

Review Article

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## Weather Manifested Rice Cultivation - A Review

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### ABSTRACT

Under the scenario of an escalating population and an epoch of climate variability, increasing the production of rice to confront the food security and overcome the human demands from the ever shrinking land resources have emerged as an obligatory step in augmenting the nations' economy. Rice productivity system is subjected to wide aberrations in the economic output and identifying the impact of weather variation at different phenological events of the crop is the predominant area of concern as it may help in understanding their response in terms of final productivity and enhance the functioning of the yield predicting models. Such assessment would enable not only to understand the extent of changes in rice production which could be already occurring due to changes in historical climate, but also to identify the rice producing regions vulnerable to weather shocks. Confiscating the biotic events and other abiotic factors, meteorological elements precisely, rainfall and temperature were identified as the paramount factors invariably controlling the potential grain yield of the crop. Rise in atmospheric temperature is detrimental for Asian rice as it may affect the phenology and physiology of the crop, and thereby, causing spikelet sterility, disruption of plant respiration, photosynthesis and shortening of grain-filling period, all of which leads to lower productivity. Further, extreme rainfall events during sowing and transplanting in high water table regions as well as deficit of the same at time of emergence and reproductive stage can diminish productivity.

#### Keywords

Rice, Productivity,  
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### Introduction

Rice is unique among the major cereals by virtue of its extent and adaptability to wider range of edaphic, climatic and cultural conditions. Though it is a hydrophilic in nature and often cultivated as a semi aquatic crop, there are varieties and strains which are grown under dry or rainfed and semi dry condition. Weather determines the potential

production of rice varieties and these affects are manifested through plant characteristics like height, tillers, leaf area and number of panicle that ultimately determines the final grain yield. Significant changes have occurred in the climate of the tropical region during the 20<sup>th</sup> century (Ramanathan *et al.*, 2001; Ramanathan *et al.*, 2005; Kumari *et al.*, 2007) and that in some regions of the tropics, weather is already approaching critical levels

during the susceptible stages of rice growth (Wassmann *et al.*, 2009a). Under changing climatic scenario, extreme meteorological events are predicted and these changes will most likely make the stress even more common and severe in addition to the on-going stresses of yield stagnation, land-use by the non-agricultural sector, competition for land, water and other resources. The observed climatic changes and attributed weather fluctuations in the past may have had significant influences on rice productivity in the tropics and thus, assessing the historical weather sensitivity of rice in this region is important (Wassmann and Dobermann, 2007). Such assessment would enable to not only understand the extent of changes in rice production which could be already occurring due to changes in historical climate, but also to identify the rice producing regions vulnerable to weather shocks. Hence, the present study has been undertaken primarily to review the impact of temperature and rainfall on the yield attributes of rice and their relative influence during various crop phenophases including the critical stages of growth.

### **Impact of weather parameters on rice production**

Crops grow to their best under a range of abiotic factors and any deviation from optimum range will lead to aberrant changes in physiological processes and they may experience severe stress (Orcut and Nilsen, 2000). Production and productivity of rice in terms of its yield, grain weight and number of grains per unit area vary in response to agro-meteorological parameters that accelerate the processes of plant growth such as crop transpiration, photosynthesis and photothermal efficiency (Mall and Singh, 2000). Moreover, meteorological parameters vary yearly and intra and inter-seasonal variations play a pivotal role in determining

