



Understanding on Climate Resilient Practices for Rainfed Rice-A Review

Perves Ahmed, Mrinal Saikia¹

10.18805/ag.R-2002

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

Department of Agronomy, SCS College of Agriculture, Assam Agricultural University, Dhubri-783 376, Assam, India.

¹Directorate of Research (Agri.), Assam Agricultural University, Jorhat-785 013, Assam, India.

Corresponding Author: Perves Ahmed, Department of Agronomy, SCS College of Agriculture, Assam Agricultural University, Dhubri-783 376, Assam, India. Email: pervesahmed@gmail.com

How to cite this article: Ahmed, P. and Saikia, M. (2021). Understanding on Climate Resilient Practices for Rainfed Rice-A Review. *Agricultural Reviews*. 42(1): 50-57. DOI: 10.18805/ag.R-2002.

Submitted: 07-04-2020 **Accepted:** 20-10-2020 **Online:** 21-12-2020

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); Safdar *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. Khaliq *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. Elemo 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 14th 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 panicle/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 July, 31st July and 16th August during 1999 and 2000. They reported that a fortnight delay in planting from 16th July 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 July 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/plant 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 PI, 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 26 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 26 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). Larijani *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 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.

REFERENCES

- Abou Khalifa, A.A. (2005). Physiological behavior of some rice cultivars under different sowing dates and seedling ages. The 11th Conference of Agronomy, Agron Dept, Agric. Assiut. Univ. Nov 15-16 pp. 285-295.
- Akbar, N., Iqbal, A., Khan, H.Z., Hanif, M.K and Bashir, M.U. (2010). Effect of different sowing dates on the yield and yield components of direct seeded fine rice (*Oryza sativa* L.). Journal of Plant Breeding and Crop Science. 2(10): 312-315.
- Ali, M.Y. and Rahman, M.M. (1992). Effect of seedling age and transplanting time on late planted Aman rice. Bangladesh Journal of Traditional Development. 5: 75-83.
- Amgain, L.P. (2011). Agro-meteorological indices in relation to phenology of promising rice cultivars in Chitwan, Nepal. Nepal Agricultural Research Journal. 11: 52-59.
- Anonymous (2019). Agricultural Statistics at a Glance 2019, Directorate of Economics and Statistics, DAC, Ministry of Agriculture, Government of India, New Delhi. pp. 48.
- Basak, J.K., Ali, M.A., Islam, M.N. and Rashid, M.A. (2010). Assessment of the effect of climate change on boro rice production in Bangladesh using DSSAT model. Journal of Civil Engineers, (IEB). 38(2): 95-108.
- Bashir, M.U., Akbar, N., Iqbal, A. and Zaman, H. (2010). Effect of different sowing dates on yield and yield components of direct seeded coarse rice (*Oryza sativa* L.). Pakistan Journal of Agricultural Science. 47(4): 361-365.
- Brar, S.K., Mahal, S.S., Brar, A.S., Vashist, K.K. and Buttar, G.S. (2011). Phenology, heat unit accumulation and dry matter partitioning behaviour of two rice cultivars transplanted on different dates. Journal of Agrometeorology. 13(2): 153-156.

