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Rice-Wheat cropping system under changing climate Scenario: A review

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Abstract

Climate change directly or indirectly influences all economics aspects, but agriculture is among the sectors which are most sensitive and inherently vulnerable to climate. The impacts of increased temperature from global warming and changes in rainfall patterns resulting from climate change are expected to reduce agricultural production and put further pressure on marginal land. Climate change and especially increase in ambient temperatures will reduce the yields of major cereal crops especially Rice-wheat. Hence, to achieve our goals of food security, we need to emphasize the use and production of food crops that can withstand the on-going changes to the climate, especially in the arid and semi-arid regions around the globe that are at a greater risk of food insecurity. There are key factors that significantly impact to mitigate stress conditions of the climate, i.e. short duration crop, value added weather services, genotype with higher per day yield potential, weather linked agricultural insurance etc.

Keywords: Climate change, rice- wheat, cereal crops, global warming, mitigation

Introduction

Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. CO2concentration in the atmosphere has increased drastically from 280 ppm to 370ppm and is likely to be doubled in 21stcentury (IPCC, 2007) [14]. World now faces one of the most complex issues which it has ever had to deal with i.e., climate change. Climate change at present has moved from being hypothesis to being reality and has become an important global threat to all economic sectors, being agriculture a major one. Globally, an unprecedented increase in greenhouse emissions has led to increased climate change impacts. Agricultural activities have been shown to contribute immensely to climate change as it ranks third after energy consumption and chlorofluorocarbon production in enhancing greenhouse emissions. In fact, emissions from agricultural sources are believed to account for some 15% of today's anthropogenic greenhouse gas emissions. Land use changes, often made for agricultural purposes, contribute another 8% or so to the total (Ozor and Nnaji, 2011) [35]. Agriculture depends on a favorable climate, hence is among the sectors of the global economy where most concern currently lies in the context of climate change in order to maintain global food security.

IPCC, Intergovernmental Panel on Climate Change has defined climate change as any types of changes that occurs on climate over time which arises as a result of both human activity and natural variability whereas UNFCC (United Nations Framework Convention on Climate Change) defines climate change as a change in climate that is contributed directly or indirectly to human activity that influence the composition of global atmosphere. Alterations in our climate are governed by a complex system of atmospheric and oceanic processes and their interactions. Agriculture depends on a favorable climate, hence is among the sectors of the global economy where most concern currently lies in the context of climate change in order to maintain global food security, and avoid large-scale human suffering in developing countries where significant portions of gross domestic product (GDP) are dedicated to agricultural production and where rural populations are most vulnerable (Mertz *et al.*, 2009) [32]. In the context of crop production, relevant atmospheric processes consist of losses in beneficial stratospheric ozone concentration (O_3) and increasing concentrations of the surface layer trace gases, including atmospheric carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and Sulphur dioxide ([SO_2]). Surface level O_3, SO_2 and CO_2 have direct impacts on crops, while CO_2, CH_4 and N_2O are critical in altering air temperature. Climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations. Generally, temperature increase would lower the yield and also the quality of food crops thus jeopardizing food supplies.

Climate change predictions

The IPCC TAR (2001) [17] provided a baseline for the prediction of climatic changes at broad scales by using historical measurements and future predictions made by several global circulation models or GCMs in addition to what the first and second assessment reports had previously outlined (IPCC, 1990, 1995) [20, 15], but included the definitions of more politically oriented scenarios (i.e. the Special Report on Emissions Scenarios (SRES) scenarios; IPCC, 2000) [16] rather than the IS92 emission scenarios described in the first and second assessment reports. Working group, I (WGI) reported.

- Average diurnal temperature had increased by 0.6°C in the 20th century, with a significant increase from 1910 to 1945, followed by a slight decrease during the period 1945–1965, and a severe increase from 1976 to 2000;
- Increases in sea level between 0.1 and 0.2 m.
- Geographically differentiated increases and decreases in precipitation of at least 1% per decade.
- Increase in frequency and intensity of heavy rainfall events, increase in cloud cover
- Reductions in low temperature extreme events and increases in high temperature extreme events such as El Niño-Southern Oscillation (ENSO).

