***Review Article***

# Heat waves and its impact on Crop production and mitigation techniques.- A Review

**Abstract**

The earth's average temperature has been rising. Heat waves are becoming extremely intense and frequent globally. In India, the months of March and April 2022, are the warmest on record, witnessed an unusual increase in maximum and minimum temperatures over most parts of the country. During this period, the extreme temperatures were found to be higher by +8 to +10.8°C and the rainfall lower by -60 to -99%, respectively compared to normal in 10 out of 36 meteorological subdivisions. In addition, 2022 will be remembered as a classic example of coupled impact of high temperature and subdued rainfall on agricultural production systems, specifically in northern and central India. Agricultural production in India is vulnerable to climate variability and change. The abnormal increase in maximum and minimum temperatures during 2022, impacted crops, fruits, vegetables and animals in the states of Punjab, Haryana, Rajasthan. Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra. The heat wave coincided with grain filling and development stage of wheat, yellowing and shriveling of grain, forced maturity, resulting in reduction of yields up to 15-25%.

Key words- Heat waves, rainfall, production and Crop



## Introduction

The earth's average temperature has been rising since the late 1970s. However, the year 2021 has broken the historical record of the global climate in many ways. The average global temperature across land and ocean surface areas in 2021 was 1.12°C higher than the twentieth-century average. Heat waves are becoming extremely intense and frequent in various parts of the world including India leading to losses in agricultural productivity and thousands of deaths. The Sixth Assessment Report of the IPCC has also reiterated that climate change is real and its impact is being felt throughout the globe. In many parts of India, warmer summer and droughts have significantly impacted agriculture. Global food production is steadily increasing, but the rate of increase especially for major cereal crops is declining. Agricultural production in India is becoming increasingly vulnerable to climate variability and change characterized by temperature rise (Rao et al., 2015) and altered frequency, timing and magnitude of precipitation (Bal et al., 2022). In spite of the large-scale development of soil-water-and crop-based technologies to optimize and sustain agricultural productivity in recent years, the latter continues to be affected by a number of factors. Factors like temperature, rainfall, relative humidity, light, availability of water, mineral nutrients etc. determine plant growth and development. The effect of each atmospheric factor on crop performance depends on its intensity and duration. However, some of these factors become stressful, due to the recurring features of climate variability, e.g. heat/ cold waves, floods/ heavy rain, hail/

thunderstorms, cyclones/ tidal waves etc., and these critical environmental threats are often referred as extreme weather events (Bal and Minhas, 2017). As climate change has become a reality, the implications of global warming for changes in extreme weather and climate events are of major concern for farmers as well as the common public. Sharma and Majumdar (2017) reported that in India, the percentage increase in the frequency of heat waves along with drought was most significant in parts of Maharashtra and southern Gujarat, Karnataka and Andhra Pradesh.

They calculated the Heat wave Magnitude Index daily (HWMId) which combines the duration and magnitude of heatwaves, and the Standardized Precipitation Index (SPI), which defines meteorological drought from 1951 to 1981. Using this as the base, they compared it with the HWMId and SPI between the years 1981 and 2010. It was found that the area affected has increased from almost nothing in 1951, to nearly 4 percent by 2010. Nearly 18 percent of the country's area has been facing at least three days of temperatures above the 85$^{th}$ percentile which is a cause of concern for agriculture and allied sectors. Chandran et al., (2017) characterized the Indian The earth's average temperature has been rising since the late 1970s. However, the year 2021 has broken the historical record of the global climate in many ways. The average global temperature across land and ocean surface areas in 2021 was 1.12°C higher than the twentieth-century average. Heat waves are becoming extremely intense and frequent in various parts of the world including India leading to losses in agricultural productivity and thousands of deaths.

