Chapter

Organic Farming to Mitigate Abiotic Stresses under Climate Change Scenario

Saikat Biswas, Rupa Das and Lay Lay Nwe

Abstract

Climate change is resultant from modern-day chemical agriculture, which is creating negative impacts on crop production. Global agriculture is now facing various problems arising due to abiotic stresses such as flood, drought, temperature extremes, light extremes, salinity, heavy metal stress, nutrient toxicity/deficiency. These stresses not only hamper the growth and production but also reduce the quality of crops through morphological, physiological, biochemical changes and synthesis of ROS. Further, they negatively impact on entire environment specially soil health. Deterioration of yield and quality often occurs due to lack of essential inputs to plants under abiotic stresses. Although plants adopt defensive mechanisms, such abiotic stresses need to be addressed properly with various eco-friendly organic farming approaches. Different organic inputs like organic manures, biofertilizers, bio-priming with microorganisms, bio-stimulants (seaweed extracts, humic acid, micro-organisms, etc.), mulches, biochar are known to alleviate abiotic stresses under climate change scenario. Further, various organic agronomic practices viz. crop rotation, intercropping, tillage, sowing methods and time, nutrient, water and intercultural operations, use of PGPB, organic formulations, grafting, selection of resistant/tolerant varieties and other scientific/wise uses of organic inputs can mitigate/escape the negative impacts of abiotic stresses resulting in upliftment in crop production as well as the quality of produce.

Keywords: abiotic stresses, agronomic management, climate change, crop growth, organic farming practices, production

1. Introduction

Food scarcity is a major challenge in today's agriculture. In order to meet the food demand of ever-increasing population, worldwide, farmers are aiming to improve agricultural productivity at the expanse of environment through application of chemical fertilizers and pesticides. Unscientific and over use of chemicals and other management practices degrades soil, water and other valuable natural resources leading to climate change scenario which is a great concern for sustainable agriculture. Further, shrinkage of agricultural land due to population growth, aim/migration for alternative job, urbanization, deforestation, anti-environmental anthropogenic activities, etc. are creating major issues of agriculture and urging for improvement of agricultural productivity and fulfillment of this urge is questionable under climate change scenario as plant has sessile growth habit. Crop growth mostly depends on interaction between genetic trait of variety with growing environment. Climate change, therefore, exerts various stresses on crops and affects crop negatively. The stresses can be biotic (living) and abiotic (non-living) stresses which often put both sole and combined impact on crop.

Abiotic stresses such as drought, flood, salinity, temperature extremes (hot/cold), heavy metals, light, wind, nutrients/chemicals, etc. due to climate change decide distribution of plants in various environmental conditions [1] and thereafter, affect crop growth especially at reproductive stage resulting in poor crop productivity throughout the world [2]. Abiotic stresses also trigger various biotic stresses leading to poor crop productivity through disruption of seed germination, vegetative growth, dry matter production and its translocation to reproductive parts [3]. World experiences around 70% yield loss due to abiotic stresses [4]. Severity in abiotic stresses causes imbalance between demand and supply of nutrients, inactivation of enzymatic activities, suppression of various genes responsible for the quality expression, etc. [5] resulting loss of yield and quality of crop through hampering crop from morphological to molecular levels [6].

These abiotic stresses indeed are serious barriers in front of food security of global population and therefore, suitable strategies are highly needed to cope with these and to achieve good crop growth, yield and quality under climate change scenario. Although few mechanisms like escaping stress, stress avoidance and stress tolerance are done by plants through making various molecular, cellular and physiological changes, there is need to explore and adopt various strategies like traditional and modern breeding approaches, agronomic management practices, exogenous applications of stress tolerating compounds, etc. to mitigate harmful impacts of abiotic stresses on crop to a high extent. Agronomic management strategies cover various technologies including organic farming approaches to alleviate abiotic stresses. Organic farming consists of chemical excluded farming practices which mostly rely on natural and organic inputs/products to improve crop growth and yield as well as other allied sectors. Various organic farming inputs (manures, biofertilizers, crop residues, bio-stimulants, etc.) and practices (selection of varieties, tillage, sowing, nutrient, weed, water management practices, etc.) play a key role in addressing various abiotic stresses and allows the crop to grow well by coping up the climate change situation. Although the published information is less in this regard, an insight knowledge on organic farming activates against abiotic stresses is highly needed. Therefore, an attempt was made in this chapter to highlight negative impacts of abiotic stresses on crop and their mitigation strategies through various organic farming approaches.