Greenhouse gases from different crops

The release of GHG including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from various crops are not well studied compared to the emission of GHGs from other industrial sectors (e.g., coal and oil), especially in the developing world. Even the data presented in the few studies conducted are highly variable due to the variability associated with the agricultural conditions in any particular region. Recent research has shown that global concentrations of CO_2, N_2O, and CH_4 are increasing rapidly and currently are 40%, 20%, and 150% of pre-industrial age levels, with agricultural operations being one of the major contributors to this phenomenon. Due to the greenhouse gas effect, the increase in GHG levels can have a substantial impact on temperatures and consequently on climatic conditions ((Gul Zazai *et al.*, 2018) Jain *et al*., 2016, Smit *et al*., 2002, Wang *et al*., 2013, Cole *e tal*.,1997) [39, 21, 47, 52, 8].

Table 1: Predicted effects of climate change on agriculture over the next 50 years MAFF (2000)

Climatic element	Expected changes by 2050	Confidence Inprediction	Effects in agriculture
CO_2	Increase from 360 ppm to 450-600 ppm	Very high	Good for crops, increased photosynthesis, reduced water use.
Sea level rise	Rise by 10 -15cm	Very high	Loss of land, coastal erosion, flooding, salinization of ground water
Temperature	Rise by 1-2°C	High	Faster, shorter, earlier growing season, heat stress risk Increased evapotranspiration
Precipitation	Seasonal changes by ±10%	Low	Impact on droughts, risk soils workability, water logging, irrigation supply, transpiration
Storminess	Increased wind speed, especially in north. more intense rainfall event	Very low	Lodging, soil erosion, reduced infiltration of rainfall

Table 2: Seasonal flux of global warming potential and carbon equivalent emission

Crop	Global warming potential (kg CO_2 eq. ha−1)	Carbon Equivalent Emission (kg C ha−1)
Rice	2890–17,000	956–4600
Millet	3218	878
Wheat	2000–18,000	545–4900
Maize	3427–17,600	935–4800
Sorghum	3358	916
Rice – wheat	7137–18,000	2000–4900
Wheat – maize	12,880–18,850	3512–5100

Global warming potential (GWP) is an estimate to assess the total amount of heat that can be trapped in the atmosphere due to GHGs. It is defined by the Intergovernmental Panel on Climate Change(IPCC) as “the radiative forcing following a pulse emission of a unit mass of a given greenhouse gas in the present day atmosphere integrated over a chosen time horizon relative to that of carbon dioxide” (IPCC, 2013) [18]. The assessment of the potential is made either based on a 20- or 100-year duration and generally it is assumed that the longer the gas is present in the atmosphere, the lower is its potency (can have exceptions Ex: Sulfur hexafluoride) (Shang *et al*., 2011) [46]. Simply, if a GHG has a higher thermal absorption rate and takes longer to degrade, it has a higher GWP. The GWP of various cereal crops like rice, wheat, maize and millets have been calculated which are reported in Table 2. Multiple studies including life cycle analyses have been conducted in different parts of the world to assess the GWP based on the regional data. The GWPs can vary widely based on agricultural practices, availability of irrigation systems, fertilizer applications, availability and mode of transportation as all these factors play a role in GHG released into the atmosphere

Carbon equivalent emission (CEE) is just a measure of total carbon equivalents calculated based on the GWP (which is the CO_2 equivalents).

CEE is obtained by using the following equation.

$$\mathrm{CEE} = \frac{\mathrm{GWP} \times \text{atomic weight of carbon}}{\text{Molecular weight of } \mathrm{CO_2}}$$

$$= \frac{\mathrm{GWP} \times 12}{44}$$

The GWP for these cereals was found to reach 17,000–19,000 kg CO_2 eq. ha^{-1}. In this study, the mean GWP and CEE for the five cereal crops was estimated to be 3598 kg CO_2 eq. ha^{-1} and 977 kg C ha^{-1} [Jain *et al*., 2016] [21]. Wheat showed the highest GWP with 3968 kg CO_2 eq. ha^{-1}, followed by maize (3427 kg CO_2 eq. ha^{-1}) and rice (3401 kg CO_2 eq. ha^{-1}).

