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Impact of weather on rice – A review

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Abstract
Climate chooses the right crop for a particular environment, while the prevailing weather condition of that environment decides the potentiality of that crop. Among the crops, rice is a sensitive crop that depends highly on weather condition. Among the abiotic stresses, weather plays the dominant role in influencing the growth and yield of rice. If water is not the limiting factor, the most important weather parameters are temperature and solar radiation. Rainfall (spatial and temporal variation) is the direct critical weather parameter in rainfed ecologies. When considering the growth stages of rice, reproductive and ripening stages are the most sensitive stages to weather. Spikelet fertility is the most sensitive yield component when rice is subjected to stress *viz*., low or high temperature, low solar radiation or water deficit (drought). Adjust the cropping schedule to reduce the risk of unfavorable weather condition during the reproductive and ripening stages. For obtaining high yields, each and every phenophase of rice should enjoy the favourable weather conditions so as to put forth the best performance in obtaining the genetic yield dictated. The review is mainly confined to the influence of weather elements during different phenophase on growth, yield components and yield of rice.

Keyword: Weather, Rice growth stages, Growth and yield

1. Introduction
Rice is a unique crop among the major food crops by virtue of its extent and adaptability to wider range of edaphic, climatic and cultural conditions. About 90 per cent of the rice production takes place in the tropical/sub-tropical Asia where 60 per cent of the world population lives. The slogan “Rice is life” during International Year of Rice 2006 reflects the importance of rice as primary source of food. Rice is essential for food security, poverty alleviation and improved livelihoods. Rice is the staple food of over half of the world population (Anonymous, 2013). Climate influences the distribution of crops over different regions of the world, while weather influences the potential production of the concerned crop. Among the abiotic stresses, weather plays the dominant role in influencing the growth and yield of rice. The elements that combined express weather are solar radiation, temperature, rainfall, relative humidity and wind velocity.

Impact of Temperature on Rice
Most of the world rice is grown in the tropics and the critical determinant for the growth to be temperature. Rice is being a tropical and sub-tropical plant that requires a fairly high temperature ranging from 20º to 40 ºC. Crop is adversely affected by high temperature in the lower elevation of the tropics and by lower temperature in the temperate regions. This critical temperature differs according to variety, duration of critical temperature, diurnal changes and physiological changes of plant.

Table 1: Response of rice to varying temperature at different growth stages

Growth stages	Critical temperature (ºC)		
	Low	Optimum	High
Germination	10	20-35	45
Tillering	9-16	25-31	33
Panicle initiation	15	-	-
Anthesis	22	30-33	35
Ripening	12-18	20-25	30

(Yoshida, 1981)

2.1. Vegetative stage

Germination

Low temperature depresses the rate of germination and prolongs it beyond the desirable span of 6 days. High temperature of 35 ºC or more halted the germination because of high respiration rate (Sreenivasan, 1985) [42]. Yoshida (1981) affirmed that temperature has a large influence on germination, especially in the first week of post germination growth. He also added that a common symptom of chilling damage is a poor and delayed germination.

Seedling emergence

Bardhan and Biswas (1983) [3] reported that before panicle initiation, leaf emerges about every 4-5 days, afterwards about 7-8 days. Temperature affects the rate of leaf emergence. When the rice plant is grown at 20 ºC, leaves emerge every 5 days. When it is grown at 25 ºC, they emerge every 4 days before panicle initiation. Low temperature adversely affects the seedling dry matter since low temperature decreased the photosynthetic activity. Optimum temperature for leaf emergence and elongation is 25 ºC and 30 ºC, respectively.

Tillering

High temperature provides more tiller buds and thereby increases tiller count. Higher maximum and minimum temperature during tillering reduce the yield. Optimum temperature for tillering is 25-31 ºC. The rate of tillering in rice tends to increase as the temperature increases. Temperature only slightly affects the tillering rate and the relative growth rate, except at the lowest temperature 22 ºC from 3 to 4 weeks after sowing. The effect of temperature on tillering is affected by the level of sunlight (Mahbubul *et al*., 1985) [23]. Under low light conditions, some of the tiller buds may not develop into tillers because of lack of carbohydrate which is necessary for growth. Under these conditions, low temperature may produce more tillers. When light is adequate, however, higher temperature increases tiller number.

