Managing Abiotic Stresses in Maharashtra Agriculture: Technologies and Policy Needs

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PREFACE

Maharashtra is the third largest state in India in terms of geographical area. It comes under tropical agro-climatic zone with annual precipitation records a marked degree of variation throughout the agro-climatic zones. Western Ghats from the Konkan region – a biodiversity hotspot, receives the highest rainfall (about 3000 mm) area in Maharashtra and other side, the state also occupies substantial part of the Deccan Plateau, where the rainfall is low and highly unstable. With the huge diversity of agro-climate circumstances in Maharashtra, a variety of crops are being cultivated throughout the state by the farming community. Further, rigorous and continuous agricultural intensification at grass-root level in many parts of the state has resulted in a significantly higher share of Maharashtra in the national agriculture production. Despite significant intensification, the agriculture in Maharashtra is suffering from the adversities of the global climate change. The global climate change and rising greenhouse gases resulting in higher temperature and erratic precipitation resulting in increased intensity of abiotic stress such as prolonged drought incidences, flooding, higher daily temperature variations in many areas, hailstorm and increasing soil salinization due to excessive groundwater irrigation and flooding adversely impacting Maharashtra agriculture production and stability. Flooding and soil salinization predominantly occurred in sugarcane belt of the Western Maharashtra. Marathwada and Western Vidarbha have witnessed severe drought incidences during the recent years. Maharashtra alone occupies around 24% of the total drought-prone area of country. In changing climatic scenario, increase in the frequency of climatic aberrations is causing huge losses to agriculture productivity in Maharashtra. This document focuses on the Impact of Abiotic Stress on Maharashtra Agriculture, promising technologies available for mitigating abiotic stress in Maharashtra Agriculture and Policy needs for managing abiotic stresses in Maharashtra Agriculture. This information may serve as ready reference for the students, academicians, scientists, teachers, farmers and policy makers interested in management of abiotic stress in Maharashtra agriculture. This can also help in orientation of research and development programs aiming at improvement of abiotic stress tolerance in crops, livestock, horticulture, floriculture and fisheries in Maharashtra.

Authors

CONTENT

1. Introduction

Maharashtra is the third largest state in India in terms of geographical area. The state occupies substantial portion of the Deccan Plateau, under western peninsular region of India. Agriculture in the Maharashtra mainly depends upon the monsoons. The rainfall is low and highly unstable in majority part of the plateau. Therefore, the growth prospect of agriculture in the state is largely associated with quantity and distribution of rainfall. Drought and crop failure, are results of less rainfall especially at critical stage of plant growth which creates severe problems for agriculture community and livestock. Four meteorological subdivisions are established in Maharashtra *viz. Vidarbha, Marathwada, Madhya Maharashtra and Konkan* for a precise monitoring of the agro-climate circumstances within the large geographical area. Maharashtra comes under tropical agro-climatic zone and its annual precipitation records a marked degree of variation throughout the area. With more than 3000 mm of annual precipitation, the Western Ghats from the Konkan region – a biodiversity hotspot, makes the highest rainfall area in Maharashtra. Typically, *Madhya Maharashtra* and *Marathwada* receive relatively less rainfall in comparison to the *Konkan* and *Vidarbha* region owing to their geographical positioning within the rain-shadow area of the Western Ghats. Overall, the state receives a mean annual precipitation around 1363 mm. Similarly the average annual temperature of Maharashtra varies with a minimum of 15.05^{0}C to the maximum temperature as high as 30.3^{0}C. During summer season, the temperature rises from 22^{0}C to as high as 43^{0}C. Depending upon the seasonal weather conditions some part of *Vidarbha, Marathwada and Madhya Maharashtra* received dew and hails in between February and March.