Millets have the lowest GWP with 3218 kg CO_2 eq. ha^{-1} for pearl millet (a minor millet) and 3358 kg CO_2 eq. ha^{-1} for sorghum (a major millet). The CEE of different crops have showed that millets have the lowest carbon emissions (878 kg C ha^{-1}), followed by sorghum with 916 kg C ha^{-1}. The highest carbon emission was released by wheat (1042 kg C ha^{-1}). Hence, to reduce greenhouse emissions from agricultural activity, cultivating millets will be a better option, which in turn could be beneficial in reducing global warming. Furthermore, a comprehensive life cycle analysis must be performed on millets to confirm the lower GWPs when transportation and other factors are also included.

Effect of climate change on rice production

Carbon dioxide

Elevated $C0_2$ accelerated rice development, increased leaf photosynthesis by 30-70 per cent, canopy photosynthesis by 30-40 per cent and crop biomass yield by 15-30 per cent, depending on genotype and environment. Elevated CO_2 had a minor effect on rice nitrogen (N) uptake, which appeared to be associated with the relatively insensitive response of leaf area growth to CO_2.

Table 1.

	Max temp (°C)	Min temp (°C)	CO_2 (ppm)	Simulated yield (q/ha)	Deviation yield (%)	Maturity date	Days to maturity	Deviation maturity days
C1	Normal	Normal	Normal	80.2	-	14 September	144	-
C2	+3	+3	Normal	87.1	8.6	27 August	126	18
C3	-3	-3	Normal	0.0	Nil	Crop did not mature	-	-
C4	Normal	Normal	350	96.3	20.0	13 September	143	1
C5	+3	+3	450	99.7	24.3	23 august	122	22
C6	Normal	Normal	700	101.4	26.4	13 September	143	1
C7	+3	+3	700	104.9	30.8	21 august	120	24
C8	-3	-3	700	0.0	Nil	Crop did not mature	-	-

Those rice responses to $C0_2$ resulted in a substantial grain yield increase under nearly optimum temperature condition. The anticipated changes in temperature and $C0_2$ have been modeled to have opposite effects on the production. Increasing temperatures shortened the growing season leading to decreased yields, while elevated $C0_2$ increased the yields (Erda *et al*., 2005) [12]. When C_3 plants, such as rice, are exposed to high $C0_2$ concentration, the net photosynthesis rate is accelerated due to both enrichment of substrate $C0_2$ as well as well as inhibition of photorespiration by high CO_2 concentration (Long *et al*., 2004) [29]. Reduction of stomatal conductance due to elevated CO_2 has been commonly observed in rice (Ainsworth, 2008) [2]. However, the response of stomatal conductance to elevated $C0_2$ varies considerably in response to various environmental factors (Ainsworth and Rogers, 2007) [3].