2. Various abiotic stresses

Abiotic stress is resulted due to the negative influence of physical or chemical environment on biological organisms either alone or in various forms of interaction. In agriculture, crop production is highly hampered due to abiotic stresses. They individually or as combination impair the normal metabolisms and other physiological functions in plants and thereby, affect crop growth and development. Combined influence of various stresses is more pronounced on crop production than their individual adverse effect. There are different types of stresses viz. drought, flood, heat and cold stresses, heavy metals, toxicity due to nutrients and pesticides, high light, low light, UV exposure, photo-inhibition, shade, wind velocity, air pollution, etc. which negatively impact on crop plants (**Figure 1**). In the following section, these stresses are briefly highlighted.

2.1 Drought stress

Among the different natural resources, water is now highly precious and scarce for living organisms including crop. Water regulates various physiological and biochemical activities of plant like photosynthesis, transpiration, nutrient uptakes, translocation of assimilates, etc. Plant growth, internal activities are seriously hampered if water availability deviates from normal which is now a common phenomenon throughout the globe as an effect of climate change due to unscientific, non-eco-friendly anthropogenic activities. Water stress mostly occurs in the form drought and flood. Drought or water scarcity may arise due to various reasons such as long period of no occurrence or less intensity of rainfall from usual, low river and stream flows, reduced ground water table, etc. in a region. In agriculture, during crop growth stages, drought may arise due to late onset and early cessation of rainfall, break of monsoon for long period, less availability of irrigation water, faulty or no water conservation practices/structures resulting in serious damage to crop growth and yield. Moreover, Under the situation of soil moisture availability, if salt concentration is high in soil, plant can't uptake water from soil properly and even, exosmosis occurs. This situation, thus creates apparent drought. High temperature triggers evapotranspiration as a part of internal cooling process, resulting in drought or water deficiency. Further, drought can also be resulted from low temperature, under which water freezes in the intercellular spaces creating protoplasmic dehydration and death of cell and eventually, the plant. Altogether, drought affects plant's germination and normal functioning.

2.2 Flood stress

When water availability becomes unnecessarily high as compared to normal for a particular period in an area, flood occurs. It may be resulted from sudden outburst of cloud coupled with excessive rainfall for a short time period (flash flood) or due to

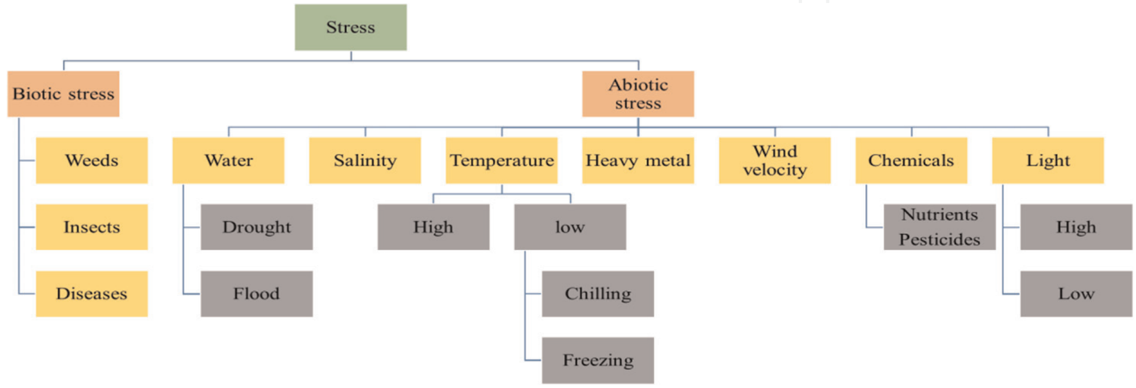

Figure 1.
Classification of various biotic and abiotic stresses [7].

continuous rainfall for few days or high water-table or overflow of river, ponds and dams associated with less drainage facility. Flash flood lasts for a very less time period from a day to only few weeks. However, deep water flood lasts for a longer period of time.