- Chen, S., Chen, X. and Xu, J. (2014). The economic impact of weather variability on China's rice sector. *Environment Development*. pp. 1-27.
- Chen, S., Chen, X. and Xu, J. (2016). Assessing the impacts of temperature variations on rice yield in China. *Climate Change*. 138: 191-205.
- Chendge, P.D., Chavan, S.A., Patil, A. and Kumar, S. (2017). Performance of different sowing times and varieties on yield and soil fertility of rice in Konkan. *Journal of Pharmacognosy and Photochemistry*. 6(5): 2456-2461.
- Chopra, N.K. and Chopra, N. (2004). Influence of transplanting dates on heat unit requirement of different phenological stages and subsequently yield and quality of scented rice (*Oryza sativa*) seed. *Indian Journal of Agricultural Sciences*. 74 (8): 415-419.
- Dahiya, S., Punia, S.S., Singh, J., Kakraliya, S.K., Singh, B., Jat, H.S. and Malik, R.K. (2017). Yield and yield attributes as affected by different sowing dates and different maturity classes cultivar on direct seeded rice. *Chemical Science Review and Letters*. 6(21): 149-152.
- Dawadi, K.P. and Chaudhary, N.K. (2013). Effect of sowing dates and varieties on yield and yield attributes of direct seeded rice in Chitwan, Nepal. *International Journal of Agricultural Sciences and Research*. 2(4): 095-102.
- Dixit, A.J., Gaikwad, V.V., Jadhav, M.G. and Thorat, S.T. (2004). Effect of sowing times on phenology and growth of hybrid rice parents. *Journal of Agrometeorology*. 6: 72-76.
- Dwivedi, S.C., Dwivedi, A., Dwivedi, M.L. and Kishore, K. (2001). and profitability of rice nad wheat in relation to sowing time. *Annals of Plant and Soil Research*. 3(2): 314-316.
- Ehsanullah Attaullah, M.S., Cheema, M.A. and Usman, M. (2001). Rice Basmati-385 response to single and split application nitrogen at different growth stages. *Pakistan Journal of Agricultural Science*. 38: 84-86.
- Elemo, A.K. and Mabbayad, B.B. (1980). Effects of sowing date on upland rice/peanut intercrop. *Philippine Journal of Crop Science*. 5: 22-29.
- El-Khoby, W.M. (2004). Study the effect of some cultural practices on rice crop. Ph.D thesis, Faculty of Agriculture, Kafr El-sheikh Tanta Univ.
- Farrell, T.C., Fox, K., Williams, R.L., Fukai, S. and Lewin, L.G. (2003). Avoiding low temperature damage in Australia's rice industry with photoperiod sensitive cultivars. *Proceedings of the 11th Australian Agronomy Conference*. Deakin University, Geelong (Feb. 2-6), Victoria, Australia.
- Ghosh, D.C. and Singh, B.P. (1998). Crop growth modeling for wetland rice management. *Environment and Ecology*. 16(2): 446-449.
- Gu Lang, H., Zhan Kui, X., Yan, C.F., Yu Wei, W., Xue Qin, D. and Xiang, H. (2014). Effects of sowing date, seedling age and nitrogen application on the yield and production characteristics of hybrid japonica rice Chunyou 84. *Acta Agriculturae Zhejiangensis*. 26(3): 564-569.
- Habibullah, N.H., Shah, N.A. and Iqbal, F. (2007). Response of rice varieties to various transplanting dates. *Pakistan Journal of Plant Science*. 13 (1): 1-4.
- Haque, M.M., Rahman, H.P., Biswas, J.K., Iftekharuddaula, K.M. and Hasanuzzaman, M. (2015). Comparative performance of hybrid and elite inbred rice varieties with respect to their source-sink relationship. *Scientific World Journal*. vol. 2015, pp. 11.
- Hayat, K., Awan, I.U. and Hassan, G. (2003). Impact of seeding dates and varieties on weed infestation, yield and yield components of rice (*Oryza sativa* L.) under direct wet seeded culture. *Pakistan Journal of Weed Science Research*. 9: 59-65.
- Hong-xing., Xu, Yang., Ya-jun, L.U., Yan-hui, Z., Xu-song, T., Jun-ce, L.A.I., Feng-xiang, F.U., Qiang, F.U., Zhong-xian, L.U. (2017). Sustainable Management of Rice Insect Pests by Non-Chemical-Insecticide Technologies in China. *Rice Science*. 24: 61-72.
- Hundal, S.S., Kaur, P. and Dhaliwal, L.K. (2005). Growth and yield response of rice in relation to temperature, photoperiod and sunshine duration in Punjab. *Journal of Agrometeorology*. 7(2): 255-261.
- Islam, A.N., Khanikar, P.G., Deka, R.L. and Goswami, B. (2017). Impact of weather parameters on winter rice productivity in the upper Brahmaputra valley zone of Assam. *Journal of Agrometeorology*. 19: 75-79.
- Jarrold, R.W., Jeffrey, R.V., Maximilian, A.D., Piedad, F.M., Achim, D. and David, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *Proceeding of the National Academy of Sciences*. 107(33): 14562-14567.
- Khade, V.N., Patil, B.P., Jadhav, S.N. and Khanvilkar, S. (1997). Effects of climatic factors on rice yield potential and grain shape by delayed sowing. *Maharashtra Journal of Agrometeorology*. 4(4): 207-219.
- Khakwani, A.A., Zubair, M., Mansoor, M., Naveed, K., Shah, I.H., Wahab, A., Ilyas, M. and Ahmed, I. (2006). Agronomic and morphological parameters of rice crop as affected by date of transplanting. *Journal of Agronomy*. 5(2): 248-250.
- Khalifa, A.A. and El-Rewainy, I.M. (2012). Study some physiological characters, yield and yield component for five new rice varieties under different sowing dates. *Advances in Applied Science Research*. 3(1): 440-445.
- Khalifa, A.A.B. (2009). Physiological evaluation of some hybrid rice varieties under different sowing dates. *Australian Journal of Crop Science*. 3(3): 178-183.
- Khalik, T., Ali, A., Ahmad, A., Ahmad, M., Muhammad, A. and Mubeen, M. (2013). A study of thermal changes on physiology and paddy yield of fine rice cultivars under subtropical conditions. *Asian Journal of Agriculture and Biology*. 1(4): 208-216.
- Khan, I.M. and Bhagat, D.V. (2005). Influence of weather on growth and yield parameters of upland rice. *Annals of Plant Physiology*. 19(1): 27-30.
- Kumar, B., Mandal, S.S., Tyagi, S., Haque, M. and Kumar, A. (2017). Studies on performance of aerobic rice cultivars under different dates of sowing in Bihar. *Journal of Pharmacognosy and Photochemistry*. SP1: 850-853.