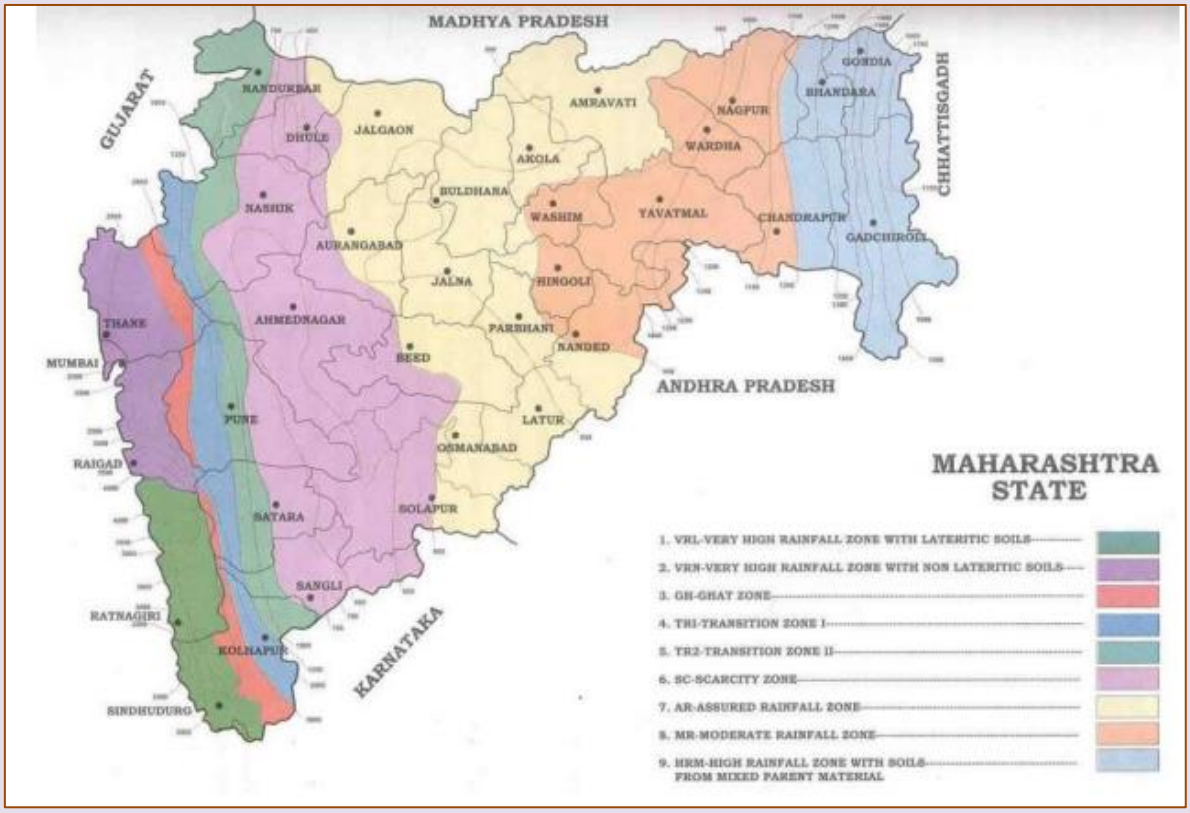

Fig. 1. Agro-climatic zones of Maharashtra.

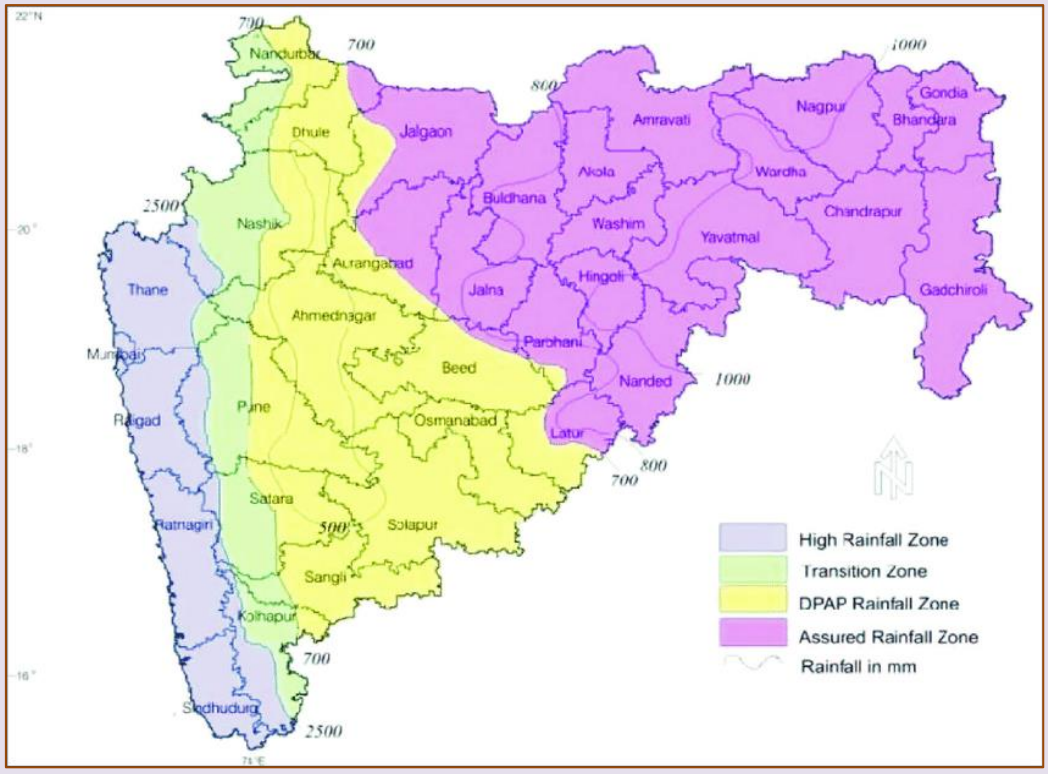

Fig. 2. Rainfall distribution in different zones of Maharashtra.
Source: Khare et al. (2020)

Fig. 3. Soil map of Maharashtra.
Source: Sehgal (1990)

Given the huge diversity of agro-climate circumstances in Maharashtra, a variety of crops are cultivated throughout the farming community. Rigorous agricultural intensification at grass-root level in many parts of the state has resulted in a significantly higher share of Maharashtra in the national crop production. During the year 2018-19, Maharashtra scored first position in cotton production (7.10 million tons) and second position in soybean (4.55 million tons) and sugarcane (92.44 million tons). In Maharashtra some major crops like sorghum, wheat, bajra, maize, pulses, gram, pigeon pea, groundnut, soybean, cotton, sugarcane, onion contributes 36.35, 1.95, 7.27, 10.33, 12.09, 13.70, 25.33, 4.63, 35.68, 33.61, 22.74 and 35.19% area and share 22.90, 0.93, 3.65, 7.08, 9.23, 10.58, 19.09, 3.21, 32.99, 24.83, 23.10 and 34.26% over all India production during 2018-19, respectively (GOI, 2018).