2.3 Salinity stress

Throughout the globe specially during arid and semi-arid areas, salinity is a major issue. It arises in areas where potential evapotranspiration is greater than the rainfall as well as insufficient leaching of salts beyond rhizospheric zone owing from poor rainfall. Presence of excess salts in soil drastically hampers the crop growth [8]. Soil salinity can be developed by both natural phenomena (Weathering of rocks, flooding and intrusion of sea water to agricultural land, seepage of saline water, wind blow, etc.) and human induced activities (poor water quality of irrigation, deforestation, overgrazing, intensive cropping, etc.). Salinity is indicated by electrical conductivity (EC). Usually, soil having EC > 4 dS/m, exchangeable sodium percentage (ESP) < 15.0 and pH <8.5 is called as saline soil [9]. Saline soil contains chloride, sulfate salts of sodium, magnesium and calcium ions. Presence of these salts in excessive quantities deteriorates soil health through changing cation exchange capacity, negatively impacting soil micro-organisms' survival, multiplication and activities, disrupting soil physical properties through deflocculation and reduction of hydraulic conductivity, etc.

2.4 Temperature stress

Temperature stress indicates both rise and fall of temperature from normal. Sudden change in temperature occurs due to climate change. Specifically, heat stress or high temperature situation arise due to due to global warming and anthropogenic activities resulting in change biodiversity, crop ecosystem, impairment of crop growth and production especially in areas of tropics and sub-tropics. Heat stress results in respiration greater than photosynthesis causing starvation injury through deficit of food reserves in plants. According to different degree of high temperature tolerance, plants are categorized as psychrophiles (up to 15–20°C), mesophiles (up to 35–45°C) and thermophiles (up to 45–100°C) [10].

In contrast to heat stress, an opposite phenomenon known as cold stress or low temperature occurs mostly in temperate areas. There are two types of cold stress viz. chilling stress and freezing stress both affecting the crop's physiological, biochemical activities and eventually, hampering crop's growth, yield and quality. Similar to heat stress, plants are also grouped into three based on cold stress tolerance: Chilling sensitive (Plants are extremely sensitive above 0°C and below 15°C), chilling resistant (plants can tolerate low temperature but highly suffer under formation of ice crystals in intra and inter cellular spaces) and frost resistant (plants are tolerant to extremely low temperature).

2.5 Heavy metal toxicity

Heavy metals impart mutagenic effects on plants by contaminating irrigation water, food chain and environment [11]. These are inorganic, non-biodegradable compounds with atomic mass >20 and density >5 g/cm^3. The source of heavy metals in the soil is use of irrigation water from contaminated area, excessive application of chemical fertilizer and pesticides. Plants absorb heavy metals from soil through roots. Ag, Cr, Cd, As, Sb, Pb, Se, and Hg are some major heavy metals which at high concentrations are non-essential and thereby, hamper soil quality and plant's normal functioning. Other than these, there are some essential elements viz. Zn, Cu, Ni, Fe, Co, etc. which at high concentrations create heavy metal toxicity in soil and plant.

2.6 Light stress

Light is essential resource not only for plant growth but also for all life. In fact, harnessing of high amount of solar energy is the prime aim of crop production. However, excessive or low light can cause negative impact on crop such as poor crop growth, wilting, dwarfing, less photosynthesis, cell damage, low productivity and quality and even death of the plant.

2.7 Wind velocity

Wind plays a major role in maintenance of aeration, pollination, etc. in crop's microclimate. However, high wind velocity over the cropped area can exert stress on crop. Wind velocity occurs due to movement of wind from one direction to other at a particular speed. It can create high evapo-transpiration, sand injury, crop lodging, pollen shedding, loss of pollen through desiccation, etc.

2.8 Chemical toxicity

Continuous dependence on chemical based inorganic fertilizers and pesticides specially after green revolution is a great concern now in present day intensive agriculture condition. Further, rapid industrialization and excessive use of untreated sewage water hampers crop's growth and productivity through exerting detrimental impacts of the chemical toxicity on the soil- plant-atmospheric continuum.

2.9 Nutrient toxicity/deficiency

Nutrient toxicity or deficiency resulted from excessive or scarce application of fertilizers and manures as well as soil own nutritional status impairs plant growth, productivity and quality of the crop. This situation is very common in today's intensive agriculture due to non-judicious, unscientific nutrient management practices by the farmers.