Sreenivasan (1985) [42] observed that tillering rate is inhibited by low temperature, but the period of tillering is prolonged, resulting in more tillers and more panicles than at high temperature. The mean temperature exceeded 26 ºC, the tiller production stopped abruptly by 5th week after planting and whenever it fell below 26 ºC the duration of tillering increased to 7-8 weeks after planting (Lalitha *et al*., 2000). It clearly indicated that temperature has an influence on duration of tillering. Temperature above 28 ºC during vegetative phase reduces the days to heading and shortens the life cycle.

2.2. Reproductive stage

Higher maximum and minimum temperature during ear initiation depress the yield. In general, high temperature accelerates the floral initiation (Vergara *et al*., 1972) [54].

Low temperature induced spikelet sterility

Booting stage is considered as the most sensitive stage to low temperature. The second most sensitive stage is heading or flowering. When the rice plant is subjected to low temperature for 3 days, it is more sensitive at the booting stage than heading, as indicated by the higher percentage of spikelet sterility. When the low temperature is continued for 6-9 days, however, heading is as sensitive as, or even more sensitive than booting. Spikelet sterility appears to be affected by both night and day temperatures (Yoshida, 1981). Cool weather causes panicle sterility by interfering with pollen grain formation. The critical temperature for inducing spikelet sterility varied from 10 to 15 ºC (Tinarelli, 1989) [49]. Alvarado (2002) [2] found that average temperature under 20 ºC for 5 days during flowering increased the probability of obtaining spikelet sterility is greater than 10 to 12 per cent. Ghosh *et al*. (1983) [9] observed that the temperature and sterility had a negative correlation which indicated lower temperature induced high sterility.

High temperature induced spikelet sterility

Rice is most sensitive to high temperatures at heading and next most sensitive at about 9 days before heading. One or two hours of high temperature at anthesis has a decisive effect on the incidence of sterility. High temperatures before or after anthesis have much less effect on sterility. The high sterility may be attributable to failure of fertilization caused by the imperfect splitting of anther or wilting of stigma induced by high temperature and low humidity. High temperature desiccated pollens (Osada *et al*., 1973) [33]. Sterility was increased at high temperature of 35 ºC (day) and 30ºC (night) as a result of smaller pollens and non dehiscence of anthers. Mackill *et al*. (1982) [22] stated that the reduced yield was a result of poor pollen shedding as well as inadequate pollen growth in temperature above about 34 ºC. The day time temperature of 32º to 38 ºC caused sterility, depending on the cultivars.

Flowering duration

Higher temperature (both maximum and minimum) and lower diurnal variation in temperature are more conducive for early flowering in rice varieties. Delayed floral initiation at low temperature had been reported and the critical minimum was around 15 ºC and the optimum was 25-30 ºC. Indica cultivars were better adapted to high temperature (Ghosh *et al*., 1983) [9]. Yoshida (1981) observed that a 13 day delay in flowering for each degree drop in temperature between 24º and 21 ºC in IR 26 rice cultivars. Even if plant growth is vigorous, temperature that remains at 14-16 ºC for more than 3 days during the period from reduction division to heading will cause serious damage because of grain sterility (Toriyama and Heu, 2000) [50].

2.3. Ripening stage

Generally grain yield was higher when temperature during ripening stage was relatively low, an effect attributed to a more favourable balance between photosynthesis and respiration. Temperature influenced the ripening of rice in two ways-first, low temperature favoured an increase in grain weight and second, low daily mean temperature increased the length of ripening period. Higher grain yield in temperate countries than in tropics could have generally been attributed to lower temperature during ripening, which extended the ripening period, so more time for grain filling. At lower temperature, translocation of photosynthates to grain took place at a slower rate and thus the maturity period got delayed. Temperature less than 28 ºC during grain filling increased its duration and seed size (Tashiro and Wardlaw, 1989) [46].

Lower night temperature during ripening stage had positive correlation with yield. A high diurnal variation leads to more efficient conversion and use of solar energy during photosynthesis leading to higher net photosynthesis. High day temperature combined with low diurnal variation is clearly not a favourable ripening temperature environment. High temperature during this stage caused impaired reduction of grain filling and 5-15 per cent reduction in test weight at 27 ºC in some cultivars. The incidence of chalky grains was associated with the spread between optimum and maximum temperature. Low grain filling at high temperature was mainly due to a lack of ability of the spikelets to serve as sink. Ear photosynthesis to grain yield ranged from 8-23 per cent and the contribution of panicles (sink) ranged from 13-20 per cent. Rice exhibits photorespiration which is stimulated by high temperature and light (Abrol and Gadgil, 1999) [2].

