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Adapting to the New Normal: Effects of Heat Wave on Agriculture

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Introduction

Climate change is one of the major rising concerns nowadays. Climate change entails rising temperatures across multiple regions (Weisheimer and Palmer 2005; Yadav *et al*. 2015). As the planet continues to warm due to climate change, heat waves have become more frequent and intense. In recent years, the agricultural sector has been hit hard by extreme heat, with crop yields dropping, water sources drying up, and livestock suffering from heat stress. The heat wave of 2022-23 was one such event that left a lasting impact on global agriculture. According to Bal *et al*. (2022), the frequency and intensity of heat waves are escalating in many regions of the world, including India. As a result, there have been significant losses in agricultural productivity and the unfortunate deaths of thousands. Warnings of heat waves have taken India's flourishing agricultural sector hostage, which has been the only beacon of hope in an otherwise slowing economy. This development has complicated matters for the government which is already dealing with persistently high inflation. In India, heat waves typically occur between March and July, with the highest concentration being between April and June (Rohini *et al*., 2016; Pai *et al*., 2013; Ratnam *et al*., 2016). The report by Sharma and Majumdar (2017) states that based on statistics in India, areas of Maharashtra and southern Gujarat, as well as Karnataka and Andhra Pradesh, recorded a disproportionately large increase in heat waves, along with droughts, over the past 50 years.

In this article, an attempt was made to explore the effects of the heat wave on agriculture and the strategies being employed to adapt to the new normal. The impact of heat on crop yields and livestock, the challenges of managing water resources in a heat wave, and

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the resilient farming practices that have emerged to cope with the changing climate were also discussed.

The Rise of Heat Waves: Understanding the Climate Trend

The rise in extreme weather events, including heat waves, droughts, floods, cyclones, and wildfires, is a direct consequence of global warming. When high-pressure systems become stationary, heat waves occur due to the continuous pumping of hot and humid air north-eastward by winds (Marx*et al*., 2021). Global warming's impact on the polar jet stream has weakened it, resulting in an increased likelihood of stationary weather conditions, ultimately leading to extreme weather events such as heat waves(Broennimann *et al*. 2009; Mann 2019).

According to the report of the Intergovernmental Panel on Climate Change (IPCC) and US Environmental Protection Agency Greenhouse Gas Emissions, the increase in heat waves is also attributed to human activities such as the burning of fossil fuels, deforestation, and industrial activities that emit large amounts of greenhouse gases into the atmosphere. The concentration of carbon dioxide and other greenhouse gases in the atmosphere has increased significantly since the industrial revolution, resulting in a gradual increase in temperatures globally.

The Impact of Heat Wave on Crop Yield

Rise in heat waves influence crop yield in several ways. Heat stress has a greater impact on the plant's biological mechanism as well as a negative impact on the pollinators which ultimately affects crop production. The combination of heat and drought stresses can negatively impact several stages of crop development, including germination of seedlings, vegetative growth by disrupting the stability of different proteins, and membranes, tiller production, dry matter partitioning, reproductive organ development, pollen tube growth, fertilization, grain filling, and grain quality (Bitaand Gerats., 2013; Sehgal *et al*., 2018 and Bailey-Serres*et al*., 2019).

Heat waves are one of the many factors contributing to the decline in bee population's worldwide (Gérard*et al*., 2022). Bees play a crucial role in pollinating crops and other flowering plants, but their populations have been declining due to climate change, especially heat waves. Giannini *et al*. (2012) reported that approximately one-third of global agriculture

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is dependent on bee pollination, and any decline or reduction in bee pollination activity could have severe consequences, including significant reductions in crop yields.

Heat Stress on Livestock: Challenges and Mitigation Strategies

Heat waves are becoming more frequent and intense, posing a significant challenge for livestock farmers also. Heat waves can have a wide range of negative impacts on livestock, including a reduction in productivity, illness, metabolic alterations, oxidative stress, immune suppression, and even death (Lacetera, 2018; Gaughan*et al*., 2009). The effects of heat waves on livestock can have economic and social consequences, affecting not only the farmers but also the wider food system and the communities that rely on it.