3. Negative impacts of abiotic stresses on crop

Plants are negatively impacted by abiotic stress. In most cases, abiotic stresses exert combined impact on crop plants and it causes more harm over individual impact of stress. Hydrogen peroxide, hydroxyl radicals, superoxide radicals, singlet oxygen and other reactive oxygen species (ROS) are synthesized under various abiotic stresses, specially under drought stress. In combinations, these cause lipid peroxidation, protein oxidation etc. and affect nucleic acids and enzyme activity resulting in death of cell. Accordingly, plants adopt defensive mechanisms against stresses. For instance, under drought stress, partial or complete closure of stomata is the one such adoptive approach by plants, which further restricts entry of sunlight, CO_2 and impairs electron flow through electron transport chain, resulting in decline in photosynthesis. Various negative impacts of abiotic stress on plants are shown in **Figure 2** and **Table 1** and highlighted hereunder.

3.1 Drought stress

Drought stress arises under water scarcity. It hampers seed germination as well as early stand establishment of a crop arising through depletion of seed reserves and mechanical obstruction by the hard soil under drought, resulting in poor vegetative growth and yield of crop. The various impacts of drought on physiological and biochemical activities of plants are shown in **Figure 3**. When drought arises, cell solutes concentrations increase due to less water uptake and it not only causes high intra- and inter-competitions for water among crop plants and between crop and weeds, but also exerts toxicity on plants. Further, under drought condition, nutrients show variations in their availability for plant's uptake. Few nutrients become more available (viz. nitrogen) and few become unavailable or less available (viz. phosphorus), while no distinct impact of drought occurs on some nutrients (viz. potassium). This creates alterations in nutrient uptake by plants resulting in impairment of nutrient metabolisms in cell [36]. Under drought stress, as the activities of enzymes such as nitrate reductase, glutamine synthetase, etc. decrease, ammonia assimilation to organic form is restricted. Among the different categories of plants, C_4 ones suffer more than C_3 plants due to closure of stomata resulting in less photosynthesis [37].

3.2 Flood stress

When flood occurs, anaerobic situation arises due to water logging or submergence, which further causes depletion in oxygen as well as restriction of movement of oxygen and other gases in root zone of plant. As a consequence, chlorosis of plant leaves and decay/death of cell occur. Less root respiration, poor root proliferation and

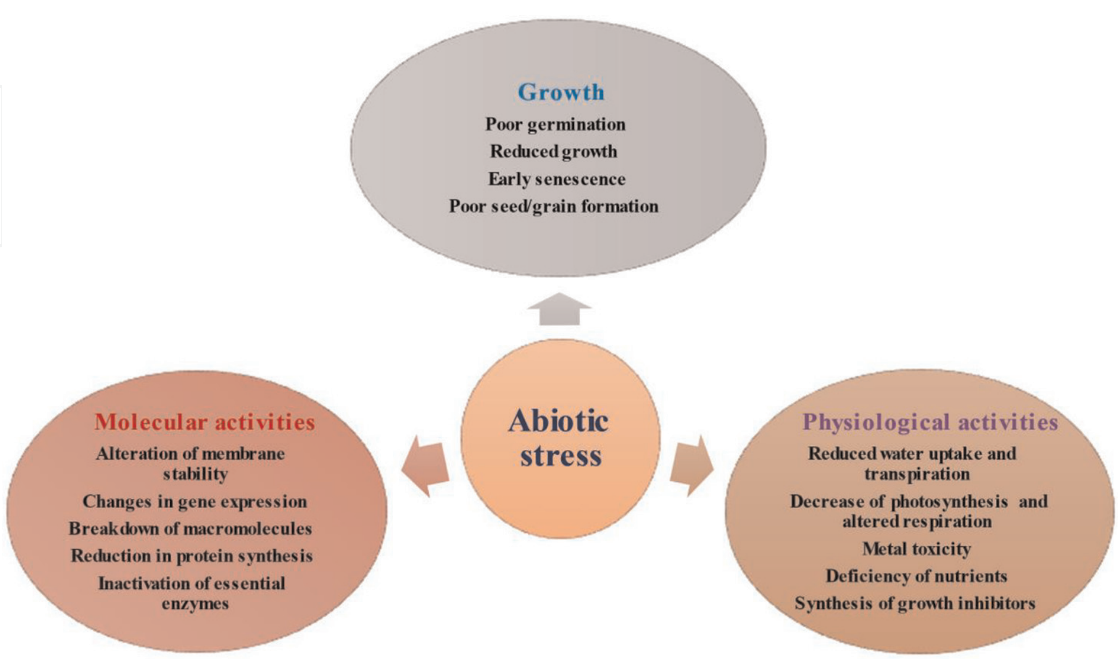

Figure 2.
Influence of abiotic stress on plant [7].