Optimum temperature for ripening is 20-25 ºC. Super optimum temperature during grain filling can reduce seed mass because of a lower rate of starch accumulation. High temperature during this stage increases the thickness of the bran. Low temperature during this stage leads to an excessive shattering of grain during harvest and transportation resulting in high losses. Higher maximum and minimum temperature during maturity depress the yield. Grain thickness in rice was most reduced by high temperature commencing 12 days after heading, but grain length and width were most sensitive to high temperature at early stages of development (Tashiro and Wardlaw, 1991) [47].

Low temperature reduced the grain dry matter increasing rate, extends the grain filling, delays grain maturation although moderate cool temperatures sometimes benefits grain yield (Egli, 1998) [7]. High temperature decreased the grain yield significantly due to the reduction of percentage of ripened grains. It shows that test weight is less affected by high temperature rather than percentage of ripened grains. Consequently percentage of ripened grain was the major contributor to differences in grain yield. Grain yield declined by 10 per cent for each 1 ºC in growing season minimum temperature in the dry season, whereas the effect of maximum temperature on crop yield was insignificant. It provides a direct evidence of decreased rice yields from increased night temperature (Kobata and Uemuki, 2004) [17].

3. Impact of Solar Radiation on Rice

Due to heavy cloudiness during the growing period in the tropics, duration of bright sunshine hours is about 3-4 hours day^{-1} and yield of rice in this region is low (1.5-2.5 t ha^{-1}). Rice yield during summer season becomes almost double of that of monsoon season in eastern and southern India whereas it increases marginally in Punjab (Biswas, 1996) [4]. Solar radiation intercepted in rice canopy plays a major role in determining biomass and grain yield. Solar radiation requirements of a rice crop differ with the phytophases. Relationship between yield and solar radiation at different phenophases showed that high association between 100 and 450 cal cm^{-2} day^{-1} during reproductive stage and 150 and 400 cal cm^{-2} day^{-1} during ripening phase and a weak relationship at 200 cal cm^{-2} day^{-1} during vegetative phase (Yoshida, 1981).

3.1 Vegetative stage

Low light intensity during the vegetative stage slightly affected the yield and yield components of rice (Yoshida, 1981). Sunshine in a week prior to transplanting and the two weeks period coinciding with the grand period of elongation was conducive for better yield (Sreenivasan and Banerjee, 1978) [41]. Sreedharan and Vamadevan (1981) [40] reported that LAI reduced to a greater extent in plants shaded from planting to panicle initiation. Shading also caused death of many lower leaves. In deep water rice, with increase in light intensity, the length of elongated internodes decreased and dry matter content increased (Gomosta and Vergera, 1988) [10].

Shading delayed tillering and decreased tillering rate. Irrespective of varieties, shading increased the plant height, LAI and total chlorophyll content and significantly reduced the tiller number and total dry matter production (Tsai and Lai, 1990) [51]. Low light intensity decreases the tiller growth due to lack of photosynthates. In long duration varieties, low light stress synchronizes with the vegetative lag phase results in considerable tiller mortality and fewer panicles m^{-2} (Murthy *et al*., 1975) [25].

Kamalam *et al.* (1988) [16] stated that accumulated sunshine hours during tillering stage had a significant positive correlation with the grain yield. A long vegetative period and high radiation during this period is generally beneficial for tillering. Higher accumulated solar radiation from transplanting to flowering resulted in more panicles m^{-2}. Boardman (1977) [5] stated that the leaves grown in low irradiance are thinner than the leaves of plants grown in higher irradiance.

3.2. Reproductive phase

Yoshida and Parao (1976) [59] reported that solar radiation and temperature during reproductive stage (before flowering) had the greatest influence on rice yield because they determine the number of spikelets m^{-2}. According to Stansel (1975) [43], the most critical sunlight requiring period was around the heading stage. During this period, a mean yield reduction of 6.5 per cent was observed for every 1 per cent reduction in solar radiation.