The state has also scored a prominent position in the horticulture crop production with more than 15 lakh hectares of area under different fruit crops. Mango, cashew nut, banana, grapes, pomegranate, orange, vegetables like onion, chilli, flower crops like gerbera and carnations are the major horticultural crops grown in Maharashtra. Supplementary to the crop production, livestock sector - one of the important sources of livelihood for farmers in Maharashtra, it plays a vital role in augmenting income of farmers, and in terms of employment generation. Maharashtra is having 33.1 million livestock population and 74.3 million poultry population (20th livestock census, GOI 2019). The livestock population has increased by 1.83% over previous livestock census (2012) and goat population increased by 25.72% over previous census. Maharashtra has 14.0 million cattle, 5.6 million buffalo, 2.7 million sheep,10.6 million goat, 0.19 million horses and ponies and 0.18 million donkeys. Maharashtra produce 11655 tons milk, 59649 lakhs number egg, 1021 tons meat, 1457 tons wool, 113.64 tons inland fish and 469.74 tons marine fish production during the year 2018-2019.

2. Climate Change and Agriculture

Despite significant intensification, the agriculture in Maharashtra is suffering from the adversities of the global climate change. The global climate change and rising greenhouse gases cause higher temperature and erratic precipitation resulting in increased intensity of abiotic stress such as prolonged drought incidences, flooding, higher daily temperature variations in many areas, hailstorm and increasing soil salinization due to excessive groundwater irrigation adversely impacting Maharashtra agriculture production and stability. Flooding and soil salinization predominantly occurred in sugarcane belt of the *Western Maharashtra*. *Marathwada* and *Western Vidarbha* have witnessed severe drought incidences during the recent years. However, high water requiring crops like sugarcane are still grown in these areas, which requires a significant amount of irrigation water and further reduce the water availability to other crops and worsen the threat of water scarcity. D'Souza et al. (2017) reported that, the major climate risks in Ahmednagar and Aurangabad region of Maharashtra were unseasonal rainfall, increased dry spells, high intensity rainfall, delayed onset of monsoon, warmer winters and very high summer temperatures. Similarly, increasing temperature is also a major threat especially in *Marathwada* and *Western Vidarbha*, which influence the cotton production in Maharashtra.

2.1. Maharashtra State Rainfall Variability Trends

Analysis of the variability and trend in rainfall in Maharashtra during the period 1989-2018 showed that about 90% of annual rainfall is received during the southwest monsoon season

only (Guhathakurta et al. 2020). The variability of monsoon or annual rainfall was 14% (Table 1).

Table 1. Mean rainfall (mm) and coefficient of variation of Maharashtra for the monsoon months, southwest monsoon season and annual

	June	July	August	September	JJAS	Annual
Mean	218.6	341.4	281.1	179.5	1020.7	1146.5
CV	30.5	26.3	26.3	34.8	14.4	14.0

Source: Guhathakurta et al. (2020)

2.2. Frequencies for Rainfall Events of Different Intensities in Maharashtra

Average frequency of rainy days, average frequency of heavy rainfall days and analysis of average frequencies for rainfall events of different intensities is calculated for Maharashtra for June, July, August, September, June to September and Annual. The month of June the maximum number of rainy days lies in the range of 13 to 15 days especially in some parts of Sindhudurg, Thane, Ratnagiri, Mumbai Suburban, Mumbai and Kolhapur districts. The minimum number of rainy days lies in the range of 6 to 8 days especially in some parts of Beed, Osmanabad, Parbhani, Latur, Jalna, Hingoli, Aurangabad, Nanded, Solapur, Jalgaon, Dhule, Ahmednagar, Nandurbar, Akola, Amravati, Wardha, Buldana, Washim and Yavatmal districts. Whereas in remaining districts, the number of rainy days lies in the range of 8 to 13 days. The average frequency of Heavy rainfall days in the month of June the maximum number of heavy rainfall days lies in the range of 2 to 3 days especially in some parts of Sindhudurg, Thane, Ratnagiri, Mumbai Suburban, Mumbai and Kolhapur districts. The minimum number of Heavy rainfall days lies in the range of 0.2 to 0.7 days especially in some parts of Akola, Amravati, Wardha, Buldana, Washim, Yavatmal, Nashik, Satara, Beed, Osmanabad, Parbhani, Latur, Jalna, Hingoli, Aurangabad, Nanded, Solapur, Jalgaon, Dhule, Ahmednagar, Nandurbar, Bhandara, Gadchiroli, Chandrapur, Nagpur, Gondiya districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.7 to 2 days. The Trend in frequency of dry days is calculated for 30 years period for June, July, August, September, June to September and found that in the month of June there is a significant increase in dry days in Nandurbar, Jalgaon, Raigarh, Kolhapur and Bhandara districts. Whereas there is a significant decrease in dry days in Pune, Solapur, Kolhapur, Ahmednagar, Aurangabad, Jalna, Beed, Hingoli, Nanded, Yavatmal, Wardha districts. While remaining districts did not show any significant change (Guhathakurta et al. 2020).