- Kumar, M., Das, A., Ramkrushna, G.I., Patel, D.P., Munda, G.C., Naropongla and Buragohain, J. (2013). Effect of nutrient sources and transplanting date on aromatic rice (*Oryza sativa*) under mid hills of north eastern India. *Indian Journal of Agronomy*. 58(3): 322-326.
- Laborte A., Nelson, A., Jagadish, K., Aunario, J., Sparks, A., Ye, C. and Redona, Ed. (2012). Rice feels the heat. *Rice Today*. July-September: 30-31.
- Larijani, B.A., Sarvestani, Z.T., Nematzadeh, G., Manschadi, A.M. and Amiri, E. (2011). Simulating phenology, growth and yield of transplanted rice at different seedling ages in northern Iran using ORYZA 2000. *Rice Science*. 18(4): 321-334.
- Magunmder, S.K.G., Ali, M.P., Choudhury, T.R. and Rahin, S.A. (2013). Effect of variety and transplanting date on the incidence of insect pests and their natural enemies. *World Journal of Agricultural Sciences*. 1(5): 158-167.
- Mahajan, G., Bharaj, T.S. and Timsina, J. (2009). Yield and water productivity of rice as affected by time of transplanting in Punjab, India. *Agriculture and Water Management*. 96: 525-532.
- Mandal, D., Singh, D., Kumar, R., Kumari, A. and Kumar, V. (2011). Effects on production potential and economics of direct seeded rice sowing dates and weed management techniques. *Indian Journal of Weed Science*. 43(3 and 4): 139-144.
- Moradpour, S., Koohi, R., Babaei, M. and Khorshidi, M.G. (2013). Effect of planting date and planting density on rice yield and growth analysis (Fajr variety). *International Journal Agriculture and Crop Sciences*. 5: 267-272.
- Nayak, B.C., Dalei, B.B. and Chodhury, B.K. (2003). Response of hybrid rice to date of planting, spacing and seedling rate during wet season. *Indian Journal of Agronomy*. 48(3): 172-174.
- Nokkoul, R. and Wichitparp, T. (2013). Effects of rainfall on yield and seed quality of three local upland rice varieties produced under organic farming system. *Research Journal of Environmental and Earth Science*. 5: 462-465.
- Pandey, K.K., Rai, V.N., Sisodia, B.V.S. and Singh, S.K. (2015). Effect of weather variables on rice crop in eastern Uttar Pradesh, India. *Plant Archives*. 1(15): 575-579.
- Pandey, N., Verma, A.K. and Tripathi, R.S. (2008). Effect of date of planting and nitrogen levels on yield and grain quality of scented rice varieties. *Oryza*. 42(2): 75-80.
- Pandey, R. and Agarwal, M.M. (1991). Influence of fertility levels, varieties and transplanting time on rice (*Oryza sativa*). *Indian Journal of Agronomy*. 36: 459-463.
- Peng, S., Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Centeno, G.S., Khush, G.S. and Cassman, K.G. (2004). Rice yield decline with higher night temperature from global warming. *PNAS*. 101: 9971-9975.
- Pillai, S. (1958). Rice cultural trials and practices in India. ICAR Monograph No. 27: 36-38.
- Praveen, K.V., Patel, S.R., Choudhary, J.L. and Bhelawe, S. (2014). Heat unit requirement of different rice varieties under Chhattisgarh plain zones of India. *Journal of Earth Science and Climatic Change*. 5(1): 165-168.
- Rai, H.K. and Kushwaha, H.S. (2008). Effect of planting dates and soil water regimes on growth and yield of upland rice. *Oryza*. 45(1): 129-132.