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**The science behind**

A heat wave is a extended period of unusually high temperatures, as and scientifically defined as the occurrence of temperatures greater than normal in a certain region. These are rare events that vary in character and impact even in the same location. A heat wave is defined by more than just a

high daily maximum temperature. It also depends on how much it cools overnight. The maximum temperature will be achieved early the next day and will linger longer if the temperature remains high overnight. High levels of humidity and very light winds, if present, exacerbate thermal stress to people. Heat stress becomes a key element in health and infrastructure function when exceptionally high night and daytime temperatures continue. Hot nights make it more difficult to recuperate from the heat of the day during heat waves, putting extra stress on the living beings. Thus, although a heat wave is a meteorological event, it cannot be assessed without reference to human impacts.

**Causes of heat wave 2022**

Heat waves are not uncommon to Indian sub-continent during March to May. However, what made heat wave of 2022 deadliest is that it started very early and extended for a longer period. Weather experts have attributed the high temperature across the country to the absence of periodic light rainfall and thundershowers, typical for this time of the year, due to the lack of active western disturbances. In addition, anti-cyclones over western parts of Rajasthan in March and the absence of western disturbances had triggered the early and extreme heat waves. Anticyclones caused hot and dry weather by sinking winds around high-pressure systems in the atmosphere.

Northwest India recorded more than four western disturbances in March and April, but were not strong enough to cause a significant change in the weather. The region also did not receive any significant pre-monsoon rainfall from March 1 to April 20, which compounded the severity of the successive heat wave spells. The effect gradually progressed downwardsto central India.

**Favorable conditions for heat wave in India**

- Transportation / prevalence of hot dry air over a region (There should be a region of warm dry air and appropriate flow pattern for transporting hot air over the region). The synoptic situation favoring a heat wave is characterized by the presence of a powerful warm anticyclone covering the entire troposphere producing a blocking situation over a region. The pressure gradient is generally weak with associated light winds which tend to produce warm air advection.
- Absence of moisture in the upper atmosphere (As the presence of moisture restricts the temperature rise).
- The sky should be practically cloudless (To allow maximum insulation over the region).
- Large amplitude anti-cyclonic flow over the area. Heat waves generally develop over northwest India and spread gradually eastwards & southwards but not westwards (since the prevailing winds during the season are westerly to northwesterly). But on some occasions, heat wave may also develop over any region in situ under the favorable conditions.
- In addition, if the soil is very dry, all the solar radiation heat this, allowing the warming of the air in contact with the soil, promoting even higher temperatures.