Crop	Abiotic stress	References	Crop	Abiotic stress	References
Lentil	Drought stress	[12]	Lentil	Heat stress	[13]
Chick pea		[14]	Wheat		[15–18]
Soybean		[19]	Rice		[20]
Common bean		[21]	Ground nut		[13]
Mung bean		[22]	Chick pea		[13]
Faba bean		[23]	Pea		[24]
Barley		[5]	Pigeon pea		[13]
Wheat		[25]	Cow pea		[13]
Cotton		[26]	Soybean		[13]
Maize		[27]	Mung bean		[24]
Spotted bean		[12]	Common bean		[28]
Black gram		[29]	Broad bean		[24]
Cow pea		[30]	Lupin		[24]
Pigeon pea		[23]	Groundnut, chickpea, green gram, soybean, pigeon pea	Cd stress	[31]
Lupin		[23]	Grass pea, chick pea	Pb stress	[31]
Soybean	Salinity stress	[31]	Chick pea, green gram	Cr stress	[31]
Chick pea		[31]	Pea, lentil, soybean, black gram	Hg stress	[31]
Lentil		[31]	Pea, chick pea, cowpea, green gram	Cu stress	[31]
Mung bean		[32]	Chick pea, cowpea, pigeon pea	Ni stress	[31]
Faba bean		[33]	Cowpea, chick pea	Zn stress	[31]
Wheat		[34]	Pea, chick pea	As stress	[31]
Soybean	Cold stress	[28]			
Rice		[35]			
Broad bean, Pea		[28]			
Chick pea		[28]			

Table 1.
Negative impacts of abiotic stresses on production of various crops.

other physiological disorders are some common phenomena visible under flood condition. Various negative impacts of flood are shown in **Figure 3**.

3.3 Salinity stress

Salinity creates two prime impacts on plants viz. osmotic stress and ion toxicity. Under the situation of salinity, drought stress is aggravated due to limited water uptake by plants from the soil resulting from greater osmotic pressure to root cell (osmotic pressure of soil solution > osmotic pressure in plant's cell sap). Oxidative damage due to soil salinity include detrimental impact on protein, nucleic acid and certain enzymes of plant as there is synthesis of ROS [38]. Under soil salinity, even if

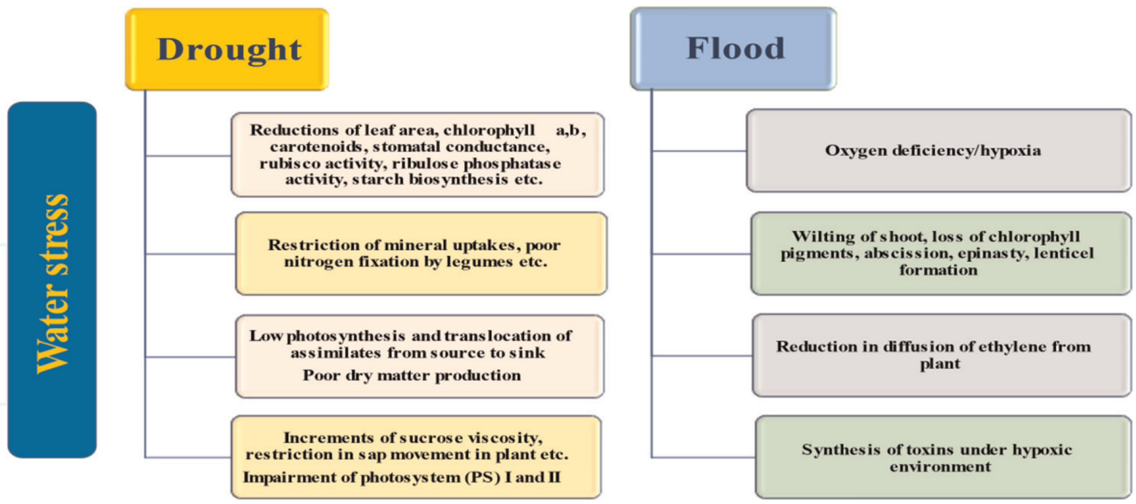

Figure 3.
Negative impacts of water stress (drought and flood) on plants.

