaya. They reported that the total uptake of N was recorded significantly higher in 16 July transplanting compared to 6 and 28 July. Chendge et al. (2017) reported that sowing of rice varieties during 23rd meteorological week recorded significantly more N, P and K content in both grain and straw over the crop sown during 23rd and 24th meteorological week. They also reported maximum uptake of N, P and K with the crop sown during 23rd meteorological week followed by 24th and 25th meteorological week sowing in descending order during both the years of study. Kumar et al. (2017) studied the performance of aerobic rice cultivars under three dates of sowing viz., 10 June, 20 June and 30 June in Bihar and found that nutrient uptake pattern varied distinctly with various treatments and produced significant response with date of sowing. Among all sowing date, they found maximum uptake of nitrogen (93.6 kg/ha) with 20 June sown aerobic rice crop and was at statistically similar (92.9 kg/ha) with 10 June sowing.

**Effect of microclimatic regime on agro meteorological indices in rice**

An increase in temperature and rainfall was found to have negative relationship with rice productivity (Saseendran et al., 2000). Another study (Peng et al., 2004) estimated a possible 10% decline in rice productivity due to 1% rise in minimum temperature in dry season. Chopra and Chopra (2004) found that the crop transplanted on 30 June took 109.5 calendar days and 3125.9 growing degree-days from transplanting to maturity (total phenophase). A linear reduction in these parameters was observed with delay in transplanting. The calendar days and growing degree-days of vegetative and generative phase I and II were reduced by 7 to 9 days and 256.5, 393.5 and 427.6 growing degree-days, respectively, with delay in transplanting (4th August) compared to 30th June. Adverse effects of late planting (28th July and 4th August) were reflected in lower yield and increased electrical conductivity values of ripening phase. Reddy et al. (2004) reported that number of days to complete the vegetative growth stage, flowering and maturity of rice variety IR-64 decreased from 108 to 86 days, from 133 to 107 and 160 to 136 days, respectively due to delayed sowing. Hundal et al. (2005) studied the leaf area development, dry matter accumulation and grain yield of rice in relation to temperature, photoperiod and sunshine duration and correlated with growing degree-days (GDD), helio thermal unit (HTU) and photo thermal unit (PTU). They observed that higher values of the agro climatic indices were required for early sown rice to achieve maturity and also observed the highest heat use efficiency (HUE) of 0.896 g/m²°C/day for dry matter and 3.63 kg/ha°C/day for grain yield in early sown date. Studying the effects of sowing dates and weather on the growth and yield of rice cv. Annada, Khan and Bhagat (2005) found that leaf area index, crop growth rate and total dry matter were highest with 9th and 19th July sowing. Correlation coefficient was positive between leaf area index and crop growth rate and sunshine hours at the vegetative phase and rainfall at reproductive phase. Yield and yield attributes were positively correlated with rainfall and sunshine hours at reproductive and grain filling stages, while it was negatively correlated with maximum and minimum temperature at grain filling stage. Singh and Singh (2007) revealed that the days taken to attain the different phenological stages decreased with the delay in transplanting in each rice cultivar. Thermal time requirement (heat units) also decreased with delay in transplanting time. Thorat et al. (2009) observed improved heat and light use efficiency of plants sown early (24th meteorological week) and increased grain and straw yields compared to plants sown late (26th meteorological week). Singh et al. (2010) reported that the highest heat use efficiency of 13.2 kg/ha°C/day and 5.88 kg/ha°C/day was recorded for dry matter and grain yield, respectively when the crop was transplanted on 25 May than on 10 June and 25 June. Jarrod et al. (2010) indicated that increased temperature (1-4°C) and decreased radiation (1, 3, 5) can reduce yield, with the impacts varying across the plant’s three growth phases (vegetative: establishment to panicle initiation; reproductive: panicle initiation to flowering; ripening: flowering to mature grain). Increasing temperatures have been found to reduce the duration of physiological maturity of the rice varieties (Basak et al., 2010). Amgain (2011) observed longer number of days required by rice cultivars to attain different phenological stages for the early plantings than the late plantings. None of the rice cultivars could show stable yield in late planting conditions suggesting their planting could be better for early planting. Brar et al. (2011) also reported that the rice variety PR 118 took 7 and 9 days more to attain 50 per cent flowering and maturity, while PAU 201 took 85 and 106 days to attain 100% flowering and maturity respectively, under early planting date. A 5.4% reduction in yield was recorded in PR 118 when transplanting was delayed from 25th June to 5th July; while PAU 201 registered almost equal grain yields.
even under delayed transplanting (5th July). Larjani et al. (2011) reported that the rice crop growth and yield in the north Iran were affected by crop duration and phenology. Silawat and Agrawal (2012) observed higher value of different agro-climatic indices and heat use efficiency for early planted rice to attain physiological maturity. Sowing dates have been shown to provide differential growth conditions such as temperature, precipitation and growth periods. Although sowing dates affect paddy yield by providing various environmental conditions, yet temperature is the key factor affected by sowing dates in medium grain rice (Safdar et al., 2013). The influences of maximum temperature and minimum temperature were more pronounced compared with that of rainfall (Sarker et al., 2012). Climate, particularly rainfall, was identified as the critical determinant of the productivity of upland rice. Rainfall at different phenological stages had differential impact on yield of rice crop (Nokkoul and Wichitparp, 2013). Praveen et al. (2014) reported that higher grain yield and straw yield along with the heat units viz., accumulated growing degree days, photo thermal unit, helio thermal unit, radiation use efficiency and heat use efficiency were recorded maximum in early crop sown (10th June) as compared to late sown crop (20th and 30th June). Chen et al. (2014) found that temperature and solar radiation had statistically significant impacts on rice yield during the vegetative and ripening stages, while the effects of rainfall on yield were not significant. They concluded that higher daily minimum temperature during the vegetative stage increased rice yield in China. Consistent with other studies, higher daily maximum temperature during the vegetative and ripening stages reduced rice yield in China, while the impacts of solar radiation on rice yield varied across the plant’s growth stages.