Temperature

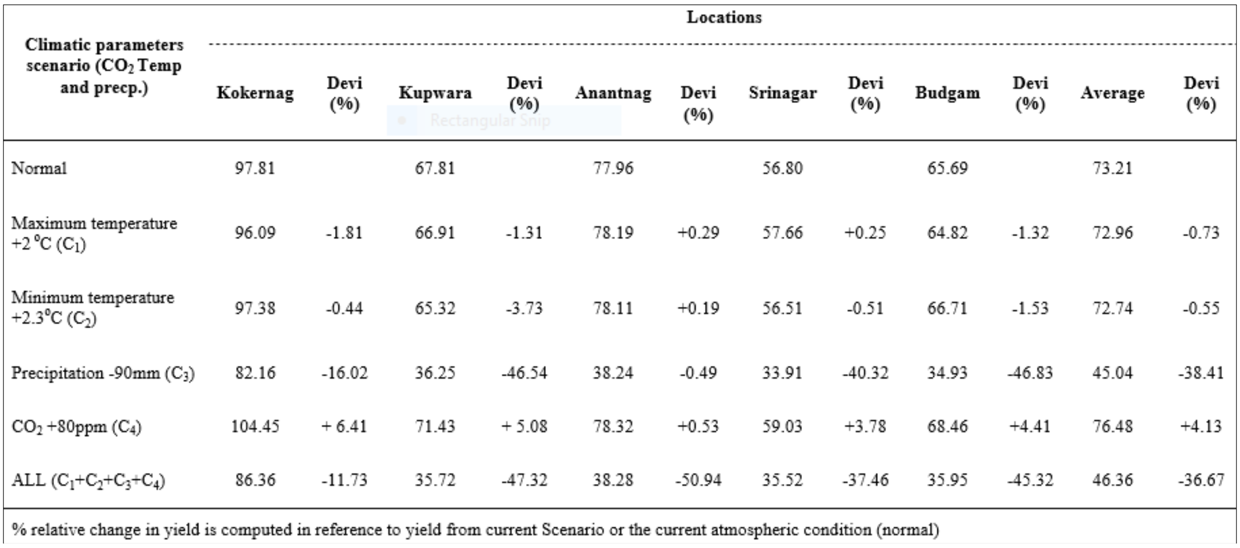
Higher temperatures affect rice yields through two fundamentally different processes: (l) gradual changes in metabolism and phenology and (2) spikelet sterility caused by temperatures (heat waves) beyond certain temperature/ humidity thresholds. Rice is grown in many regions where current temperatures during grain filling are only slightly below the critical limits for spikelet sterility (Wassmann *et al*., 2009) [53]. Grain yield declined by 10 per cent for each 1^{O}C increase in growing-season minimum temperature in the dry season, whereas the effect of maximum temperature on crop yield was insignificant (Peng *et al*., 2004) [37].

Sensitivity of CERES – rice model to climate change has been validated under temperate conditions of Kashmir (Singh; 2006). Simulated effect elevated ambient maximum and minimum temperature by 3°C (C2) resulted in increased rice yield by 8.6 percent over normal temperature (table 3) and decreased days to maturity by 17 days. The effect of elevated CO_2 (350 ppm) of the base value 330 ppm on simulated grain yield showed increase of 20.0 per cent and also matured the crop only one day earlier over base value. Further increase in CO_2 i e. 700 ppm (C6) recorded increase of 26.4 per cent over 330 ppm level (base value). Increase in maximum and minimum temperature 3°C under elevated CO_2 concentration of 450 ppm (C5) and 700ppm (C7) improved grain yield by 24.3 and 30.8 per cent than treatment (C1) respectively. Decrease in maximum and minimum temperature by 3°C under normal (C3) and 700 ppm (C8) did not mature the crop.

Deka reported model sensitivity to interaction of temperature and CO_2 level while predicting the effects of potential future global warming on rice yields, studies that examine the effects and interaction of both temperature and CO_2 are far more relevant than studies that examine only the effects of CO_2 or temperature enrichment (Nakagawa *et al*. 2000) [34] The net effect of an increase in CO_2 Simulated yield of rice as function of change in temperature and CO_2 level (Singh; 2006). and temperature is complicated and depends on the relative effects of both variables in a given region (Pathak *et al*. 2003) [36]. The interaction effect of temperature (0°C, +1°C, +2°C, +3°C, +4°C, +5°C and 6°C) and atmospheric CO_2 concentration (390,450,550, 650 and 750 ppm) showed that for all the CO_2 levels considered the CERES -Rice model predicted increasing yield of rice due to an increase in air temperature upto 5°C (table 4). Mean relative yield increase was 7% at +1°C and increased linearly upto 13.2% at +5°C followed by a short decrease at +6 temperature (table 4). Similarly, for all the temperature increments considered, mean relative yield increased from 6.3% at 390 ppm to 11.4% at 750 ppm of CO_2 concentration. Relative yield increase over the base yield was maximum (17.8%) at +5°C air temperature and 750 ppm CO_2 under prevailing condition of study area.

Any further rise in temperature from +5°C with 750 ppm CO_2 leads to a decline in relative yield. The result also indicated that the positive effect of elevated CO_2 on rice yield (550ppm, 650 ppm and 750 ppm) was cancelled out at temperature >4° Simulated yield of cultivar Jhelum at different locations is presented in Table 5, as a function of various climate change parameters.