uptake of water takes place, there is also intrusion of various salts (Na^+, Cl^-, etc.) inside the plant along with water, which exert negative impact on plant's cell through by impairing activities of various essential enzymes. Plants show burnt like visual symptoms on leaves under excessive salt uptake. Salt stress not only increases the Na^+, Cl^-, etc., but also causes deficiency of various essential elements like calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), nitrate (NO_3^-), etc. in rhizospheric zone of soil. Calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), nitrate (NO_3^-) are known to influence photosynthesis and therefore, their limited uptake by plants under soil salinity results in less photosynthesis and translocation of assimilates from source to sink. Some major impacts of soil salinity include less leaf expansion, stunted growth, less dry weight of plant, sterility of florets, loss of pollen viability, high epidermal thickness, mesophyll thickness, palisade cell length and diameter, spongy cell diameter, reduction of intercellular space in leaves of plant [7]. Partial or complete of stomata under high salt situation causes less transpiration and cell division resulting in reduction in plant's growth, defoliation and senescence of aerial parts and eventually, plant dies [39]. Under salinity stress, Na^+/K^+ ratio of the cell is excessively increased, resulting in reduction in cell turgidity, enzyme activity and membrane potential of plant. Further, due to abundance of Na^+ in cell, various essential enzymatic activities get downregulated resulting in impairments of cell expansion as well as division, membrane stability and cytosolic metabolism.

3.4 Temperature stress

High temperature or heat stress increases evapotranspiration loss of water resulting in drought like situation. This is further triggered under increase of soil temperature coupled with drought. Due to high temperature, respiration exceeds photosynthesis resulting in depletion of food reserve or loss of carbon (respiration rate doubles with each 10°C rise in tissue temperature). It is also observed that sudden temperature rise causes relatively more harm than gradual increase in temperature due to higher reductions of biochemical, physiological and molecular activities of the plant by sudden temperature rise. Among the categories of plant, C_3 plants suffer comparatively more than C_4 plants due to fluctuations in energy supply and carbon metabolisms under high temperature (**Figure 4**) [40].

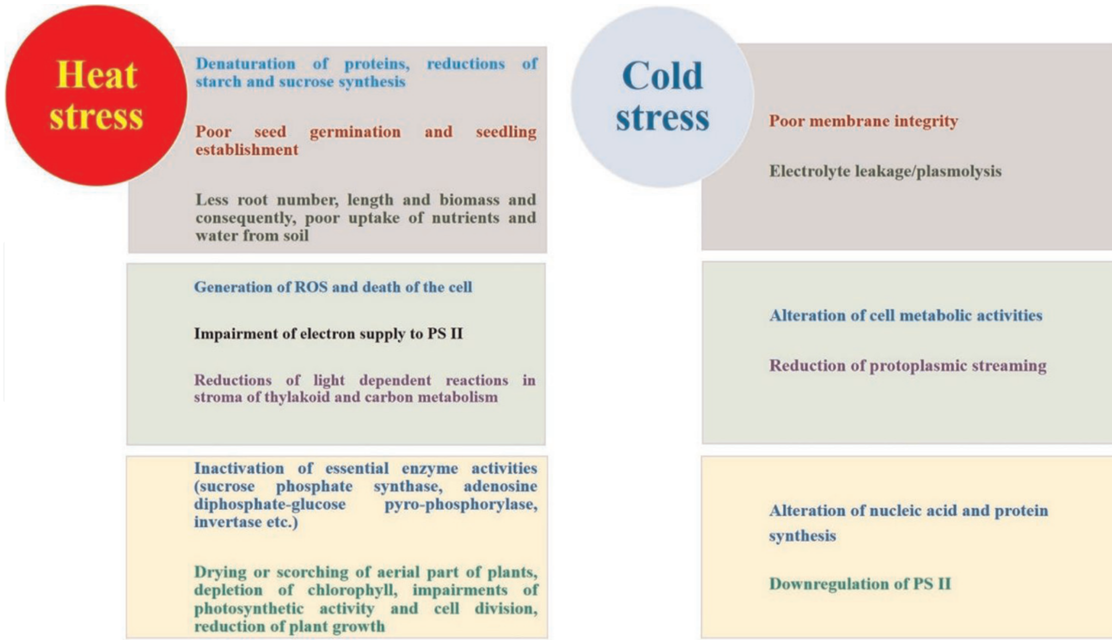

Figure 4.
Negative impacts of temperature stress (heat and cold) on plants.

