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Impact of climate change on growth and development of seed

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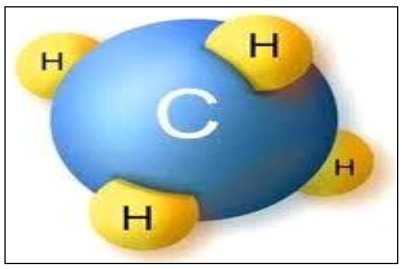
Climate Change refers to an overall alteration of mean climate conditions which increases in the surface temperature of the earth's atmosphere, ocean, and landmass. Primary causes of climate change are the increases in concentrations of various atmospheric ''greenhouse gases'' which include water vapour, carbon dioxide, methane, nitrous oxide, and the chlorofluorocarbons (CFCs). These gases were contributed by different sectors like energy supply, industries, forestry, agriculture, transport, residential and commercial building and other waste.

The atmosphere is a layer of gases that surrounded the earth, without it, our days would be too hot and our nights are too cold. Weather is the condition of the atmosphere in a specific place at a specific time. It describes factors such as wind, temperature, relative humidity and moisture. Climate refers to the condition of the atmosphere over a large area and averaged over many years.

Methane (CH_4) is the most significant greenhouse gas released within the agriculture sector. Methane has the highest global warming potential, which is about 300 times the potential of carbon dioxide and about 20 times that of nitrous oxide. Most of the methane releases come from paddy fields (91%) and less significantly from animal husbandry (7%) and the burning of agricultural wastes (2%).



Carbon dioxide (CO_2) primarily, deforestation due to agricultural expansion and land speculation was caused a major source of carbon emissions. CO_2 is also released during the burning of agricultural crop waste, for example, during the burning of cereal straw, sugarcane stubble and paddy straw.

Nitrous Oxide (N_2O) Most of the agriculture-based N_2O emissions come from nitrogen fertilizer usage, legume cropping and animal waste. Some N_2O emissions are also released during biomass burning. Many farmers use nitrogen fertilizers on their fields to enhance crop growth. The crop takes up most of the nitrogen, but some of them leach into surrounding surface and ground waters and some of it enters the atmosphere.

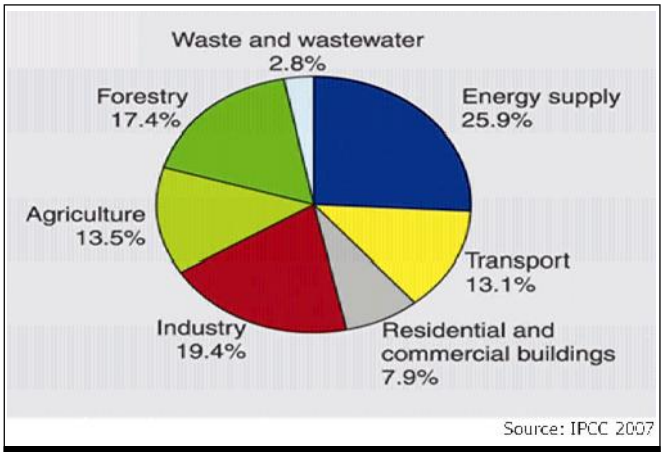


Fig. 1 : Contribution of different sectors in world to climate change (Sources of Greenhouse Gas Emissions)

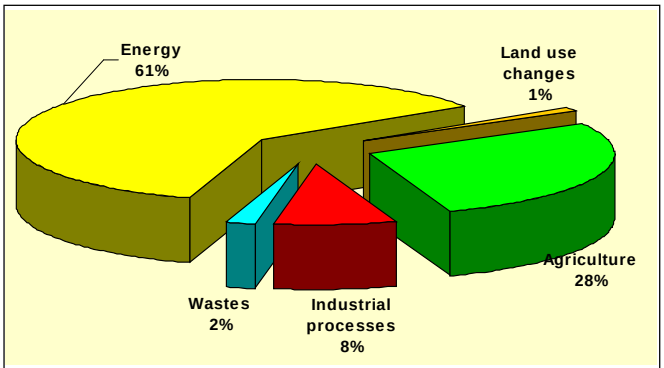


Fig. 2 : Contribution of different sectors in India to climate change (Sources of Greenhouse Gas Emissions in India)