Being a Deccan Plateau region, Maharashtra is more challenge with multitude of several abiotic stresses. Amrit et al (2021) analyzed 113 years (1901–2013) of rainfall data and reported that Hingoli, Latur, Ahmednagar, Jalna, Osmanabad, Solapur, Beed, and Parbhani districts are more prone to the frequent and severe drought events with return period of 4–5 years. Drought return periods were studied for three different periods: 1901–1950, 1951–2013, and 1981–2013, and it was found that drought became more frequent and severe during the period 1981–2013. The maximum rainfall deficiency in the state was observed to be in the range of 43–73%. The long-term data analysis of rainfall revealed that 1918, 1920, 1971, 1987, and 2001 were the years of severe droughts in Maharashtra. Also major parts of the state faced maximum persistency of 2 years. Udmale et al. (2014) reported that recurring drought is a major challenge in the Drought Prone Area of Maharashtra State in India, where rainfed cropping and livestock are the major income activity of over 64% of the state's population. Maharashtra alone occupies around 24% of the total drought-prone area of

country, which causes huge losses in agriculture production. Todmal (2019) investigated the intensity and frequency of droughts over the five semiarid river basins in Maharashtra during the past (1980–2013) and future (2015–50). Reported that the study area experienced three severe rainfall droughts in 1985/86, 2002/03, and 2011/12, higher frequency of low-intensity droughts is observed, particularly after 2000. The estimation suggests occurrence of moderate, severe, and extreme droughts once in 6, 28, and 50 years, respectively. Among the selected basins, the Agrani, the Karha, and the Man are expected to experience intense droughts and hence require special attention in drought management. As agricultural productivity and cropped areas heavily depend on the monsoon rainfall, the meteorological droughts result in agricultural droughts. The future warming (by about 1°C) over the study area is very likely to exacerbate the meteorological droughts (estimated to occur in the 2030s) and increase the agricultural water demand. These problems are likely to aggravate with climate change, it is one of the future challenges that the agriculture sector will face. Kelkar et al. (2020) estimated the possible effects of change in climatic factors on the production of major crops in Maharashtra and reported that there will be significant reduction in the production of three major crops, viz. sugarcane, cotton and rice. This decline will be more prominent in central and central-east Maharashtra.

Over the past few decades abiotic stresses are constantly affecting fruit crops in Maharashtra, with most predominant influencing stressors being drought, high temperature and hailstorms. They cause many morphological, anatomical, physiological, and biochemical changes in plants that ultimately affect the productivity and quality characteristics of fruit. Similarly, heat and water is the most stressful among all the abiotic stresses especially for livestock production in *Marathwada, Vidarbha* and some part of western Maharashtra. Thus, for a thorough understanding of the adverse influence of abiotic stresses on agriculture, a strategic mitigation program is critically needed to ensure the sustainable production of climate-sensitive crops/livestock in Maharashtra. Typically, drought, salinity and temperature stresses should be seriously considered as these three stresses can potentially threaten the production and productivity of major commercial crops/fruit/livestock of the state.

Overall, establishment of a robust mechanism is imperative in Maharashtra to strengthen the existing administrative and scientific pipelines of agricultural intensification, and critically develop, and disseminate sustainable technology interventions at grass-root level, widen the horizons of climate-awareness and smart-farming practices among large as well as small holders, and reinforce the existing forecast mechanisms and decision support system. This document presents the major impacts of abiotic stresses to the agriculture in Maharashtra, technologies available for mitigating abiotic stress in agriculture and policy needs for managing abiotic stresses in Maharashtra Agriculture.

3. Impacts of Abiotic Stresses on Maharashtra Agriculture

Abiotic stresses cause negative impact across the sectors of agriculture (crops, horticulture, livestock, birds, fishes and others) with non-optimal environmental factors those may act independently or in multiples. These abiotic stressors like temperature (heat, cold, chilling/frost), water (drought, flooding/hypoxia), radiation (UV, ionizing radiation), chemicals (mineral/ nutrient deficiency/excess, pollutants heavy metals, pesticides, gaseous toxins), mechanical (wind, soil movement, submergence) and others are responsible for major reduction in agricultural production (Kumar et al. 2019).

All the abiotic stresses have profound impact on agriculture system, among that, changing rainfall patterns and reduced precipitation is causing the frequent onset of severe drought around the Maharashtra. Horticultural plants subjected to drought stress results in fruit cracking, sun scorching, aril breakdown during autumn (Ambia) season crop which reduce the quality. Heavy/untimely rainfall causes heart rot of fruits and attack of biotic problems like scab and bacterial blight, as well, flower and fruit drop, depending on stage of crop.