the final crop yield (Prabhjyot and Hundal, 2009). Under unlimited water supply, the most important weather parameters affecting growth and development of rice are temperature and solar radiation (Sridevi and Chellamuthu, 2015). The impact of other weather parameters such as relative humidity and wind velocity are not considered so crucial. Further, reproductive and ripening phases are the most sensitive to weather, and in order to obtain the potential yield of the crop, adjustment must be done in the cropping schedule to reduce the risk of unfavorable weather condition during these stages. On the other hand Gorski *et al.*, (1994) and Gorski and Gorska (2003) reported that weather variability at the sowing/planting and reproductive (ripening) phase is equally important that contribute more towards grain size and crop yield. Shahid *et al.*, (2013) investigated the effect of inter-seasonal variations in meteorological parameters on morphological and yield traits of autotetraploid and diploid rice including *indica* and *japonica* genotypes and concluded that photothermal quotient showed closer relationship with yield and seed set compared to temperature or solar radiation alone. The impact of the individual weather events vary with the advancement in the phenological age of a crop and it is a fundamental step to perceive an elaborate knowledge of the influence of different weather parameters on the final yield of rice.

### **Impact of temperature**

Temperature is considered to be the most critical yield determinant of rice and high temperature in the lower elevation of the tropics and lower temperature in the temperate regions adversely affect the crop (Yoshida, 1981). Moderate warming in the coming decades, will possibly imply a net negative impact on yield of rice (Welch *et al.*, 2010) and the productivity may decrease by

4.17% (Upadhyay, 2012). All-India *kharif* rice yield would have been 8.4 per cent higher (or cumulative 172 million tons) had the pre-1960 climate prevailed during 1969-2007 (Pattanayak and Kumar, 2013). The critical limits of the weather parameters required for growth and development of the crop have already reached its threshold in most parts of the globe and any further increase of temperature in the future, as predicted by the IPCC (2013) will drastically reduce its grain yield (Wassmann *et al.*, 2009a). The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the rice crop by affecting its phenology, physiology, and yield components (Singh, 2001 and Sheehy *et al.*, 2005). It can affect the crop at all stages of development, particularly during flowering when it causes spikelet sterility. It increases plant respiration, affects photosynthesis and shortens the grain-filling period, all of which leads to lower productivity (Peng *et al.*, 2004). On the other hand, relatively low temperature and high solar radiation during the reproductive stage had remarkable effects on increasing spikelet number and hence grain yield (Yoshida and Parao, 1976). Rise in the night temperature is another reason for decline in historical rice yield in addition to the observed changes in the climatic conditions (Kumar, 2004) particularly during the ripening phase of the crop (Auffhammer *et al.*, 2012). Night-time warming at the end of the growing season had a greater impact on yield than the increase in the maximum temperature and changes in rainfall characteristics (Auffhammer *et al.*, 2011; Auffhammer *et al.*, 2006). Due to increase in minimum temperature along with decrease in radiation, the potential yield trend of rice from 1985 to 2000 were found to be negative at six of the nine sites of India, four of which were statistically significant (Pathak *et al.*, 2003). Increase in both frequency and intensity of high temperature, along with its large variability, is emerging as a potential

threat to the sustainability of rice production as it is a C<sub>3</sub> plant and in such plants growing under hot tropical conditions photosynthesis becomes inefficient when the temperature rises above long term mean temperatures and deteriorates further when temperature increases beyond this threshold, which is likely to be the cause due to global warming (Jagdish *et al.*, 2007). High temperature stimulates grain filling rate and shortens grain filling period to increase protein content and chalky grains but decrease amylase and grain weight as well as reduce pollen germination percentage and cause sterility of spikelet which ultimately reduces grain yield (Kim *et al.*, 2011). Such reduction in grain size and amylase content further reduces the potential economic benefits farmers can derive due to depression in farm-gate and/or milled grain prices (Zhu *et al.*, 2005 and Yamakawa *et al.*, 2007).