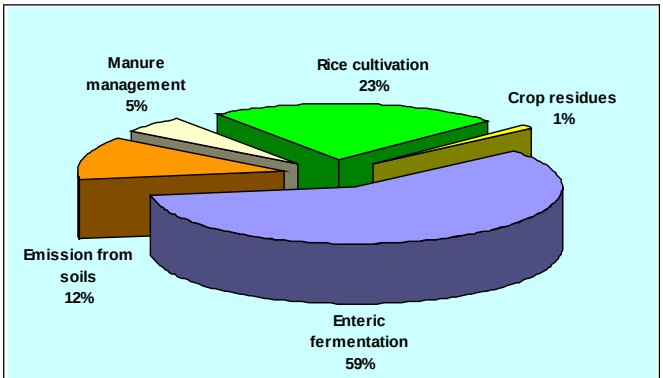


Fig. 3 : Sectors of agriculture in India contribute to climate change (Sources of Greenhouse Gas Emissions)

Impact of climate change on seed development and its attributes :

- Physiological process
- Seed germination and emergence
- Vegetative growth and development
- Reproductive development
- Flower initiation
- Pollen production and viability
- Seed set
- Seed filling period
- Number of seeds and seed size
- Seed yield
- Harvest index
- Seed composition

Physiological process : Many physiological processes like photosynthesis, respiration, transpiration, stomatal conductance and water use efficiency are adversely affected by increasing temperature above optimum level. Eg. Photosynthetic rate decreases for many crop plants, like soybean (*Glycine max*) and rice (*Oryza sativa*), when air temperature is above 30 ^{0}C, although photosynthesis in many cultivars of wheat (*Triticum aestivum*) decreases above 25 ^{0}C.

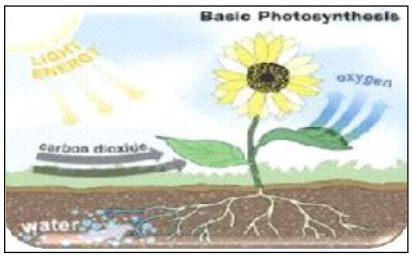


Table 1 : Temperature range for germination and growth of some crops

Temperature	Crops	Germination (^{o}C)			Growth (^{o}C)		
		Optimum	Min	Max	Optimum	Min	Max
High	Egg plant	20-25	15	33	22-28	17	33
	Pepper	20-30	15	35	25-30	15	35
	Water melon	25-30	15	35	25-30	13	35
	Soybean	25-30	10	35	25-30	10	35
	Maize	25-30	10	40	20-30	10	35
	Melon	25-30	15	40	25-30	18	35
Medium	Wheat	25-30	2	40	20-25	4	30
	Tomato	15-27	11	30	21-26	5	35
	Cucumber	25-30	18	30	18-25	12	35
	Pumpkin	20-25	15	40	17-25	10	35
Low	Lettuce	15-20	4	25	15-20	8	25
	Carrot	15-25	11	30	16-20	5	28
	Cabbage	15-30	8	35	15-20	5	25
	Spinach	15-20	5	30	15-20	3	25
	Potato	Vegetative prapogated			15-24	10	29
	Strawberry				17-23	10	23

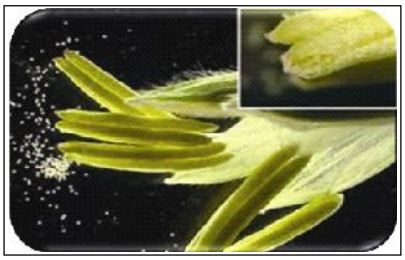
Seed germination and emergence : The optimum temperature for seed germination differs among plants. A temperature range for optimum germination of cool-season vegetable seed is from 3–17^{0}C and for warm season crops, 20 – 25 ^{0}C . Temperatures above or below the optimum temperature inhibit the rate of seed germination. Doubled concentration of CO_2 has no effect on seed germination.