Unseasonal rain and hail-storm are the major abiotic stress concerns for the vineyards as they cause berry cracking followed by bunch rooting which adversely affect the quality of grapes. Further, high and low temperatures adversely affect the sugar development in the berries, while soil salinity influences the uptake of nutrients.

Heat stress greatly affects the morphological, biochemical and physiological changes in crop plant. The rising in temperature may cause a shift of growing periods and distribution of the agricultural crops. Increase in temperature influences the colour, fragrance and ecosystem in floriculture. Abiotic stresses cause hindrance in the production and quality of the traditional flowers. Increase in carbon dioxide concentration positively impacts floriculture due to increase in photosynthesis rate, which may ultimately enhance production and productivity of flowers. Besides high temperatures, low temperatures can also result in losses for many crop species that are grown in winter/spring season like fruit and vegetable crops.

In climate change scenario with changing precipitation and temperature patterns, Salt-affected soils in Maharashtra are 0.61 million ha (Mandal et al. 2018). Salt affected area is likely to increase. Salinity affects almost all aspects of plant development including germination, vegetative growth, and reproductive development (Machado and Serralheiro 2017). Salinity results by high accumulation of soluble salt, especially NaCl in soil and water. Salinity hampers the growth and survival of many field crops such as wheat, maize, cotton, sugarcane, sorghum and horticulture crops. Salinity, alkalinity/sodicity, chemical contaminants including heavy metals, toxic metabolites including ammonia, micro-plastics, and bio-toxins produced from harmful algal blooms (HABs) and occasional incidences of extreme weather including hailstorm are some of the important stresses in aquaculture and culture based fisheries.

Inadequate crop nutrition can induce excesses or lack of some essential elements, which effects on growth, yield, or quality of the produce depending on the species (Francini and Sebastiani 2019). In Maharashtra most of the horticulture crops suffers from this types of stresses like pomegranate, grapes, mango banana etc.

Heat stress has been generally associated with detrimental effects on physiological equilibriums of livestock and their various systems such as nervous, endocrine and immune (Castanheira et al. 2010). Heat stress is one of the most important stressors especially in hot regions. Heat stress reduces milk yield, feed intake, growth, libido, fertility and embryonic survival in animals. High yielding livestock breeds are more prone to abiotic stresses, which lead to physiological stresses and loss of productivity. Heat stress and humidity are major abiotic factors in livestock production while water deficit leads to nutritional, physiological and immunological stress, which ultimately leads to decline in the productivity of livestock. Heavy rain and flood stress situation may cause spared of water borne diseases, ticks problem, zoonotic diseases (animals act as amplifiers) and stress results in lower reproduction in livestock.

Fig. 4. Soil salinity due to waterlogging.

Fig. 5. Severely damaged sugarcane crop during flood.

Fig. 6. Livestock camps during drought in Maharashtra.

Fig. 7. Orchards severely affected by drought.

Fig. 8. Grape orchard affected by hailstorm.

4. Technologies for Mitigating Abiotic Stresses in Maharashtra Agriculture

Crop/ Component	Recommended Technologies for Mitigating Abiotic Stress
1. Floriculture	• Drip irrigation should be used for flower cultivation for enhancing the water productivity. • Protected cultivation should be adopted for abiotic stress mitigation. • Use of nanotechnology and physiological breeding can help to mitigate abiotic stress in floriculture. • Apply the nutrition through drip irrigation. • Vertical gardens improve indoor air quality and carbon sequestration. • Lawn grasses contribute about 90% carbon sequestration. • Butterfly gardens can be very beneficial to improve eco-system services especially natural pollination.
2. Onion and Garlic	• Bhima Super onion variety should be recommended for high rainfall prone areas of Maharashtra. • Raised bed technology for *Kharif* onion production. • Storage losses in kharif onion can be reduced by adopting storage technology developed by ICAR-DOGR.
3. Wheat	• Optimum sowing time (location specific) is one of the most crucial to ensure assured germination of the seed, steady seedling establishment, and yield maximization of wheat. • Combined application of 240 kg N ha−1 along 40 mm water per irrigation will optimally maximizing the yield, WUE, and reducing the terminal moisture stress. • Wheat cultivation under reduced and zero tillage with retention of surface residue is one of the technology to combat various abiotic stress. • Wheat can be grown in situations where, sugarcane is harvested late then neither onion or chickpea or other crop can be grown and wheat

