



Heat Waves and Its Impact on Crop Production and Mitigation Techniques: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Globally, heat waves are getting worse and more common. India experienced its warmest March and April on record, with maximum and minimum temperatures unusually rising in most of the nation. In 10 out of the 36 meteorological subdivisions during this time, the extreme temperatures were found to be higher by +8 to +10.8°C and the rainfall lower by -60 to -99 percent, respectively, compared to normal. Additionally, 2022 will be remembered as a prime example of the combined effects of high temperatures and low rainfall on agricultural production systems, particularly in northern and central India. Climate variability and change have an impact on India's agricultural production. In the states of Punjab, Haryana, and Rajasthan, abnormally high maximum and

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minimum temperatures in 2022 had an impact on livestock, crops, and fruits and vegetables. Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Bihar, and Maharashtra, as well as Jammu and Kashmir. The heat wave coincided with the wheat crop's grain filling and development stage, causing the grain to yellow and shrivel, forcing it to mature, and lowering yields by 15 to 25 percent. A variety of technologies are available to reduce the yield loss in wheat caused by a heat wave, and some of them have been implemented on farmer fields. As compared to the local variety HD-3086, several heat-tolerant wheat varieties, including PBW 803, DBW 187, and DBW 222, can withstand high temperatures while still producing normal yields.

Keywords: Heat waves; rainfall; production; crop.

1. INTRODUCTION

Since the late 1970s, the planet's average temperature has been increasing. The global climate record has been broken in a number of ways by the year 2021, though. 2021 saw a $1^{\circ}12^{\circ}\text{C}$ increase in average global temperature across land and ocean surface areas compared to the previous century. Numerous countries around the world, including India, are experiencing increasingly severe and frequent heat waves that are causing thousands of deaths as well as losses in agricultural productivity. The IPCC's Sixth Assessment Report has also reaffirmed the existence of climate change and the fact that its effects are being felt all over the world. Agribusiness has been severely impacted in many areas of India by droughts and warmer summers. The amount of food produced globally is rising, but at a slower rate than before, particularly for the major cereal crops. According to Rao et al., [1] temperature increases and other forms of climate variability are making India's agricultural production more and more susceptible. changed precipitation's frequency, timing, and amount [2]. "Despite the extensive development of technologies based on soil, water, and crops to maximize and sustain agricultural productivity in recent years, the latter is still impacted by a number of factors. factors like temperature, precipitation, relative humidity, light, water availability, mineral nutrients, etc. find out how a plant grows and develops. The duration and intensity of each atmospheric factor determine how it affects crop performance. However, because of the recurrent characteristics of climate variability, e.g. Heat/cold waves, floods/heavy rain, hail/thunderstorms, cyclones/ tidal waves, etc. Extreme weather events are a common name for these serious environmental threats" [3]. Since climate change has become a reality, both farmers and the general public are extremely concerned about how it may affect changes in extreme weather and climate events. According

to Sharma and Majumdar [4], "areas of Maharashtra and southern Gujarat, Karnataka, and Andhra Pradesh experienced the greatest percentage increase in the frequency of heat waves along with drought. They calculated the Standardized Precipitation Index (SPI), which describes meteorological drought from 1951 to 1981, and the Heat wave Magnitude Index daily (HWMId), which combines the length and intensity of heat waves. They used this as the starting point and contrasted it with the HWMId and SPI between 1981 and 2010". The area affected was discovered to have grown from almost nothing in 1951 to almost 4% by 2010. It is concerning for the agricultural industry and related sectors that nearly 18% of the country has experienced temperatures that have exceeded the 85th percentile for at least three days Chandran et al. [5].

Since the late 1970s, the earth's average temperature has been increasing, according to, (2017). The year 2021, however, has significantly outperformed previous records for the global climate. In comparison to the average over the previous century, the average global temperature in 2021 across land and ocean surface areas was $1^{\circ}12^{\circ}\text{C}$ higher. In many parts of the world, including India, heat waves are becoming increasingly severe and frequent, which has a negative impact on agricultural productivity and killed thousands of people. The IPCC's Sixth Assessment Report has also reaffirmed the existence of climate change and the fact that its effects are being felt all over the world [6-8].

Droughts and warmer summers have had a major impact on agriculture in many parts of India. The amount of food produced globally is rising, but at a slower rate than before, particularly for the major cereal crops.