Vegetative growth and development : Vegetative development includes the initiation and expansion of roots, leaves, shoots, branches, and tillers, all processes that are strongly driven by temperature. In most of the determinate annual crop species, increases in temperature will not only hasten the initiation of organ growth, but will also shorten the duration of growth. This results in less time for photosynthesis before the start of reproductive growth. Increasing temperature, 25^{0}C for wheat and 35^{0}C for soybean, generally increases vegetative growth rates. Above a certain threshold temperature in each crop, the growth rate will decline. The effects of elevated CO_2 on crop development are smaller compared to those of temperature.

Flower initiation : There is tremendous diversity among plant species in the initiation of flowering. On some annual plants, flowers develop after a certain number of leaves are produced and in the tropical region, flowering will often occur at the end of the dry season. High temperatures will often result in early flowering, and elevated CO_2 may also lead to early flowering.

Reproductive development : Reproductive growth is often depressed by the same conditions that enhance vegetative growth. With slight increases in temperature, reproductive events are likely to reduce. Flowers may abort before producing seed due to the sensitivity of pollen and fertilization to increased temperature. In addition to that, effective filling period is often shortened at higher temperature, leading to few and smaller seeds.

Pollen production and viability : Temperatures above the optimum level for each crop can have negative effects on plant reproductive processes. Pollen production and pollen viability are very sensitive to slight increases in temperature above optimum. Daytime temperature >34^{0}C significantly reduces pollen production and viability of peanut (*Arachis hypogaea*), a warm season crop.

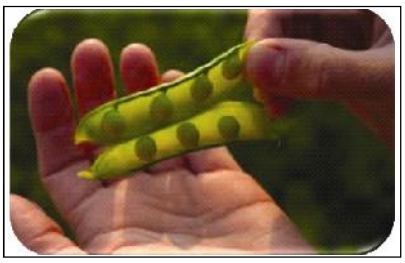


Seed set : Seed set is the process during which the fertilized ovule develops into a seed. Temperatures above

Table 2 : Effects of drought stress on pollination traits

Pollination traits	Effects related to drought	References
Pollen grain availability	Decrease number of pollen grain availability	Agren (1996); Trueman and Wallace (1999); Sheoran
Pollen grain sterility	Increase number of pollen grain sterility	Schoper (1986) and Al-Ghzawi *et al.* (2009)
Pollen grain germination and pollen tube growth	Decrease number of pollen grain germination and reduce pollen tube growth	Lee (1988) and Pacini (2000)
Anther development	Decrease anther development.	Nishiyama (1984)
Ovary abortion	Increase number of ovary abortion	Westgate and Boyer (1986)
Flower induction and Inflorescence development	Delay in flowering (anthesis), or even complete inhibition	Wopereis *et al.* (1996) and Winkel *et al.* (1997)
Flower size	Reduce flower size	Jonas and Geber (1999)
Flower attractiveness	Decrease flower attractiveness	Al-Ghzawi *et al.* (2009)
Jordan University of Science and Technology, Jordan		Ahmad *et al.* (2011)

the optimum level decrease seed set in most seed producing crops including rice, wheat, corn, peanut, cowpea and pigeon pea. The main reason for decreased seed set (or fruit set) is decreased pollen production, lower pollen viability, reduced pollen germination, and less pollen tube growth.



Seed filling period : An increase in temperature will shorten the overall life cycle and seed filling period of many seed producing crops, leading to smaller seed. An increase of 4–5^{0}C above optimum (26^{0}C) temperature will decrease the duration of the seed filling period in wheat and rice resulting in lower yields, particularly in tropical regions. In contrast, there is very little effect of elevated CO_2 on Seed filling period.