Table 5: Simulated rice yield (q ha^{-1}) of cultivar Jhelum of different locations as function of various climate change parameters (Tabassum; 2014) [48]



Climatic parameters scenario (CO_2 Temp and precp.)	Locations											
	Kokernag	Devi (%)	Kupwara	Devi (%)	Anantnag	Devi (%)	Srinagar	Devi (%)	Budgam	Devi (%)	Average	Devi (%)
Normal	97.81		67.81		77.96		56.80		65.69		73.21	
Maximum temperature +2 °C (C_1)	96.09	-1.81	66.91	-1.31	78.19	+0.29	57.66	+0.25	64.82	-1.32	72.96	-0.73
Minimum temperature +2.3°C (C_2)	97.38	-0.44	65.32	-3.73	78.11	+0.19	56.51	-0.51	66.71	-1.53	72.74	-0.55
Precipitation -90mm (C_3)	82.16	-16.02	36.25	-46.54	38.24	-0.49	33.91	-40.32	34.93	-46.83	45.04	-38.41
CO_2 +80ppm (C_4)	104.45	+ 6.41	71.43	+ 5.08	78.32	+0.53	59.03	+3.78	68.46	+4.41	76.48	+4.13
ALL (C_1+C_2+C_3+C_4)	86.36	-11.73	35.72	-47.32	38.28	-50.94	35.52	-37.46	35.95	-45.32	46.36	-36.67

% relative change in yield is computed in reference to yield from current Scenario or the current atmospheric condition (normal)

It was observed that with the increase of 2°C temperature as estimated by 2040 it was expected an overall decrease of rice yield by 0.7% at all the locations, as estimated increase in minimum temperature by 2.3°C also simulated decrease by 0.55% across different locations. Precipitation with estimated decrease of 90mm of rainfall by 2040 huge decrease of yield was simulated at Kupwara, Anantnag, Srinagar and Budgam however decrease in Kokernag was not considerable. On an average decrease across the locations was 38 Increase of CO2 by 80ppm as estimated by 2040 recorded considerable increase in the yield at Kokernag, Kupwara, Srinagar and Budgam was 6.41,5.08,3.78 and 4.05 respectively, where at Anantnag the increase was only 0.5%. With regard overall change of all climatic parameters simulated the decrease of yield across the all locations is 36.67%. (Tabassum; 2014) [48]. Ria Biswas reported that Crop maturity period is highly dependent on prevailing temperature and crop duration decreases with the temperature enhancement. The effect of increased minimum temperature has pronounced impact on grain yield. Shah *et al.*, (2011) [44] also emphasized on adverse impact of higher temperature on yield of rice. The maturity period of Shatabdi variety was reduced by 3 to 7 days due to 1-2°C temperature enhancement.(Chhagan *et al.*, 2019) [7] The model output also showed the simulated LAI would decrease with increase of temperature. During panicle initiation and grain filling stages, the enhanced temperature effect on LAI would be more (Table 6). With the normal DOS (4th week of May) and the common management practices,5-10 per cent yield reduction would be observed with rise in temperature upto 2°C. Under elevated thermal condition, the yield decrease occurs mainly due to the lower LAI throughout the crop growth stages and shorter crop growth period, which is evident from the study.

Table 6: Performance of rice under elevated thermal condition (Biswas, 2018)

	AT*	**AT+1°C**	**AT+2°C**
LAI at Panicle Initiation stage	6.1	5.5	4.4
LAI at grain filling stage	7.2	6.9	5.8
Days to mature	110	107	103
Reduction in days to maturity (days)	-	3	7
Yield (kg ha-1)	4238.6	4006.5	3784.2
Yield reduction (%)	-	5.5	10.7