2. THE SCIENCE BEHIND THE HEAT WAVES

A heat wave is an extended period of unusually high temperatures. According to science, a heat wave is when temperatures in a particular area are higher than usual. Even in the same place, these uncommon occurrences can differ in personality and effect. A heat wave is more than just a period of exceptionally high daily maximum temperatures. The amount of overnight cooling also affects the outcome. The maximum temperature will be reached early the following day and last longer if it rises significantly overnight. If present, high humidity and weak winds make people more susceptible to thermal stress. When unusually high night and daytime temperatures persist, heat stress becomes a crucial component of health and infrastructure operation. When there are heat waves, warm nights make it harder for living things to recover from the heat of the day, which puts them under more strain. As a result, even though a heat wave is a meteorological phenomenon, its effects on people must also be considered.

3. CAUSES OF HEAT WAVE 2022

From March to May, the Indian subcontinent frequently experiences heat waves. The fact that the 2022 heat wave started early and lasted longer, though, made it the deadliest one. Because there aren't any active western disturbances, weather experts believe that the country's high temperatures are caused by the absence of periodic light rain and thundershowers, which are typical for this time of year. The early and intense heat waves had also been brought on by anti-cyclones over western Rajasthan in March and the lack of western disturbances. By sinking winds around high-pressure systems in the atmosphere, anticyclones brought on hot, dry weather. Northwest India noted more than four western disturbances in March and April, but they were not powerful enough to significantly alter the weather. From March 1 to April 20, the area did not experience any significant pre-monsoon rainfall, which added to the severity of the subsequent heat wave spells. The impact progressively spread down to central India.

Favorable conditions for heat wave in India:

- The movement or predominance of hot, dry air over a region (There should be an area of warm, dry air and the right flow pattern to

move hot air over the region). When an intense warm anticyclone covers the entire troposphere and creates a blocking situation over a region, the synoptic conditions are favorable for a heat wave. In general, the pressure gradient is weak, and the light winds that are present tend to cause warm air advection.

- Lack of moisture in the upper atmosphere (because moisture limits temperature rise).
- There should be almost no clouds in the sky (to provide the greatest amount of insulation over the area).
- Anticyclonic flow with a large amplitude over the region. Since westerly to northwesterly winds are predominant during the season, heat waves typically develop over northwest India and move gradually eastward and southward, but not westward. However, under the right circumstances, a heat wave could occasionally form over any localized area.
- In addition, if the soil is extremely dry, all of the solar radiation will heat it, causing the air that comes into contact with the soil to warm and thus drive up the temperature.

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.

“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" [1].

4. EFFECT OF HEAT WAVES ON CROP PRODUCTION

The minimum and maximum temperatures rose between March and April 2022, which led to dry winds, high evapotranspiration, and moisture stress. Due to the heat wave events that were

brought on by the temperature rise in several districts of Punjab, wheat grain has yellowed and shrunk, forcing it to mature, and this has reduced yields by up to 25%. Green gram was found to have an increased whitefly infestation, poor vegetative growth, and poor pod setting, all of which led to yield reductions of up to 20%. In the Punjabi districts of Faridkot, Bathinda, and Gurdaspur, delayed growth and a fall army worm attack on maize resulted in yield reductions of up to 18 percent.

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

March to July with peak temperatures in April, May, 2 nd fortnight of October	South India: Khammam and Ramagundam (Telangana), Kalburgi and Bangalore (Karnataka)
	Eastern India: Bankura and Kolkata (West Bengal) 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, [1]