Number of seeds and seed size : Increased temperature may result in a lower number of seeds per plant. In contrast, elevated CO_2 increases the number of seeds due to increased tillering, branching, and growth. Increases in temperature generally decrease the seed size of many seed legume crops, such as soybean and green gram. There is very little effect of elevated CO_2 on individual seed size.

Seed yield: Seed yield of crop plants are decrease when temperature increase above the optimum temperature. For example, above a mean temperature of 26^{0}C, seed yield of rice and wheat declined by 6-10% per every 1^{0}C rise above the optimum temperature for each cultivar.

Seed composition : Warmer temperatures generally decrease starch concentration, while elevated CO_2 may

Table 3 : Effects of drought stress on yield and yield component traits

Yield traits	Effects related to drought	References
Seeds per spike	Decrease number of seeds per spike	Agueda (1999); Mogensen (1992) and Garcia (2003)
Fertile florets	Decrease number of fertile florets	Otegui and Slafer (2004)
Fertile spike per plant	Decrease number of fertile spike per plant	Mogensen (1992); Sanchez *et al.* (2002) and Samarah (2004)
Sterile spikes per plant	Increase number of sterile spikes	Mogensen (1992); Sanchez *et al.* (2002) and Samarah (2004)
Spikes per plant	Decrease number of spikes per plant	Mogensen (1992); Sanchez *et al.* (2002) and Samarah (2004)
Individual seed weight	Decrease weight of individual seed	Mogensen (1992); Agueda (1999); Sanchez *et al.* (2002); Garcia (2003) and Samarah (2004)
Seed yield	Decrease seed yield	Agueda (1999); Garcia (2003) and Samarah (2004)
Harvest index	Decrease harvest index	Ekanayake *et al.* (1989) and Samarah *et al.* (2009)
Jordan University of Science and Technology, Jordan		Ahmad *et al.* (2011)

Table 4 : High temperature injury of crops

Crop	High-temperature injury
Rice	Male sterility (over 30^{0}C)
Wheat	Male sterility (over 30^0 C)
Tomato	Male sterility (over 30^0 C)
Cucumber	Male sterility (over 30^0 C)
Pumpkin	Abnormal differentiation of male and female flower (over 30^{0}C)
Potato	Poor tuber formation (over 21^0 C), No tuber formation (over 29^0 C)

increase the concentration of carbohydrates. Total oil concentration decreases in soybean when grown above optimum temperatures.

Harvest index : Harvest index is the ratio of seed yield (economic yield) to biological yield. Above a certain optimum temperature for each crop, increased temperature will decrease harvest index almost in direct proportion to the decrease in seed yield. For example in peanut, the rate of change of harvest index decreases at temperatures above a mean temperature of 26^0C. In most seed legumes, harvest index is decreased at elevated CO_2 because the increase in vegetative growth is greater than that of seed yields.

Conclusion : Methane, carbon dioxide and nitrous oxide are the major greenhouse gases that cause the climate change by increasing the surface temperature of the earth's atmosphere, ocean and land mass.

When temperature increasing in above or decreasing below the optimum level will reduce the rate of different physiological process, seed germination, vegetative growth, flower initiation and reproductive development.

In majority of the crops increasing temperature above the optimum level is reduce the pollen production and viability, seed setting, and number of seed which is ultimately reduce the seed yield.

There is very little effect of elevated CO_2 on different stage of plant except vegetative growth and flower initiation.

In some crops like rice, wheat, tomato and cucumber temperature is increase above the 30^0 C which leads to male sterility.

In case of potato no tuber formation, when night time temperature is increase above the 20^0 C.

Future prospects : Need to study the pollen viability of different crop for hybrid seed production at different temperature condition.

Seed viability study for processing, storage and transport at different temperature condition.

Need to standardize the pollination time for all the crops.

There is need to prepare a package of practice for seed production with respect to climate change.

At national level initiation is needed for climate resistance seed production programme.

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