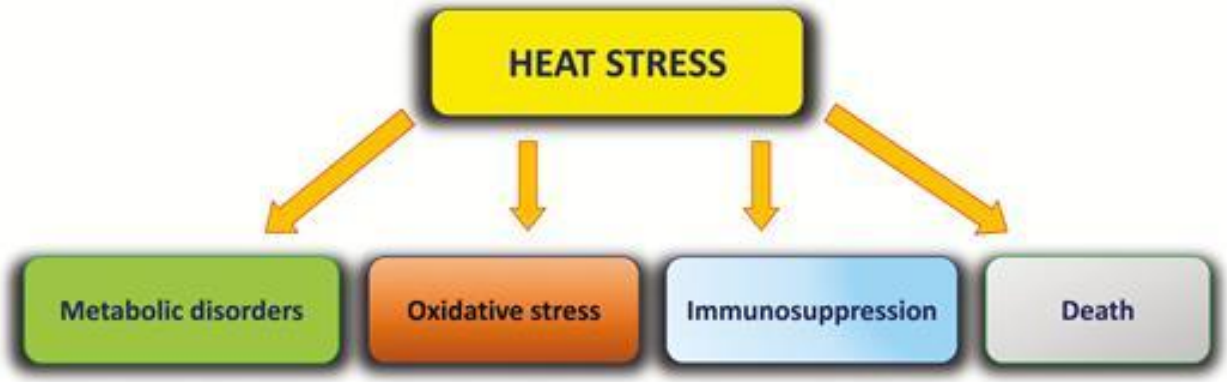

Fig. 1: Schematic representation of the most frequent consequences of heat stress on animal health (Lacetera, 2018).

Heat waves can create conditions that are more favorable for the reproduction and population growth of insects that transmit diseases (Wittmann *et al*., 2001), as well as for the growth of mycotoxin-producing fungi in stored grain (Frank, 1991) which when consumed by livestock may experience interference with their natural disease resistance mechanisms and weakened immune responsiveness, rendering them more vulnerable to infections, as stated by Bernabucci*et al*. (2011). In addition, changes in temperature and precipitation patterns can also impact the survival and development of parasites that cause diseases in livestock.

Farmers should be aware of the signs of heat stress in livestock and take useful measures to prevent it, such as:

- **Providing shade:** Animals should have access to shaded areas where they can escape the sun and heat. Trees, buildings, and shade cloth can all be used to provide shade.

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- **Providing ventilation:** Good ventilation is important to ensure that animals have access to fresh air and to reduce the buildup of heat and humidity. Fans, misters, and air conditioning systems can be used to improve ventilation.
- **Providing cool water:** Livestock should have access to cool, clean water at all times, as dehydration can exacerbate the effects of heat stress.
- **Adjusting feeding schedules:** Feeding livestock during the cooler parts of the day can reduce their heat load and improve their digestion.
- **Adjusting breeding schedules:** Breeding livestock during cooler months can reduce the stress on animals and improve fertility rates.
- **Using heat-resistant breeds:** Some breeds of livestock are better adapted to hot and humid environments and can tolerate heat stress better than others. Farmers may consider breeding or purchasing more heat-tolerant animals.
- **Managing stocking densities:** Overcrowding can increase the heat load on animals, so farmers should manage stocking densities to ensure that animals have enough space to move and cool down.

The Water Crisis: Managing Irrigation and Drought in a Heat Wave

One of the major problems that arise due to heat waves is the water crisis. Agriculture is water dependent and requires adequate water for its proper growth and development. Any hindrance in water requirement may lead to a high loss of production or it may lower the productivity of the crops. During a heat wave, the water requirement of crops increases due to the higher rates of evapo transpiration. This increased water requirement can put a strain on the available water resources, especially in regions that are already water-scarce. In such situations, farmers may face the challenge of balancing the water needs of different crops and ensuring that the most important crops receive adequate water. Moreover, prolonged heat waves can also lead to droughts, which can have severe impacts on agricultural production. Insufficient water availability in the rhizosphere can impede plant growth, leading to suboptimal nutrient uptake by plants (Elemike*et al*., 2019) which has caused significant decreases in the yield of crops (Bal and Minhas, 2017; Hafez and Seleiman, 2017).To tackle the challenge of managing irrigation and drought during a heat wave, various strategies can be put in place by farmers and the government, such as:

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- **Water conservation measures:** Drip irrigation is a technique that farmers can use to mitigate water usage during a heat wave. This method can reduce water consumption by 30-50% compared to traditional irrigation techniques (Çetin and Akalp, 2019), while also reducing issues such as Stalinization and water logging (Burt and Isbell, 2005; Hodgson *et al*., 1990). Additionally, this technique can achieve up to 95% irrigation efficiency (Howell, 2003). Soil moisture sensors and weather stations can also be used to determine when to irrigate, thereby reducing water waste.
- **Adjusting irrigation schedules:** Since the water requirements for crop growth are not uniform throughout their lifespan (Azevedo *et al*., 2007), adjusting irrigation schedules based on crop water requirements and weather conditions can be beneficial. This allows for more precise irrigation and reduces the water crisis.
- **Prioritizing water use:** In regions with limited water resources, farmers may need to prioritize water use to ensure that the most important crops receive adequate water. This may involve reducing irrigation for less important crops or switching to less water-intensive crops.
- **Improving water management infrastructure:** Investments in water management infrastructure, such as irrigation systems, watershed management systems, and rainwater harvesting systems, can help to tackle the water crisis.
- **Developing drought preparedness plans:** To prepare for droughts, both the government and farmers can collaborate to develop plans that include measures such as water storage, crop diversification, and the cultivation of drought-resistant crop varieties. These strategies can help to reduce the impact of droughts on agricultural production and ensure the sustainable use of water resources.

The Future of Agriculture: Adaptation Strategies for a Warmer World

Agriculture is a crucial sector for food security and economic development, but it is also highly vulnerable to climate change. As temperatures continue to rise, farmers will face a range of challenges, including heat stress, drought, flooding, and changes in the distribution and intensity of pests and diseases. However, there are several adaptation strategies that farmers can adopt to manage these challenges and build resilience in their farming systems. Some of these strategies include:

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- **Planting of crop varieties resistant to drought:** The use of more drought-resistant crops in drought-prone areas may help farmers to cope with heat waves. Crop such as wheat can help to reduce vulnerability to climate change and requires less irrigation water compared to dry season rice. Smallholder farmers in Nigeria, Senegal, Burkina Faso, and Ghana have tried using drought-resistant crop varieties as adaptation methods to climate change (Ngigi, 2009).
- **Diversifying crops:** Farmers can reduce their risk of crop failure by growing a range of crops that are better adapted to local climate conditions. Crop diversification can also improve the ability to control pest outbreaks and reduce pathogen transmission, which is expected to intensify under future climate scenarios. Additionally, diversification can help mitigate the impact of increased climate variability and heat waves on crop production (Lakhran *et al*., 2017).
- **Improving water management:** Water scarcity is a major concern in many regions, so farmers can adopt water-saving techniques like drip irrigation as it not only conserves water but also maintains the profile of the soil at heat stress (Wang *et al*., 2000), rainwater harvesting (Pandey *et al*., 2003), and improved water storage systems.
- **Using climate-smart agricultural practices**: Adapting crops to climate variations such as heat waves requires climate-smart agriculture (Raza *et al*., 2019). In addition conservation agriculture, agro forestry, and integrated pest management can help them adapt to climate change may help farmers to adapt the heat stress during heat waves.
- **Investing in climate information services**: Access to timely and accurate weather and climate information can help farmers to make more informed decisions about planting, harvesting, and managing their crops and livestock.

Conclusion

The heat wave of 2022-23 serves as a stark reminder of the severe impact of climate change on agriculture, particularly in regions like India where heat waves are becoming more frequent and intense year after year. As a result of such heat waves, crop yields are reduced significantly, water sources are dried up, and livestock are at risk. Although farmers are increasingly adapting to the changing climate with resilient farming practices, these practices are often not sufficient to combat the effects of heat waves. Therefore, the combine efforts of

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farmers and government is required to mitigate the impact of heat waves so that it will not hamper the growth ofIndia's agriculture sector and will create a more resilient and sustainable future.

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