- Rakesh, K. and Sharma, H.L. (2004). Effect of dates of transplanting and varieties on dry matter accumulation, yields attributes and yields of rice (*Oryza sativa* L.). *Himachal Journal of Agricultural Research*. 30(1): 1-7.
- Reddy, D.R., Sreenivas, G., Sudhakar, T.R. and Rao, S. (2004). Growth of rice varieties in terms of degree days under South Telangana agro climatic conditions. *Journal of Agrometeorology*. 6(2): 274-277.
- Safdar, M.E., Noorka, I.R., Tanveer, A., Tariq, S.A. and Rauf, S. (2013). Growth and yield of advanced breeding lines of medium grain rice as influenced by different transplanting dates. *Journal of Animal and Plant Science*. 23(1): 227-231.
- Sarker, M.A.R., Alam, K. and Gow, J. (2012). Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data. *Agricultural System, Elsevier Ltd*. pp. 11-16.
- Sartori, G.M.S., Marchesan, E., Azevedo, C.F., Streck, N.A., Roso, R., Coelho, L.L. and Oliveira, M.L. (2013). Grain yield and water use efficiency in irrigated rice according to sowing date. *Ciencia Rural*. 43(3): 397-403.
- Saseendran, S.A., Singh, K.K., Rathore, L.S., Singh, S.V. and Sinha, S.K. (2000). Effects of climate change on rice production in the tropical humid climate of Kerala, India. *Climate Change*. 44: 495-514.
- Sharief, A.E., El-Hinidi, M.H., Abd El-Rahman, A.A. and Abdo, G.M. (2000). Rice productivity as influenced by planting dates and seedling age. *Journal of Agricultural Science Mansoura University*. 3: 1511-1521.
- Silawat, S. and Agrawal, K.K. (2012). Growth and yield response of rice in relation to different thermal environments at Kymore plateau zone of Madhya Pradesh, India. *JNKVV Research Journal*. 46(3): 346-340.
- Singh, A.K. and Singh, L. (2007). Role of thermal time in rice phenology. *Environment and Ecology*. 25(1): 46-49.
- Singh, H., Singh, K.N., Kasan, B. and Khan, A.A. (2010). Agro climatic models for prediction of growth and yield of rice under temperate Kashmir conditions. *Indian Journal of Agricultural Sciences*. 80(3): 254-257.
- Soomro, H., Soomro, A., Oad, F.C., Ansari, A.H. and Oad, L. (2001). Effect of transplanting dates on yield and its related traits in Rice (*Oryza sativa* L.). *Journal of Biological Sciences*. 1(5): 363-64.
- Sreenivas, G., Raji Reddy, D. and Narasimha Rao, S.B.S. (2005). Influence of weather parameters on yield of lowland rice. Agromet-Cell, Agricultural Research Institute ANGRAU, Rajendranagar Hyderabad. *Journal of Agrometeorology*. 7(1): 69-75.
- Subba Rao, I.V., Shobharain, N., Mahender Kumar, R. and Viraktamath, B.C. (2002). Influence of date of sowing and fertilizer on seed yield and quality of rice hybrids. *Extended Summaries* (1): 2nd International Agronomy Congress, Nov. 26-30 New Delhi, India. pp. 149-150.
- Sun, X.L., Wang, H.D., Cao, K.R., Zhu, J.L. and Zhong, X.M. (2008). Study on the relationship between sowing date and the occurrence of small brown planthopper and stripe disease. *China Plant Protection*. 28(10): 18-19.
- Tashiro, T., Saigusa, M. and Shibuya, K. (1999). A trial of no-tillage direct seeding of rice (*Oryza sativa* L.) at early spring in cold climate region in Japan. *Japanese Journal of Crop Science*. 68(1): 146-150.