Yoshida (1973) from IRRI, Philippines reported that the seedling growth is very sensitive to temperature in the first week of post-germination. The growth rate increases linearly between 22 and 31 °C, suggesting that chemical reactions dominate growth. The enzymatic breakdown of the seed reserves support more than 70 per cent of growth during this week. After the first week, temperature influences on growth is less and the relative growth rates are about the same at 25 °C, 28 °C, and 31 °C. During the tillering stage, increase in the temperature resulted in an increased number of tillers per plant. At 3-5 weeks after sowing, temperature only slightly affected the tillering rate and the relative growth rate, except at the lowest temperature (22 °C) tested. Yoshida (1981) explained the cardinal range of temperature required for optimum growth and development of rice according to its phenological phases and suggested that the minimum, optimum and maximum cardinal range of temperature for the rice crop at

germination stage is 10 °C, 20-25 °C and 45 °C respectively; at tillering stage it is 9-16 °C, 25-31 °C, and 33 °C respectively; at anthesis it is 22 °C, 30-33 °C and 35 °C respectively; at ripening it is 12-18 °C, 20-25 °C and 30 °C respectively. At panicle initiation stage the lower threshold limit should not exceed 15 °C. At some stations in India, the maximum rice yield was observed when maximum and minimum temperatures ranged between 29-32 °C and 23-25 °C respectively (Samui, 1999). In Punjab rice grain yield was positively correlated with maximum temperature during the entire growth period and the deviation of maximum temperature from normal in high yield years was less compared to that in the low yield years (Sandhu *et al.*, 2013) from) and such results were in consonance with the findings of Islam *et al.*, (2017). Grain yields reached the plateau at mean daily minimum air temperature of 23 °C, mean daily mean air temperature of 26.5 °C and mean daily maximum air temperature of 29 °C (Ho *et al.*, 2013).

Higher temperatures can adversely affect Asian rice yields through two principal pathways, *viz.*, higher maximum temperatures in combination with high humidity causing spikelet sterility and adversely affect grain quality and increased night time temperatures that may reduce assimilate accumulation (Wassmann *et al.*, 2009b). Oh-e *et al.*, (2007) investigated the effect of temperature variation on rice in a temperature gradient chamber study in Japan and found that crops exposed to 3.6 and 7.0 °C higher temperature than ambient, from heading to middle ripening stage, reduced photosynthesis by 11.2 to 35.6 per cent, respectively. This decline in the photosynthesis can be attributed to structural changes in the organization of thylakoids (Karim *et al.*, 1997) and more particularly due to loss of stacking of grana in the chloroplast or its ability to swell (Wahid *et al.*, 2007). In consonance to such results

Rani and Maragatham (2013) also summarized that, under elevated temperature of 4°C and 2°C, the grain yield was 23 and 13.3 per cent less from the ambient. It was suggested that yield loss under elevated temperature is most possibly due to anomaly in temperature which affected the cellular developmental processes leading to reduced fertility, grain quality (Barnabas *et al.*, 2008) in addition to higher grain dry matter accumulation rate leading to shortened grain-filling period (Kobata and Uemuki, 2004). Chen *et al.*, (2014) provided a county-level analysis of the impacts of weather variability on rice yield in China, and found that temperature had statistically significant impacts on rice yield during the vegetative and ripening stages. In contrast to nearly all previous studies focusing on rice production in tropical and subtropical regions, they discovered 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. Various models developed to study the effects of weather variables on rice yield in India at different stages of growth indicated that above average maximum daily temperature had beneficial effects during ripening stage, detrimental effects during reproductive stage of the crop, while, in the initial growth and lag vegetative phase effects were fluctuating. The effect of increase in minimum temperature was beneficial during initial lag vegetative and reproductive stages, detrimental during ripening stages, and fluctuating during active reproductive stage (Agarwal *et al.*, 1984).