The low light intensity up to flowering in *kharif*, imposed a ceiling on tillering and dry matter production as compared to *rabi* season (Venkateswarlu *et al*., 1977) [53]. Reduced solar radiation during this stage inhibited panicle heading. Low light intensity from 10 days before heading to 20 days after anthesis induced high spikelet sterility leading to poor grain yield (Murty and Murty, 1982) [26]. Low light stress reduced grain number $panicle^{-1}$ in short duration varieties, increased spikelet sterility in medium duration varieties and decreased panicle number in long duration varieties (Murty and Sahu, 1987) [27].

Spikelet sterility under low light at flowering was associated with decrease in carbohydrate content, protein synthesis and cytokinin accumulation and increase in gibberellins and soluble N in the panicle. Shading at panicle initiation caused the plants to grow better. On the contrary, the tiller progressively got weakened and unproductive. This was particularly true in case of secondary and tertiary tillers. It results in reduction of DMP and panicles m^{-2} (Thangaraj and Sivasubramanian, 1990) [48].

3.3 Ripening stage

Yoshida and Parao (1976) [59] reported that solar radiation during ripening period has the greatest influence on grain yield. Sreedharan (1975) [39] opined that the yield attributes and grain yield recorded a positive correlation with solar energy during ripening stage. At low light intensity, photosynthesis becomes low causing mortality of the weak and unproductive tillers during this phase when there was greater demand for photosynthates from the developing grains (Thangaraj and Sivasubramanian, 1990) [48].

Under low light, dry matter is reduced mostly by impaired photosynthesis. Low light causes spikelet sterility. The impaired translocation under subdued light of carbohydrates from source to developing grain during this stage results in high sterility. Low grain yield under reduced light intensity is attributed to the cumulative influence of fewer panicles m^{-2} and grain number $panicle^{-1}$ and lower test weight and higher percentage of spikelet sterility (Nayak and Murty, 1980) [31]. Reduced light from flowering reduces auxins and cytokinins and increases gibberellins in the spikelets. Under low light, proline content decreases in the panicle and increases in the leaf and culm, especially in the shade susceptible varieties. Such low proline content in the panicle is attributed to translocation impairment and also to an increase in proline oxidation caused by depletion in carbohydrates in the shade. Proline deficiency in the spikelets may also be a factor in high sterility (Murty and Sahu, 1987) [27].

Thangaraj and Sivasubramanian (1990) [48] observed that filled grains percentage and test weight are reduced due to light intensity or shading during ripening stage, hence it results in yield reduction. Dry matter accumulation during post flowering was more in dry than in wet season during ripening stage, which was due to higher solar radiation and demand of developing sink (Narasingarao, 1987) [28]. The reduction in grain number per panicle by shading of the plants from flowering to harvest is only due to poor grain filling, which was evident from the high sterility percentage (Patro and Sahu, 1986) [34]. A positive relationship between 300-600 cal cm^{-2} day^{-1} radiation during post flowering and 50-180 filled grains per panicle was found by Oldeman *et al*. (1987). Vamadevan and Murty (1976) [52] concluded from their studies that cumulative solar radiation of 14,000 g cal cm^{-2} and 200 hours of sun shine during 30 days preceding to harvesting is optimum for obtaining maximum grain yield.

High diffuse radiation during this stage causes hopper burns among *kharif* crops due to ammonia toxicity when the sky is overcast with heavy clouds. During this period, the stomata of plant remain closed. Nitrogen accumulates in plants and forms ammonia (Nathan, 2003) [30]. Therefore, overcast skies with diffused radiation particularly during flowering of rice and 45 days prior to its harvest tend to lower the grain yield (WMO, 1983) [58]. Chauhan (1994) [6] reported that the principal component to be affected by increasing shading intensity was filled grain percentage whereas test weight remained unaffected. It appears that solar radiation affects grain filling and hence filled grains by controlling source activity.

4. Impact of Rainfall on Rice

Rainfall amount and distribution is the most critical weather component in rain fed rice ecologies (Upland, lowland and flood prone). Its effect on irrigated ecology is indirect through availability of water in irrigation sources (tank, canal, well etc.,) and its effect on evapotranspiration of the crop through changes in temperature, solar radiation and wind speed. Daily rainfall is more critical than monthly or annual rainfall. A rainfall of 100 mm/month distributed evenly during the growing period was preferable than 200 mm/month, which fell in two or three days. Availability of about 200-300 mm of water per month is considered minimum to produce good crop of rain fed rice.