**Types of heat wave**

India Meteorological department has classified heat waves into two, *viz.,*

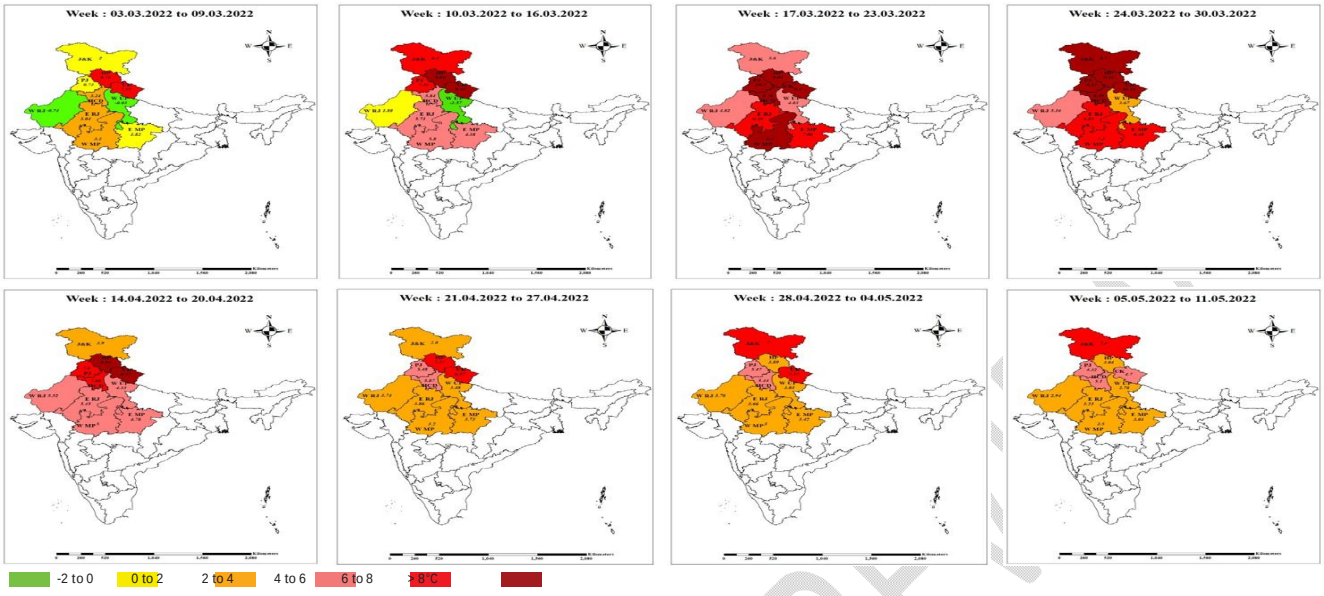
- Heat wave: either departure of daily maximum temperature is 4.5 to 6.4°C from the normal or when actual maximum temperature is in between 45 to 46.9°C
- Severe heat wave: either departure of daily maximum temperature is greater than 6.4°C or when actual maximum temperature is greater than or equal to 47°C Similarly, the Australian institute for disaster resilience has classified heat waves into three categories, *viz.,*
- Low intensity heat waves: more frequent during summer and are relatively easy to overcome
- Severe heat waves: less frequent and challenging for vulnerable sectors of the society
- Extreme heat waves: rare and may create problem for even healthy people. People who work outdoors have high risk of being affected by this.

Table 1. Types of heat wave in various places in India.

| | |
|---|---|
| March to July with peak temperatures in April, May, 2nd fortnight of October | South India: Khammam and Ramagundam (Telangana), Kalburgi and Bangalore (Karnataka) |
| | Eastern India: Bankura and Kolkata (West B<br>engal) and Bhubaneswar, Titlagarh and Jharsuguda (Odisha) |
| | North India: Punjab, Allahabad and Lucknow (UP), Gaya (Bihar), Delhi |
| | West India: Vidarbha and Marathwada (Maharashtra), Churu (Rajasthan), Ahmadabad (Gujarat) |
| | Central India: Jashpur (Chhattisgarh), Harda (Madhya Pradesh) |

*Source: Bal and Minhas, 2017*

During the months of March and April 2022, several states have recorded higher minimum and maximum temperatures. These extreme temperatures have considerable impact on crop growth and yield and caused substantial economic damage. The observed heat wave effects on crops, horticulture, livestock, poultry, fisheries and groundwater are elaborated in this section.




**Source : AICRP on Agrometeorology**

**Fig.1 Weekly mean maximum temparature departure in 10 meteorological subdivisions (northern and central India) during January-May 2022**

## Effect of Heat Waves on crop production.

Increase of minimum and maximum temperatures during March and April 2022, resulted in dry winds, high evapotranspiration and moisture stress. Several districts of Punjab were affected with heat wave events due to increase in temperature which has resulted in yellowing and shriveling of wheat grain, forced maturity, resulting in reduction in yields up to 25%. Increased whitefly infestation, poor vegetative growth and poor pod setting was observed in green gram causing reduction in yields up to 20%. Retarded growth and fall army worm attack was observed in maize, led to reduction of yields up to 18% in maize inFaridkot, Bathinda and Gurdaspur districts of Punjab.

Increase in maximum temperature upto 5°C over normal was observed in Kullu district of Himachal Pradesh, effected the *rabi* crops. Heat wave caused poor vegetative growth and poor pod setting in chickpea, wiltingand forced maturity in wheat, resulting in yield reduction in these crops.