Effect of temperature variability on wheat productivtity

Changes in global climate are likely to influence spatial and temporal trends of temperature and rainfall, which will affect crop phenology and yield (Jalota and Vashisht, 2016) [22]. A gradual or abrupt change in weather parameters especially maximum temperature (Tmax) and minimum temperature (Tmin) compared to apposite can adversely impact growth and yield of wheat. Field experiments also revealed that during six years of experimentation, wheat yield increased with inter-seasonal Tmax and Tmin, which ranged from 21.5–24.4°C and 8.5– 10.2°C, respectively. This may be ascribed to the fact that average seasonal Tmax and Tmin in the present study period were within the optimum or apposite temperature limits of 20–25°C Tmax and 5–10°C Tmin, reported by Porter and Gawith (1999). However, in simulation study (1989-2008) it was observed that the inter–seasonal Tmax and Tmin varied from 22.4–29.7°C; and 9.1–15.9°C, respectively and wheat yield followed a polynomial function with temperature. The wheat yield started declining beyond 27°C and 11°C of Tmax and Tmin, respectively (Fig. 1). Increased temperatures impart negative impact of on crop production by reducing the length of the growing period of wheat (Jalota *et al.*, 2013 [23]; Jalota and Vashisht, 2016 [22]; Zacharias *et al.*, 2014 [55]; Kingra, 2016) [25].

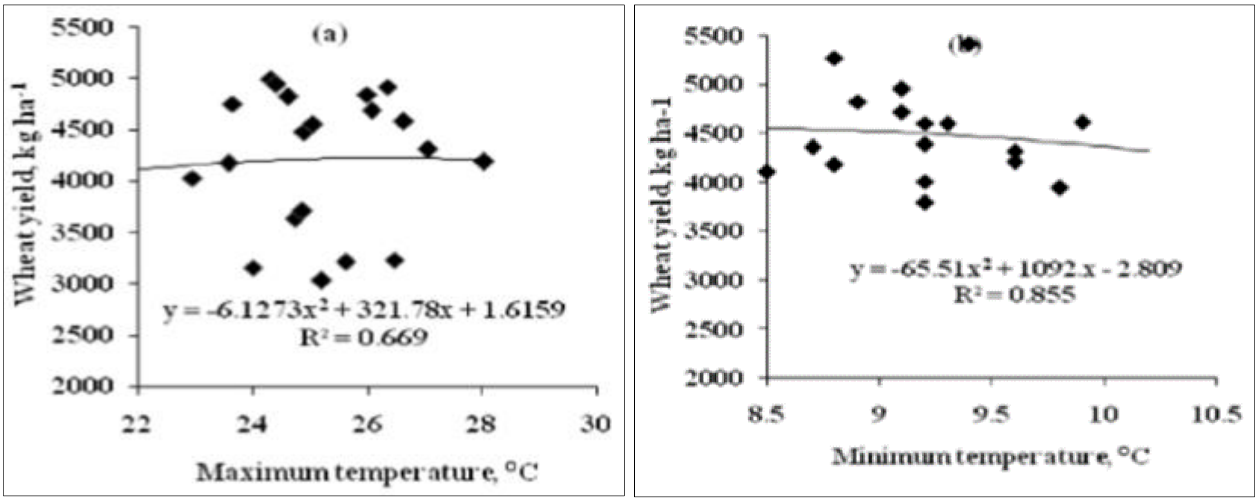


Fig 1: Effect of twenty years (1989-2008) averaged seasonal maximum and minimum temperatures on simulated wheat yield

Effect of maximum and minimum temperature on yield of rice and wheat

Reduction in yields of rice and wheat crops in different time slices was found to be directly related to increased Tmax and Tmin (fig. 2.). In comparison to the increased Tmin the magnitude of yield reduction in both the crops was higher with increased Tmax, confirming the finding of jalota *et al.* (2009 b) [24]. However, with, increased Tmin the reduction was more in rice crop than wheat. These results corroborate the findings of Peng *et al.* (2004) [38], at the international rice research institute, Philippines, that night temperature decrease rice yield. Actually increased temperature has shortened the crop duration in addition to higher respiration than photosynthesis, less assimilation per unit water consumed, decreased nutrient absorption, low dry mass production, high spikelet sterility and sink capacity at grain filling stage, reduced grain weight etc. (Kobata *et al.*, 1992 [26]; kobata and Uemuki, 2004 [27]; Mackill *et al.*, 1987 [30]; Matasubayashi, 1965 [31]; Saini *et al.*, 1986 [42]; Satake and Yoshida,1978 [43]; Yoshida, 1961) [54].