4.1. Vegetative phase

In rainy season, tillering is continued up to 42-45 days, whereas it is up to 50-55 days in dry season. According to Kamalam *et al*. (1988) [16], the accumulated rainfall during the tillering phase of the crop growth over and above the normal requirement had an adverse effect (significant negative correlation) on the straw yield. High rainfall during the active growth period resulted in taller plants and they lodge and decay in standing water. High rainfall may result in the decreased availability of sunlight. Variability in rainfall affects the stand establishment and growth duration of the crop.

Narayanan (2004) [29] reported 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, where as 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.

4.2. Reproductive stage

Variability in rainfall is associated with an untimely cessation at this stage, the yield reduction is severe. Wind damage to the crop at this phase was triggered by temporary water stress in the panicle spikelet and the injury was less when wind was accompanied by rain. Rice flowering was affected when rain occurred continuously for three days during flowering (Vijayakumar, 1996) [55]. Low yield was obtained due to continuous rain coupled with strong wind at flowering in wet season (Pradhan and Dixit, 1989) [35]. Due to heavy rainfall, panicles have large number of blank florets and nitrogenous fertilizers are less effective. The response of paddy to rainfall during the sharp critical phase of panicle initiation is significantly favourable. This beneficial influence persisted even when this factor was taken jointly with other climatic elements namely mean temperature and sunshine (Sreenivasan, 1985) [42].

Narayanan (2004) [29] observed a positive non-significant correlation between grain yield and total rainfall; whereas total rainfall was negatively correlated with straw yield in non-significant manner. Girish and Hittalmani (2004) [12] 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. It indicates 10 days after 50 per cent flowering to be the most critical stage for grain filling.

Among the rice growth stages, panicle initiation stage is more sensitive to moisture stress (www.agrimetassociation.com). Jeyaraman and Balasubramanian (2004) [15] reported that panicle initiation and flowering stages are more sensitive to submergence. They also found that muddy or turbid water inflicts a greater damage to plants than clear water because sediments in turbid water block the pores in the plant body and hamper the respiration and photosynthesis process.

4.3. Ripening stage

Viswanathan *et al*. (1989) [56] reported a negative correlation between yield and number of rainy day during maturity phase. Wet spells are detrimental to rice crop from flowering to maturity. Narayanan (2004) [29] stated that total rainfall during this stage was negatively correlated with grain and straw yield in a non-significant manner.

Gupta *et al*. (2000) [14] explained the yield variations in rain fed rice by quantum of precipitation during the critical vegetative and reproductive phases. Deficit soil moisture during grain filling stage drastically reduces the grain yield even if there was normal rainfall during preceding phases. On the contrary, however, in 1995 more than normal and normal yield of rice were obtained despite deficit rainfall during the season, because respectively 86 mm of rain was received during grain filling stage. It suggests yield variations are largely due to rainfall received during the grain filling stage of the crop.

5. Impact of Relative Humidity on Rice

Relative humidity is a function of temperature and moisture in the atmosphere is invariably much more in the morning than in the afternoon. Rice which is cultivated in the standing water builds up an environment with high relative humidity.

5.1. Vegetative stage

Rice requires a fairly high degree of humidity for proper growth. RH of 80-85 per cent is ideal for shoot growth. Rice grown at 22, 28 or 34 ºC, the photosynthetic rate is increased with increase in humidity and vice versa. The increase is greatest at 28 ºC and smallest at 34 ºC. Leaf temperature and stomata aperture in the upper part of the canopy also increased with increasing humidity (Hirai *et al*., 1989) [11]. Root dry weight production was more influenced by RH than shoot dry weight. The root-shoot dry weight of plants at 90 per cent was lowest at low temperature but higher at high temperature than in plants grown at 60 per cent RH. At the intermediate temperature, RH had little effect on root-shoot dry matter ratio (Hirai *et al*., 1992) [12].

Low relative humidity of 60 per cent induced a decrease in moisture content, loss of chlorophyll and faster senescence of leaf. Nitrogen uptake and content of leaves and roots in plants grown at 90 per cent RH were higher than those of the plants grown in 60 per cent RH (Hirai *et al*., 1993) [13]. Increase in relative humidity during active tillering increase the number of panicles per hill. High relative humidity with high solar radiation positively influenced the number of leaves per plant. Low relative humidity shortened the days taken from transplanting to panicle initiation (Sunil, 2000) [45].