Several districts in Haryana were also affected with heat wave, which resulted in wilting and shriveling of grains in wheat and chickpea. Heat wave led to reduction of wheat yield up to 10 to 15% particularly in the late sown wheat and up to 19% in chickpea. Extreme temperature in Datia, Morena and Tikamgarh districts of Madhya Pradesh resulted in early maturity and lower grain weight of wheat and chickpea.

Wheat and late sown mustard were also got affected in several districts of Uttar Pradesh. Heat waves resulted in reduction of wheat yield by 11 to 21% in Baghpat and Kushinagar, 9 to 21% in Gorakhpur, 15 to 20% in Gonda and 32 to 34% in Jhansi. In Gorakhpur and Kushinagar districts of Uttar Pradesh, mustard and cow pea yield were reduced by 14 to 18% and 9 to 11%, respectively. Similarly, several NICRA villages in Rajasthan experienced heat wave and recorded yield losses up to 4 to 5 q/ha in wheat and 2 to 3 q/hain mustard compared to normal.

**Metigation Stratigies against Heat wave.**

Increase in temperatures in many parts of India has triggered the heat wave conditions during March-April 2022, impacting the yields of *rabi* crops particularly wheat. The prevailing maximum temperatures have increased by 4-5$^{o}$C compared to the previous year at several locations. Wheat crop experienced heat stress during 3$^{rd}$ and 4$^{th}$ weeks of March where the crop is at milking stage and resulted in shriveled grains, affecting both quality and weight of output.

In India, wheat crop was sown in an area of about 31 million ha during 2021-22 crop season. Out of this approximately 75 per cent lies under timely sown (planted on or before November 15). Timely sown crop was in excellent condition under NWPZ (Haryana, Punjab, West UP) and NEPZ (east UP, Bihar and West Bengal) till second week of March but suddenly rise in temperature affected the crop. The late sown crop (in about 6-7 millionha area) got affected severely.

Various technologies are available to minimise the yield loss in wheat due to heat wave and some of them are transferred to farmers' fields. Several heat tolerant wheat varieties, PBW 803, DBW 187 and DBW 222 can tolerate high temperatures and can produce normal yields compared to local variety HD-3086 (Table 2). Technologies such as residue management of rice by various machines enable timely sowing of wheat. Direct seeding of rice can result in early maturity by 10 days which can enable timely sowing of wheat. Spray of $KNO_3$ @ 0.5% at boot leaf and anthesis stages can minimise the yield loss. Providing additional irrigation through effective methods during heat stress period can alleviate the stress with optimal water use.

**Table 2: Wheat varieties possessing heat tolerance traits (HSI<1.0) for different zones of India**

| **Zone** | **Varieties** |
|---|---|
| **North WesternPlains Zone (NWPZ)** | DBW327, DBW332, DBW 303, DBW 187, WH 1270, DBW 222, HD3226, PBW 723, HD 3086, JKW261, HD 3298, HI 1621, HD 3271, |
| **North EasternPlains Zone (NEPZ)** | DBW222, HD 3249, DBW 187, NW 5054, K 1006, DBW 39, Raj 4120, K307, HD 2824, HI 1621, HD 3271, DBW 107, HD 3118, HD 3293, DBW252, HI 1612, K 1317, HD 3171 |
| **Central Zone(CZ)** | **Bread Wheat:** DBW187, GW513, HI1636, HI 1544, GW 366, GW 322, JW-3288, GW 273, HI 1634, CG |

| | |
|---|---|
| | 1029, MP 3336, MP 1203, HD 2932, MP4010, DBW 110, MP 3288, MP 3173, HI 1531, HI 1500<br>**Durum Wheat:** HI8823(d), HI 8759(d), HI 8737(d), HI8498(d), DDW47(d), UAS 466(d) |
| **Peninsular Zone(PZ)** | **Bread Wheat:** DBW 168, MACS 6478, UAS 304, MP1358, NIAW 3170,GW366, HI 1605<br>**Durum Wheat:** DDW48, MACS 3949(d), NIDW 1149 (d), MACS 4058(d), GW 1346(d), HI 8777(d), UAS 446 |

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