Crop/ Component	Recommended Technologies for Mitigating Abiotic Stress
	is the only option, which can be sown upto January first week.
4. Pomegranate	• Bio-fortified varieties of pomegranate (Solapur Lal), which gives good yield. • Bio-priming with *Glomus Species* can give good results. Microbes may also play important role in stress conditions. Salicylic acid and jasmonic acid play significant role in reducing sunburn. • Protective cultivation can be beneficial to mitigate the effect of unseasonal rain. • Raised bed with mulching produce good yields with minimum application of irrigation water through drip system.
5. Grape	• In case of hailstorm damage in grapes immediately after back pruning, pinch the shoot just below the hail-injury and spray the plant with copper oxychloride 2 g L^{-1}. • Sub-surface irrigation minimize water requirement and mulch + anti-stress product improve abiotic stress tolerance. • Grape cultivation using plastic covering can protect the crop from hailstorms and also different biotic stresses. • Advanced pruning technology can be adopted for color development in vineyards. • Image-assisted technologies can be used for abiotic stress mitigation in grapes based on the nutritional demand of crop.
6. Livestock	• Housing management and shelter designs can reduce the abiotic stress. • Promotion of locally adopted breeds through selection will play crucial role for sustainable livestock production. • Cultivation of drought resistant fodder crop varieties. • Development of livestock contingency plan for mitigation of abiotic stress in livestock at district levels.
7. Poultry	• Shiny surface roofs can reflect twice as much solar radiation as a rusty or dark metal roof. • Addition of fat and reduction of excess protein in feed are recommended to reduce the adverse effects of heat stress. • Supplementation of 1g vitamin C per liter of drinking water during heat periods can help to reduce heat stress.
8. Fisheries	• Environmental biotechnology approach for reclamation of alkali/sodic soils and bio-remediation through bio-stimulation and bio-augmentation can be adopted • Application of multi-omics and bio-sensing techniques for monitoring and mitigating adverse effects of chemical contaminants. • Adoption of species diversification and integrated multi-trophic aquaculture for abiotic stress mitigation should be followed.
9. Cotton	• Adequate drainage: Cotton crops grown in well-drained soils are less at risk of developing para wilt than those grown in poorly drained soils. • Sowing of cotton crop on contour ridges results in good crop growth

Crop/ Component	Recommended Technologies for Mitigating Abiotic Stress
	and optimum plant population both in high and low rainfall situation. • Avoid excess fertilizer doses. • Desi cotton is more tolerant than hybrid cotton.
10. Sugarcane	• Use of Multifunctional Ratoon Manager Drill can enhance the input-use efficiency, crop productivity and profitability of the sugarcane, in addition to reducing the environmental pollution by avoiding the trash burning and reduced emissions of GHGs. • In case of water stress at 60, 120 and 180 days after plantation, the crop should be sprayed with 2% urea and 2% muriate of potash. • Propping up should be carried out to prevent from lodging due to strong winds.
11. Soybean	• Use of drought tolerant varieties such as JS 97-52, NRC 136. • Application of mycorrhiza for enhancing drought tolerance. • Application of thio-urea for mitigating drought stress. • Application of agriculture machinery (Broad Bed Furrow (BBF) seed drill/planter) for moisture management.
12. Groundnut	• Providing irrigation during moisture-sensitive stages like flowering & pod development. • Applying anti-transpirants (400 ppm aspirin and/or 8% kaolin at 62 DAS). • Farmers may adopt drip irrigation method for groundnut crop in large fields. • Mulching with sugarcane trash or white polythene. • Adoption or cultivation of drought tolerant varieties. • Intercropping with sorghum (Shading of groundnut by sorghum in the intercrop ameliorated to some extent the effects of high temperature and water stress, in the drought stands.) • Application of gypsum (Gypsum increase early pod development and provides an escape mechanism from drought).
13. Chickpea	• Growing drought tolerant varieties such as Vijay (Phule G-81-1-1), PKV harita (AKG 9303-12) and early varieties such as Vishal (Phule G87207). • Utilization of drought tolerant varieties as a genetic resource in chickpea breeding programme for improving drought tolerance of elite chickpea genotypes. • Sowing of chickpea crop during third/fourth week of September under changing rainfall situation in medium deep soils of scarcity zone of Maharashtra. • Sowing of sorghum and chickpea in strips (3:3) at 45 cm spacing. • Spraying of 6 BA, 20 ppm (20 mg L) on chickpea grown on medium deep black soil at branching and 50% flowering stage.
14. Red gram	• Intercropping of pigeon pea + pearl millet (1:2), pigeon pea + sorghum (1:2 or 1:4), pigeon pea + cotton (1:6 or 1:8) and pigeon pea + soybean/ green gram/ black gram (1:2 or 1:3) should be followed for better risk management due to excess or suboptimal