- Thorat, T.N., Patil, B.P. and Mahadkar, U.V. (2009). Crop weather relations of hybrid rice (cv. Sahyadri) in Konkan. *Journal of Maharashtra Agriculture University*. 34(1): 20-22.
- Tiwari, P., Tiwari, R.K., Tiwari, A., Yadav, V. and Tripathi, S.K. (2015). Effect of sowing dates on growth, yield and economics of rice varieties under upland conditions of Rewa, Madhya Pradesh. *JNKVV Research Journal*. 49(1): 37-40.
- Tripathy, R., Ray, S.S. and Singh, A.K. (2009) Analyzing the impact of rising temperature and CO₂ on growth and yield of major cereal crops using simulation model, ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, India.
- Upadhyay, A.P., Agrawal, K.K., Metange, K.K. and Shankar, U. (2004). Crop-weather relationship studies on rice. S-VII: National Seminar Cum Workshop "Challenges for Enhancing Rice Production in Fragic Environment", held during October 19-21, pp. 85.
- Verma, A.K., Pandey, N. and Tripathi, R.S. (2004). Leaf growth, chlorophyll, nitrogen content and grain yield of hybrid rice as influenced by planting times and nitrogen levels. *Annals of Agricultural Research*. 25(3): 456-458.
- Vishwakarma, A., Singh, J.K, Sen, A., Bohra, J.S. and Singh, S. (2016). Effect of transplanting date and age of seedlings on growth, yield and quality of hybrids under system of rice (*Oryza sativa*) intensification and their effect on soil fertility. *Indian Journal of Agricultural Sciences*. 86(5): 34-39.
- Yao, Yi., Huo, Z.Y. , Zhang, H.C., Xia, Y., Ni, X.C., Dai, G.G., Xu, K., Wei, H.Y., Xiao, Y.C. and Wang, X. (2011). Effects of sowing date on yield and quality of direct seeding rice of different types and varieties. *China Agricultural Science*. 44(15): 3098-3107.
- Zhu, J.L., Zhu, Z.R., Feng, J.X., Cai, X.T., Zhong, X.M. and Cheng, J.A. (2011). Effect of sowing/transplanting time on occurrence of main locally overwintering insect pests and diseases. *Acta Agriculturae Zhejiangensis*. 23(2): 329-334.