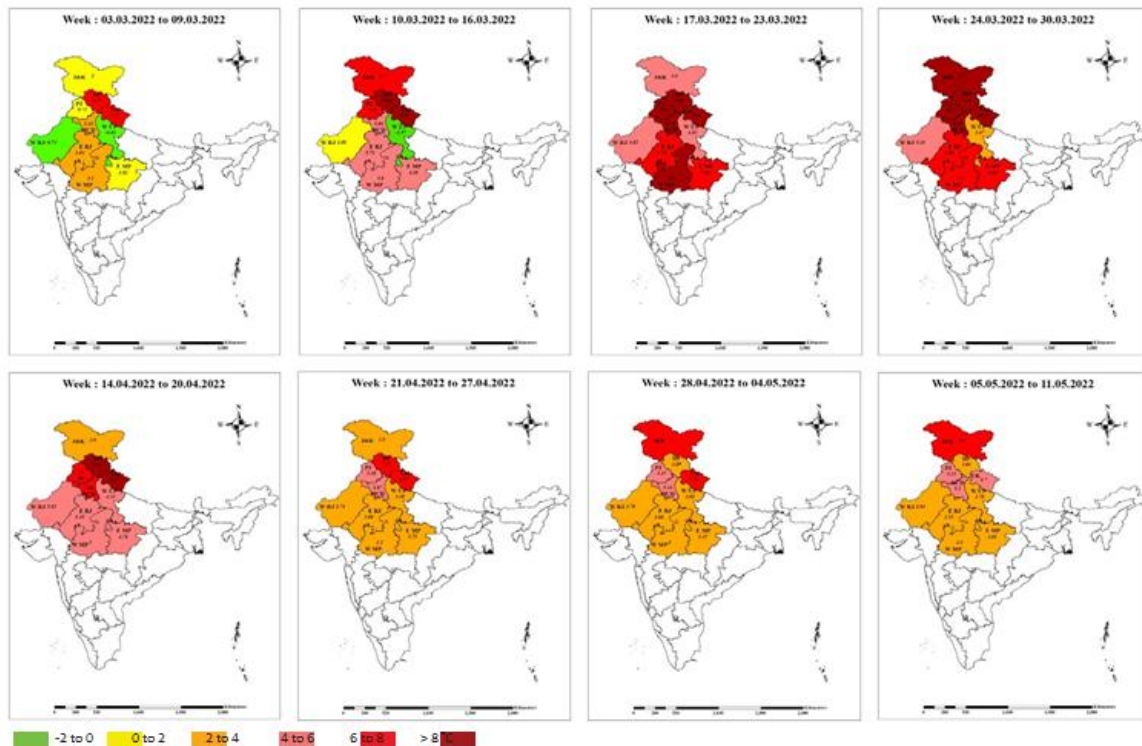


Fig. 1. Weekly mean maximum temperature departure in 10 meteorological subdivisions (northern and central India) during January-May 2022

Source: AICRP on Agrometeorology

In the Kullu district of Himachal Pradesh, maximum temperatures rose up to 5°C above average, which had an impact on the rabi crops. Heat wave reduced chickpea vegetative growth and poor pod setting, as well as wheat wilting and forced maturity, which decreased crop yields in these crops.

The heat wave also affected a number of Haryana districts, which caused the grains of wheat and chickpea to wilt and shrivel. The heat wave caused a 10 to 15% decrease in wheat yield, especially in late-sown wheat, and a 19% decrease in chickpea yield. Extreme heat in Madhya Pradesh's Datia, Morena, and Tikamgarh districts caused wheat and chickpea to mature earlier and have smaller grains.

In several districts of Uttar Pradesh, wheat and mustard that had been planted late also experienced problems. Wheat yields were decreased by 11 to 21% during heat waves in Baghpat and Kushinagar, 9 to 21% during Gorakhpur, 15 to 20% during Gonda, and 32 to 34% during Jhansi. The yield of cow pea and mustard decreased by 9 to 11 percent and 14 to 18 percent, respectively, in the Uttar Pradesh districts of Kushinagar and Gorakhpur. As a result of the heat wave, several NICRA villages in Rajasthan saw yield losses of up to 4 to 5 q/ha in wheat and 2 to 3 q/ha in mustard when compared to average.

5. MITIGATION STRATEGIES AGAINST HEAT WAVE

The March–April 2022 heat wave in many parts of India was brought on by rising temperatures,

which also had an effect on the wheat yields in winter crops. At several locations, the average maximum temperature has risen by 4-5°C from the previous year. In the third and fourth weeks of March, when the wheat crop was in the milking stage, heat stress caused the grains to shrivel, which had an impact on both the quality and weight of the crop's output. During the 2021–22 growing season, wheat was planted in an area of about 31 million ha in India. The portion of this that was timely sown (planted on or before November 15) makes up about 75% of the total. Up until the second week of March, the timely sown crop was in excellent condition under NWPZ (Haryana, Punjab, West UP) and NEPZ (East UP, Bihar, and West Bengal), but a sudden rise in temperature had an impact on the crop. Approximately 6-7 million ha of the late-sown crop were severely impacted.