Pandey et al. (2015) studied the individual and joint effect of weather variables on rice yield. They found that individually sunshine (hr) is more important with rice yield 67.57 per cent followed by wind velocity and rainfall with 48.63 and 46.74 per cent contribution, respectively and jointly rainfall and wind velocity are more important with 82 per cent followed by rainfall and sunshine (hr) with 63 per cent and wind velocity and sunshine (hr) with 53.8 per cent contribution, respectively. Chen et al. (2016) reported that daily minimum temperature had a large and positive impact on rice yield during the vegetative stage. They also observed a negative impact on rice yield of higher daily maximum temperature during the vegetative and ripening stages, a negative impact of increased sunshine duration during the vegetative stage, a positive impact of increased sunshine duration during the ripening stage and a negative impact of rainfall during the reproductive stage. Islam et al. (2017) reported the impact of rainfall, rainy days, temperature (maximum and minimum), relative humidity (morning and evening) and bright sunshine hours on winter rice productivity at Jorhat and Dibrugarh districts of Assam over a dataset of 31 years from 1984 to 2014. Number of rainy days at ripening phase, maximum temperature at vegetative and total growth phase and bright sunshine hours at vegetative, ripening and total growth phase revealed significant correlation with winter rice yield. The coefficient of variation was found to be the highest for rainfall and rainy days precisely during ripening phase.

**CONCLUSION**

Climate change may cause a dramatic drop in rice production in major growing regions, a decline that could jeopardize critical food supplies, researchers report. New experiments exploring rice production in future climate conditions show rice yields could drop about 40% by 2100 with potentially devastating consequences in parts of the world that rely on the crop as a basic food source. Thus, a better understanding on effect of microclimate on performance of rice is need of the hour. The sustainable increase of rice production for food security will require efforts to enhance the capacity of rice production systems to adapt to global climate change as well as to mitigate the effects of rice production on global warming. Policy support to rice research and development to develop and transfer appropriate and efficient technologies, however, will be vital for the realization of such measures for sustainable rice production.

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