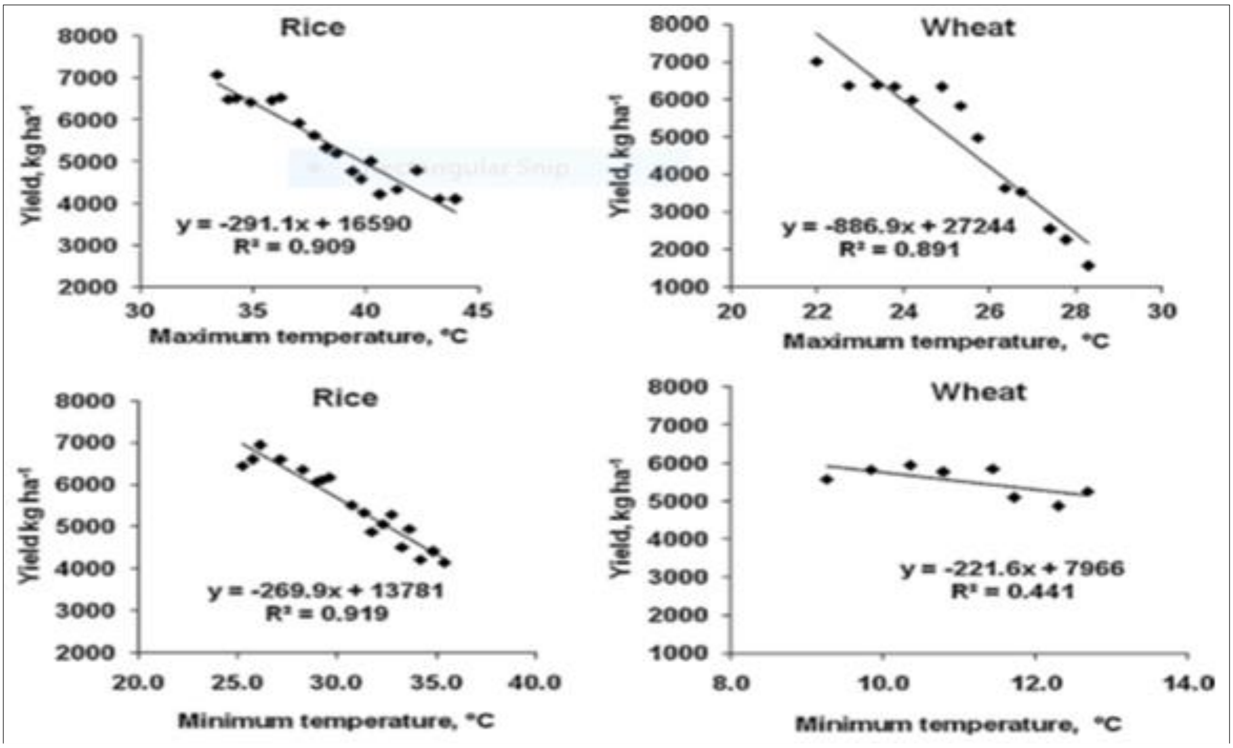


Fig. 2: Yield of rice and wheat as influenced by maximum and minimum temperature

Effect of temperature change on deviation in phenology of rice and wheat crop

CERES-rice and CERES-wheat have been validated for commonly sown cultivars of rice and wheat under Ludhiana (Punjab) conditions. Since rice and wheat are grown under assured irrigated conditions in Punjab, optimum (non limiting) moisture conditions were assured (Hundal and Prabhjyot, 2007) [13].

Table 7: Effect of temperature change from normal on deviation on phenology (days) of crop

	Temperature change (°C)								
Phenological event	-3.0	-2.0	-1.0	-0.5	Normal temperature	+0.5	+1.0	+2.0	+3.0
Rice									
Heading	5	2	0	0	101*	0	0	-1	-4
Maturity	12	6	2	0	141*	-1	-1	-1	-5
Wheat									
Heading	25	17	8	3	95*	-3	-6	-12	-16
Maturity	22	15	8	4	135*	-3	-6	-12	-17

(Hundal and Prabjyot, 2007) [13]

Both maximum and minimum temperature were increased and decreased by 0.5°C, 1.0°C, 2.0°C and 3°C from normal while keeping while keeping other climate variables constant. Heading as well as maturity of rice was not much affected by increase or decrease in temperature of 1°C from normal (table 7), but with a decrease in temperature by 3.0°C heading and maturity were delayed by 15 and 12 days respectively, from normal. On the other hand, anthesis and maturity of wheat revealed more drastic changes as the phenology was significantly advanced by increasing temperature, but was delayed by decreasing temperature (table 7).