### **Impact of rainfall**

Rainfall variability has significant impact on the agricultural productivity system and when the annual rainfall diverges from its mean, the

yield levels of all the agricultural crops diminish significantly (Aberra, 2011). Rice crop is very much sensitive to weather conditions, with high water requirement per unit of produced mass (Heinemann and Stone, 2009). The effect of rainfall variation on rice production changes over time and such non-stationarity can be explained by long-term rainfall change. However, the mechanism causing this change remains unclear, and there are still many uncertainties in the non-stationarity of the rainfall–rice production relationship (Asada and Matsumoto, 2009). Economic output of rainfed rice is in consonance with fluctuating total amount of rainfall, total number of rainy days and period of monsoon season, and yields are significantly correlated with the quantum of rainfall, length of rainy season and number of rainy days (Gupta *et al.*, 2000). Global studies suggests that rice harvest have declined over the period 1972-1998 due to the changes in historical climate characteristics attributable to the combined influence of atmospheric brown clouds and greenhouse gas emissions causing variability in rainfall, solar radiation and other economic variables (Auffhammer *et al.*, 2006). Simulation studies confirmed that much increase in rainfall and mean temperature in long run will negatively affect rice production in future (Shakoor *et al.*, 2015). Further, drought stress, generally caused by scarcity in precipitation, is severely damaging during reproductive stages of the crop, especially during flowering, although drought in other stages can also lead to significant yield reductions (Liu *et al.*, 2006).

The rice crop reacts differently to climatic variables during different stages of its growth and an increase particularly in rainfall seems beneficial throughout the crop season suggesting that crop production can be increased by supplying additional water (Agarwal *et al.*, 1979). The effect of total rainfall was found beneficial during the

vegetative phase of the crop (Hoa and Singh, 1993) with significant correlations (Bhargava, 1974), whereas, the number of rainy days during the same phase was negatively correlated with the grain yield (Reddy and Reddy, 1992 and Ogbuene, 2010). Low rice yields coincided with years of deficient or poorly distributed rainfall, and thus, excess water should be collected in high rainfall months in run-off ponds for the use for use at critical growth stages (Chaudhary, 1998). Ekanayake *et al.*, (1993) from Virginia investigated the nature of panicle resistance to water loss by understanding the effect of low tissue water potentials and relative water content (RWC), induced by water deficit stresses, on diffusive resistance, transpiration rate and degree of tissue desiccation. They revealed that, increased water losses during the flowering stage causes spikelet sterility, white heads and yield losses, particularly in upland areas. Girish and Hittalmani (2004) found that moisture stress after 10 days of 50 per cent flowering significantly reduced single panicle weight, test weight, fertile spikelets per panicle, total spikelets per panicle and spikelet density and significantly increased sterile spikelets per panicle. 10 days after 50 per cent flowering is the most critical stage for grain filling and that, panicle initiation stage is more sensitive to moisture stress. Water deficit, even if moderate, can cause high-yield losses, especially when occurring during flowering and early grain filling and may be one of the major reasons for considering upland rice crops under high climate risk (Silva and Assad, 2001). Further, continuous cloudy days or rainfall during critical stages of growth, such as panicle differentiation or grain-filling stages, often induce great loss of grain yield and poor grain quality (Praba *et al.*, 2004). The growing season rainfall intensity (GRSI) on rice yield variability was found significantly negative ( $p < 0.1$ ) which indicated that, an increase in rainfall intensity would result in a decreased

variability of rice yield and thus, production risk in rice farming was reduced as rainfall intensity increased (Edeh *et al.*, 2011). This collaborates the finding of Adams *et al.*, (2000) and Chen *et al.*, (2000) that increase in rainfall results in decreased variability of crop yield. Hence, the growing rainfall intensity is a risk-reducing environmental factor in rice production. Moreover, the growing season rainfall duration (GSRD) had its coefficient negatively signed though not significant with the final yield of the crop. Asada *et al.*, (2009) studied the regional differences in the temporal variation of the correlation coefficient between rainfall and yield and observed that the correlation coefficient in Uttar Pradesh (UP) of India remained high, and exceeded the 5% significance level. In Bihar positive relation was found between yield and rainfall over the 40 year period. In Assam, Bangladesh and WB, the correlation coefficient was not constant, and the fluctuations were much larger than UP and Bihar. In Assam, the correlation coefficient was negative until 1975, but after that it turned positive, which means that the drought effect became more prominent than the flood effect. The relation between rice production and Southwest Monsoon Rainfall (SMR) is very low in Bangladesh and Assam, and this is because the correlation coefficient changed adversely from positive to negative and vice versa over the 40 year period.