Different technologies are available to reduce the yield loss in wheat caused by heat wave, and some of them are applied to farmers' fields. When compared to the nearby variety HD-3086, several heat-tolerant wheat varieties, including PBW 803, DBW 187, and DBW 222, can withstand high temperatures while still producing average yields (Table 2). Wheat is sown on time thanks to technologies like rice residue management by various machines. Direct sowing of rice can cause it to mature 10 days earlier than usual, allowing for the timely sowing of wheat. The yield loss can be minimized by applying KNO₃ in a 0 point 5 percent solution at the boot leaf and anthesis stages. During times of heat stress, providing additional irrigation using efficient techniques can reduce the stress while making the best use of water.

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

Zone	Varieties
North Western Plains 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 Eastern Plains 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 Durum Wheat: HI8823(d), HI 8759(d), HI 8737(d), HI8498(d), DDW 47(d), UAS 466(d)
Peninsular Zone (PZ)	Bread Wheat: DBW 168, MACS 6478, UAS 304, MP1358, NIAW 3170, GW366, HI 1605 Durum Wheat: DDW48, MACS 3949(d), NIDW 1149 (d), MACS 4058(d), GW 1346(d), HI 8777(d), UAS 446

6. CONCLUSION

In contrast to previous heat wave events, the extreme heat in 2022 will affect many regions of the country. According to predictions, extreme events like the current one will happen more frequently and severely in the years to come due to climate change. In light of this, concerted efforts are required to predict such events in advance, monitor their occurrence, and fully understand their impacts. The development of crop varieties and technologies that can reduce the effects of multiple stresses is already underway, but given the impending increase in the frequency and severity of such extreme events, these efforts must be stepped up across the agriculture, horticulture, livestock, fisheries, and poultry sectors. By improving weather forecasts and agro-advisory services, farmers can make well-informed choices regarding the upcoming weather. For climate resilient technologies to be adopted more widely, farmer capacities must be increased along with widespread awareness of them. Such initiatives will significantly improve the ability of different agricultural sectors in India to withstand climatic extremes, like the heat wave that was experienced in 2022. The National Agricultural Research System has worked hard to develop a number of technologies that can help production systems reduce the negative effects of heat waves. As a component of National Innovations in Climate Resilient Agriculture (NICRA), the technologies are being demonstrated to farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rao BB, Chowdary PS, Sandeep VM, Pramod VP, Rao VUM. Spatial analysis of the sensitivity of wheat yields to temperature in India. *Agric. For. Meteorol.* 2015;200:192-202.
2. Bal SK, Minhas PS. Atmospheric stressors: Challenges and coping strategies, In: P.S. Minhas et al.(eds) *Abiotic Stress Management for Resilient Agriculture*, Springer Nature Singapore Pte. Ltd. 2017;9-50. Available:http://doi.org/10.1007/978-981-10-5744-1_2.
3. Bal SK, Sandeep VM, Vijaya Kumar P, Subba Rao AVM, Pramod VP, Srinivasa Rao Ch, Singh NP, Manikandan N, Bhaskar S. Assessing impact of dry spells on the principal rainfed crops in major dryland regions of India. *Agric. For. Meteorol.* 2022;313:108768. Available:<https://doi.org/10.1016/j.agrforme.2021.108768>.
4. Sharma S, Mujumdar P. Increasing frequency and spatial extent of concurrent meteorological droughts and heat waves in India, Divecha centre for climate change, Indian Institute of Sciences, Bangalore; 2017.
5. Chandran MAS, Subba Rao AVM, Sandeep VM, Pramod VP, Pani P, Rao VUM, Visha Kumari, V, Srinivasa Rao C. Indian summer heat wave of 2015: A biometeorological analysis using half hourly automatic weather station data with special reference to Andhra Pradesh. *Int. J. Biometeorol.* 2017;61(6): 1063-1072.
6. Guis H, Caminade C, Calvete C, Morse AP, Tran A, Baylis M. Modelling the effects of past and future climate on the risk of bluetounge emergence in Europe. *J. R. Soc. Interface.* 2012;9(67):339–350.
7. Guleria S, Gupta AK. Heat wave in India documentation of state of Telangana and Odisha - 2016. National Institute of Disaster Management, New Delhi. 2018;124.
8. Haas B. 3 August. North Korea warns of natural disaster as heatwave sears crops. *TheGuardian*; 2018. Available:https://www.theguardian.com/global-development/2018/aug/03/north-korea-warns-natural-disaster-heatwave-sears-crops?CMP=tw_t_a-environment_b-gdneco

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