When the maximum temperature decreased by 0.25 to 1°C from normal and minimum increased simultaneously from 1 to 3°C from normal keeping other climate variables constant, the phenology of rice and wheat was advanced by as much as 1-8 days (Table 8). In rice and wheat, when minimum temperature increased by 1.0-3.0°C and maximum temperature decreased by -0.25 to -1.0°C from normal, both the anthesis and maturity were advanced by upto 8 days from normal

Table 8: Effect of increasing minimum temperature above normal and decreasing maximum temperature below normal on deviation in phenology (days) of crop (Hundal and Prabjyot, 2007) [13]

Minimum temperature changes (°C)										
		+1.0			+2.0			+3.0		
		Maximum temperature changes (°C)			Maximum temperature changes (°C)			Maximum temperature changes (°C)		
Normal (DAS)		-0.25 -0.5 -1.0			-0.25 -0.5 -1.0			-0.25 -0.5 -1.0		
Phonological Event Rice										
Heading	101	-1	-1	-2	-2	-3	-3	-4	-4	-4
Maturity	141	-2	-2	-3	-4	-5	-4	-7	-8	-8
Wheat										
Anthesis	95	-2	-2	0	-6	-4	-3	-8	-8	-6
Maturity	135	-1	-1	1	-5	-4	-3	-8	-7	-6

Climate change–Mitigation and adaptation in agriculture

Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes**.** It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred. Adaptation has three possible objectives: to reduce exposure to the risk of damage; to develop the capacity to cope with unavoidable damages; and to take advantage of new opportunities**.** Following are some strategies to mitigate ill effects of climate change

1. Assist farmers in coping with current climatic risks by providing value-added weather services to farmers. Farmers can adapt to climate changes to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations.
2. An Early warning system should be put in place to monitor changes in pest and disease outbreaks. The overall pest control strategy should be based on integrated pest management because it takes care of multiple pests in a given climatic scenario.
3. Participatory and formal plant breeding to develop climate-resilient crop varieties that can tolerate higher temperatures, drought and salinity.
4. Developing short-duration crop varieties that can mature before the peak heat phase set in.
5. Selecting genotype in crops that have a higher per day yield potential to counter yield loss from heat-induced reduction in growing periods.
6. Preventive measures for drought that include on-farm reservoirs in medium lands, growing of pulses and oilseeds instead of rice in uplands, ridges and furrow system in cotton crops, growing of intercrops in place of pure crops in uplands, land grading and leveling, stabilization of field bunds by stone and grasses, graded line bunds, contour trenching for runoff collection, conservation furrows, mulching and more application of Farm yard manure (FYM).
7. Efficient water use such as frequent but shallow irrigation, drip and sprinkler irrigation for high value crops, irrigation at critical stages.
8. Efficient fertilizer use such as optimum fertilizer dose, split application of nitrogenous and potassium fertilizers, deep placement, use of neem, karanja products and other such nitrification inhibitors, liming of acid soils, use of micronutrients such as zinc and boron, use of Sulphur in oilseed crops, integrated nutrient management.
9. Seasonal weather forecasts could be used as a supportive measure to optimize planting and irrigation patterns.
10. Provide greater coverage of weather linked agriculture insurance.

Conclusion

Both current and future climate changes will influence crop yield especially of cereal crops. This statement has drawn attention of the world, because different aspects of climate variability (temperature, precipitation) impact the crop growth and their productivity results. Researchers and growers should develop diversification strategies based on local conditions.

This should be part of the strategy for achieving food security within the context of climate change and a rapidly increasing population. Furthermore, it has to be noted that a holistic approach is required in tackling food in security issue as there is no single solution that can solve the issue. Coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. To cope with the impact of climate change on agriculture and food production, India will need to act at the global, regional, national and local levels.

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