5.2. Reproductive stage

Relative humidity plays a major role in altering the days to first flowering (Rangasamy, 1996) [37]. The minimum relative humidity required for flowering of rice was 40 per cent; the optimum being 70-80 per cent. If the RH is below 40 per cent, flowering is inhibited (Vijayakumar, 1996) [55]. According to Wang *et al*. (1992), duration of lemma closing in rice decreased with increase in relative humidity from 60 to 100 per cent.

Relative humidity influences the rate of transpiration. The increased transpiration may influence the physiological process affecting the yield. The yield decreased with the increasing relative humidity during this phase (Ghildyal and Jana, 1967) [10]. In areas with high temperature and low relative humidity or low temperature with high humidity, glume did not open and finally resulted in poor viability of pollen (Subbiah, 1996) [44]. Narayanan (2004) [29] found that relative humidity had negative correlation with straw yield and positive correlation with grain yield during this stage. It suggests that relative humidity during this stage had profound influence on growth and yield of rice.

5.3. Ripening stage

Relative humidity was the most significant meteorological factor affecting spikelet fertility in rice followed by mean temperature at 3 days after heading. Spikelet fertility was reduced with increasing RH (Shi and Shen, 1990) [38]. Krishnakumar (1986) [18] observed that relative humidity showed a negative relationship with panicles m^{-2}, grains m^{-2}, percentage of filled grains and grain yield. Low relative humidity (around 43%) during grain formation with a temperature range of 12-13 ºC was conducive to yield increase (Ghildyal and Jana, 1967) [10]. Narayanan (2004) [29] found that relative humidity had negative correlation with both grain yield and straw yield during this stage but in a non-significant manner.

6. Impact of Wind on Rice

6.1. Vegetative stage

Kamalam *et al*. (1988) [16] observed that wind velocity at tillering stage had a positive significant correlation with grain yield; the effect with straw yield was positive but was non-significant. Strong winds caused leaf breakage and delay in crop maturity (Lin-Meng Huri *et al*., 1994) [21]. Sunil (2000) [45] reported that wind speed during active tillering to heading stage had a significant negative correlation with number of panicles per plant and straw yield.

6.2. Reproductive stage

Lenka (2000) [20] reported that the 88 cm tall rice var. ‘CR 1009’ (170 d) lodged to 80-85º (displacement from the vertical) due to 8-9 kmph (24 h mean) wind at flowering stage during *kharif* season resulting in 63 per cent panicle grain sterility and heavy loss in grain yield. Grain yield was more affected than straw yield due to wind at this stage. Strong winds at the time of the flower opening may induce sterility and increase the number of abortive endosperms (Sreenivasan, 1985) [42]. Strong wind causes sterility at flowering by desiccating the plant. A hot, dry air causes white head, particularly when it occurs during panicle exertion (Hitaka and Ozawa, 1970).

According to Kamalam *et al*. (1988) [16] wind velocity during reproductive stage had the significant positive correlation with grain yield; the effect with straw yield was positive but not significant. But, Sunil (2000) [40] observed a negative correlation between grain yield and wind speed during flowering stage. Marchezan *et al*. (1993) [24] analysed the reproductive organs and found that the anthers and ovaries were absent or desiccated due to prevalence of wind speed of 43-48 kmph. High wind speed during flowering had caused pollen dehydration and consequent spikelet sterility in rice (Prasada Rao, 2003) [36]. Fertilization in rice was inhibited by wind speed of more than four meter per second (Viswambaran *et al*., 1989) [56].

6.3. Ripening stage

Strong winds during the ripening period lead to the shredding of leaves, serious lodging and shattering of grains (De Datta and Zarate, 1970 and Sreenivasan, 1985) [42, 9]. The occurrence of white grains was increased by wind at 14-21 days after heading (Viswambaran *et al*., 1989) [56]. Kamalam *et al*. (1988) [16] opined that the wind velocity is significantly correlated with grain yield. Under strong winds, grain development and maturity were found to be poor.

7. Conclusion

Among the abiotic stresses, weather plays the dominant role in influencing the growth and yield of rice. The most important weather elements that influence growth, development and yield of rice are solar radiation, temperature and rainfall. Relative humidity and wind velocity influence the crop growth to some extent. Rice cultivation continues to be a risky enterprise, despite advances made in modern technologies. The deviation in the weather can be exploited by resorting to optimum time of sowing or planting.

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