Crop/ Component	Recommended Technologies for Mitigating Abiotic Stress
	rains. • Protective irrigation may be given in alternate rows at critical stages. • Avoid further inter-culture operations after the harvesting of the intercrop. • Use harvested intercrops' biomass as mulch to preserve soil moisture and to maintain microbial activity. • Growing drought tolerant varieties BDN-711, BDN-716 & 708.
15. Vegetables	• Raised beds/ridges for planting vegetable crops to be preferred to avoid damage due to waterlogging. • Frequent irrigation at the interval of 3-4 days preferably with drip irrigation system to be done to overcome the effect of heat and drought stress to avoid the flower drop in vegetable crops. • Plastic mulch of 25 micron should be practiced to reduce the soil evaporation loss. • Hail damaged fruit and vegetable crops to be sprayed with KNO_3 3-5gm L^{-1} to facilitate recovery of plant growth.
16. Microbial technology	• Use of microbes such as nitrogen fixing bacteria and plant growth promoting microbes particularly for crops like in chickpea and lentil. • Use of Trichoderma and residue decomposers to enhance soil organic carbon and for higher productivity of crops.
Natural calamities/ disaster	**Management of livestock during Natural Calamities/disaster**
Flood	• In case of weather forecast of heavy rains, the animals near low lying areas should be brought to safer places. • Proper planning, coordination and management of relief activities can minimize the losses due to flood. • Animals during flood will be in acute stress and will be difficult to manage. The animals will be handled with care. • Animal should be moved to higher areas. • Animals are natural swimmers; therefore, can escape drowning if they are not tied. • Check for injuries to the animals and immediate treatment should be carried out with the help of Veterinarian. • Avoid the mixing of manure pits into water sources. • All local drains and canals should be inspected for any obstruction. • Ensure that the animals are vaccinated for all infectious diseases. • Prevention of disease outbreak can be done by following health management protocol.

Crop/ Component	Recommended Technologies for Mitigating Abiotic Stress
Cyclone	• Cyclone shelters can be made to house affected animals away from the cyclonic area. • During cyclones the animals are safer outside than those sheltered. • There are chances of entry of water in sheds/houses during flood; proper facility for drainage of water should be carried out. The animals should be shifter to higher grounds. • Proper storage of feed, fodder and medicines. • Make provisions for early disposal of carcasses.
Earthquake	• The animals should be shifted to safe place, where the animals can be maintained with minimum assistance. • The animals should be housed in loose housing system. • Vaccinate the animals against tetanus or against most prevailing infectious disease in that particular area. • All the farm tool and heavy items should be placed away from the wall as they may cause injury to the animals. • Persons taking care of the indoors should take cover under a sturdy piece of furniture and should stay away from objects that shatter like windows etc. • Seek for veterinary and medical advice in case of emergency.
Drought	• Proper planning depending upon weather data in that particular region will help in better management of drought. • Early plans should involve procurement of feed and fodder, water resources and veterinary health services. • Feeding and watering of animals should be adequate such that it meets up the nutritional needs and well reduces illness. • Partial feeding of unconventional feed and fodder can be adopted. • Enrichment of poor quality of roughages should be carried out. • Dry fodder reserves, urea molasses licks, bricks made of fodder urea and molasses etc. can be stored. • Conservation of fodder should be done by either hay making or silage preparation. • Growing of alternative drought resistant fodder crops.

Recovery and rehabilitation measures for livestock affected with various natural calamities	
Treatment of injured animals	• The emergency treatment of injured animals should be carried out relive pain and suffering. • All injured animals should be promptly treated and antibiotics can be provided in case of susceptible illness. • The animal health component includes appropriate nutrition, care of pregnant animals, care of new-born and young animal etc. • Take care that there should not be spread of diseases.
Vaccination of animals	• There is always a fear of spread of disease in the herd after natural calamity. • The risk can be avoided through mass vaccination programme of diseases like Foot and mouth disease, *Haemorrhagic septicaemia*, Anthrax, PPR, etc.
Disposal of dead animals	• An important problem that has to be faced during disaster and after disaster is proper disposal of dead animals. • This poses acute problems during floods and cyclone, as the number of

	animals dying would be enormous. • Most states have fallen animal management programs and carcass utilization program. • Never throw the body of dead animal in rivers and streams. • The carcass should be burned or buried as per the protocol. • Precaution on pest control along with proper hygiene and sanitation maybe followed.
Disposal of animal waste	• Animal waste, dung can be either used as manure or caked and dried for fuel. • Improper disposal of dung leads to pest problems. Manure pits can be made by digging the earth and layered with lime regularly.
Control of diseases	• Following proper sanitation measures such as digging manure pits, providing clean potable drinking water facilities, drainage facilities and proper disposal of dead animals will help in control of disease. • Temporary shelter camps and hospitals veterinary should be established in hospitals in the affected areas. • For efficient health care operations local peoples participation required. • Avoid animals/markets, transportation of animals to control spread of disease in natural disaster affected areas.

5. Policy Needs for Managing Abiotic Stresses in Maharashtra Agriculture

Policy support from the Government of Maharashtra can reduce the present constraints and enhance the income for farmers from agriculture. Some of the recommendations by the experts in different disciplines of agriculture expressed in the meeting organized by National Academy of Agricultural Sciences (NAAS) and NIASM are given below.

1. Wheat

- Modern varieties of wheat with high yield potential and tolerance to drought are not reaching the farmers due to limited seed availability. There is need of Govt. support to strengthen seed production and distribution chain.
- Release of canal water should synchronize with the crop demand at the critical growth stages. The Irrigation Department of the state should work closely with the farmers to schedule the release of canal water.
- Taking advantage of largely rainfed and restricted irrigation situation and high quality of wheat, Government of Maharashtra should promote production and export of durum wheat.