In India the kharif rice harvest was found lower when total June-September rainfall was less than the long term average normal (Kumar *et al.*, 2004) and such results were in accordance with those of Webster *et al.*, (1998) and Selvaraju (2003). Weather-rice yield relationship for India stated that increased weather extremes and lower rainfall along with other weather parameters are resulting in a decrease of rice yield (Krishnamurthy *et al.*, 2009 and Lal *et al.*, 1998). Low precipitation coupled with high

temperature adversely affects the yield of cereals (Bhandari, 2013) and the grain yield decreased as the amount of water applied decreased (Islam *et al.*, 1997). Variability in rainfall affects the stand establishment and growth duration of the crop (Kamalam *et al.*, 1988). Samui (1999) made a study of growth and yield of one high yielding and four traditional photosensitive rice cultivars grown during the kharif season under rainfed conditions at four sites of India with different rainfall and temperatures. The cultivar technique was used to examine the influence of meteorological parameters on yield of rice. His results reported that, the maximum rice yield was observed when average rainfall ranged between 100-115 cm. Auffhammer *et al.*, (2011) opined that monsoon rainfall is not the only weather variable affecting the kharif rice yield in India. Their statistical analysis of state-level Indian data confirms that drought and extreme rainfall negatively affected rice yield in predominantly rainfed areas during 1966–2002, with drought having a much greater impact than extreme rainfall. Results from the study suggest that total June–September rainfall is very crucial for determining the yield of the crop. Statistical results obtained from the experiment clearly indicate that this variable (*i.e.*, total rainfall during June to September) is significantly correlated with rice yield and that it can be used to generate a simple drought indicator that is also significantly correlated with yield. Moreover, simulation results indicated that changes in total June–September rainfall and drought frequency had about equal impacts on rice yield during 1966–2002. Increase in rice yield owing to improvements in farming technology have been partially offset by the observed changes in weather over the period 1966-2002 (Auffhammer *et al.*, 2012). On the contrary, for some cultivars such as Jaya, yield decreased with increase in total rainfall during planting to maturity from 900 to 1100 mm (Samui, 1998). Results of Narayanan

(2004) revealed that, total rainfall during nursery stage was negatively correlated with grain yield in non-significant manner but with straw yield it was significant and positively correlated. During vegetative stage it was non-significant with grain yield, whereas, it showed a significant negative correlation with straw yield. Water deficit during the vegetative stage reduces the plant height, tiller number and leaf area but the crop can recover without much loss in yield if water is available before flowering (Narayanan, 2004). The accumulated rainfall during the tillering phase of the crop growth over and above the normal requirement had significant adverse effect on the straw yield. Rice grain yield was found negatively correlated with rainfall during vegetative stage and number of rainy days during reproductive stage (Sandhu *et al.*, 2013).

Dry weather with reduced number of rainy days is beneficial for the rice crop during the ripening phase which ensures proper grain development and drying. Increase in the number of rainy days may result in higher rainfall which may cause lodging of the crops along with decaying of grains in standing water resulting in a reduced yield (Islam *et al.*, 2017). Flooding caused by high rainfall affects rice crops at any stage of growth although submergence intolerance at the vegetative stage is the most common problem (Mackill *et al.*, 2010).

Production and productivity of rice in terms of its yield, grain weight and number of grains per unit area vary in response to agrometeorological parameters that accelerate the processes of plant growth and development. By exploring the rice-weather associations, it can be encapsulated that, optimum amount of well distributed rainfall during the vegetative and reproductive phase of the crop coupled with reduced aberrations in temperature might probably the main factors dictating rice yield.

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