2. Sugarcane

- Promotion of integrative conservation agriculture practices with trash retention, micro-irrigation, fertigation and minimum tillage for improving cane yield, water and nutrient use efficiency and soil health in ratoon crop.
- Promotion of recently developed technologies by ICAR Institutes (NIASM, Baramati and IISR, Lucknow) such as multifunctional ratoon manager drill (MRMD)/SORF machine, known for multiple operations such as stubble shaving, rooting pruning, off baring placement of fertilizers and seeds of inter-crop in a single pass.
- Promotion of use of sub-soiler for breaking of hard-pan in black soils and drainage management in saline and sodic soils through subsidies or special schemes.

- Promotion of organic cultivation with use of organic compounds, bio-stimulants and bio-fertilizers for enhancing abiotic stress tolerance.
- Considering the longer window of harvesting (October to April), a practice of intercropping of vegetables, cereals and pulse crops should be promoted for increasing farmers' income and efficient utilization of land and water resources.

3. Soybean

- Promotion of the use of tractor-drawn machineries for making ridges and furrows for reducing ill-effects of waterlogging due to heavy rainfall and also to reduce irrigation water requirement.
- Promotion of drought tolerant soybean varieties such as JS-9752 and NRC 136 developed by ICAR-Indian Institute of Soybean Research, Indore by including them in the seed chain.
- Promotion of the use of bio-formulations such as microbial inoculants containing Rhizobia for enhancing the abiotic stress tolerance and reduce fertilizer use.

4. Cotton

- Promotion of broad bed furrow method of cultivation for enhancing yield and water conservation.
- Training to personnel engaged in selling and spraying of pesticides
- Controlling purchase of pesticides only from the authorized dealers to avoid spurious materials.

5. Sorghum

- Promoting drought tolerant varieties for obtaining sustainable yield in arid or semi-arid regions.
- Supporting farmers engaged in maintenance of local varieties, which are usually drought or heat tolerant.
- Promoting dual-purpose varieties such as Maldandi 35 and CSH 19 for higher yield and nutritious fodder.

6. Pulses and Oilseeds

- Promoting diversification to pulses and oilseeds with suitable varieties in the rainfed areas through interventions like quality seed production and distribution, seed treatment, technology demonstration and financial support.
- Strengthening the Seed Hub Program for pulses and oilseeds with financial and technical support to the seed producers in arid and semi-arid regions.

7. Floriculture

- Including floriculture in the Smart City Projects and integrating floriculture in Agro/Eco Tourism.
- Formulating policy for import substitution and export promotion in floriculture sector.
- Discouraging import of artificial flowers for public places.

8. Pomegranate

- Provide financial support for protected pomegranate cultivation.
- Promotion of sensor-based irrigation and fertigation technologies.

9. Grape

- Promoting protected cultivation to reduce losses caused by unseasonal rain and unpredictable hailstorm.
- Provide financial support to promote the use of plastic in vineyards to protect the crop from heavy rain, hail, and similar factors that damage the vines every year, and result in crop losses.

10. Onion and Garlic

- Promoting drought and high temperature tolerant varieties up to some extent such as Bhima Kiran.
- Supporting modernization of existing storage technology, developed by ICAR-DOGR, Pune.
- Promotion of micro-irrigation technology on raised bed for increasing water and fertilizer use efficiency and saving about 40% irrigation water.

11. Vegetable

- Promotion of grafting technology in vegetable crops using drought hardy wild species and germplasm as a rootstocks to reduce the effect of water stress.
- Convergence of technologies like mulching, drip irrigation and grafted vegetables for productive use of water.

12. Livestock

- Senior officials from the Department of Animal Husbandry to be associated with concerned scientific institutes for the development of species-wise livestock contingency plan for mitigation of abiotic stress in livestock at district levels.
- Government should promote locally adapted breeds.
- Strengthening quality fodder supply in the cattle camps during the drought years.
- Development of new livestock production systems for reducing abiotic stress, improving productive performance and animal welfare.

13. Poultry

- Construction of well-designed shelters for protecting birds from heat stress.
- Native and improved poultry birds should be promoted among the farmers.
- Assessing the adaptability and profitability of other fowls before large-scale promotion.

14. Fisheries

- Diversification of fish species to be promoted in inland fisheries to enhance productivity under alkaline/sodic conditions.
- Growing of salt-tolerant species viz. GIFT tilapia, *Lettopeneous vannemei*, mud crab, Asian Seabass and grey mullet for salt affected water-logged areas.
- Promotion of farm pond-based aquaculture as integrated farming system for minimizing the risk due to climatic vagaries and getting surplus income to the farmers.

15. Climate-smart Integrated Farming System

- Promotion of diversification of components and within components of integrated farming system for minimizing the climatic risks.

- The government subsidy program for the adoption of the micro-irrigation technologies should be made popular among the farmers for making the efficient use of available water resources.

16. Capacity Building

- Large-scale training of farmers and other stakeholders to adopt resource saving and climate resilient package of practices.
- Establishment and strengthening soil, water and plant testing laboratories for quality control and efficient resource use.

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