On the other hand, cold stress or low temperature causes chilling and freezing injuries to the plant. Chilling injury results in disfunctioning of physiological properties, while freezing injury results in cell dehydration. Some major impacts of cold stress on plant include Wilting, bleaching through pigment photo-oxidation, leaf necrosis, browning, cell death, etc.

3.5 Heavy metal toxicity

When there is abundance of heavy metals in soil, plant's physiological, morphological, biochemical, molecular activities are highly affected. After being taken up by the plant's roots, these metals (Pb, Cu, Hg, etc.) move inside the plant through xylem due to transpiration pool and negatively impact nutrient distribution, photosynthesis, enzyme activities, Cu/Zn-SOD, ethylene receptors, etc. resulting in reduction of molecular oxygen content and increment of ROS [41]. Synthesis of ROS thereafter, damages the plant at cellular level.

3.6 Other abiotic stresses

Chemical toxicity/persistence in environment is a great concern today, which results from excessive and unscientific application of chemicals. Environmental hazard or pollution under chemical toxicity leads to poor ecosystem health and diversity. These chemicals not only include pesticides but also cover inorganic fertilizer. Unnecessary use of pesticides and fertilizers are creating climate change resulting in reductions of crop growth, yield and quality. Specifically, complete dependence on chemicals for crop production results in damage of soil health and eventually, soil productivity declines. Contamination of underground fresh water as well as surface water, air pollution, land pollution, etc. is commonly associated with chemical toxicity. Plants known to be grown in an area earlier, are facing trouble in adaptation to changing climate in the same area. Changing climate is linked with various biotic and abiotic stresses which exert detrimental impacts on crop's germination, photosynthesis, translocation of assimilates, etc. and thereby, reduces crop yield. On a contrary, nutrient deficiency arises due to scarcity of nutrients in soil, resulting in their less uptake by plant roots and translocation inside the plants. As a consequence, plants show various deficiency symptoms and its growth diminishes, leading to poor yield and quality of crop.

When wind blows at high velocity over the crop field, plants specially the tall growing or weaker one lodges down, resulting in poor growth, shedding of flower, pollen, grains and thereby, reduction in yield. High wind velocity also causes soil erosion and washes the essential nutrients away from plants. Further, there is an increase in evapotranspiration loss of water under high wind velocity, which demands for frequent water application leading to high cost of cultivation and failure of supply of water leads to poor growth and yield of crop.

Light is one of the prime requisites for photosynthesis and therefore excessive light can disrupts photosynthetic apparatus (photoinactivation and photodamage), while scarcity of light reduces photosynthesis and dry matter production. Plant's growth reduces when light is less or shading by taller plants/trees or other structures occurs. Due to hot sunlight intensity, heat stress or drought stress occurs which alone or together, affects the crop growth. UV ray impairs DNA and causes leaf bleaching, oxidative stress through synthesizing ROS. Under excessive light, breakdown of D1 protein of PS II and decrement of PS I polypeptides like PsaA, PsaB, and PsaC occurs in plants [42].

4. Organic farming and its components

Sustainable agriculture greatly relies on non-chemical, eco-friendly organic farming approaches. Organic farming is defined as holistic production management system which promotes and improves agro-ecosystem health covering bio-diversity, biological cycle and soil biological properties. It completely or largely excludes the use of synthetic off-farm inputs like fertilizers, pesticides, growth regulators, livestock feed additives, etc. and mostly relies on on-farm agronomic, biological and mechanical inputs such as crop rotations, crop residues, organic manures, biofertilizers, green manuring, organic wastes, mineral grade rock additives, biological means of nutrient mobilization and plant protection (botanical pesticides), etc. leading to improvement of soil health, crop growth and yield as well as safety of environment. The major components of organic farming are briefly highlighted below.

4.1 Organic manures and biochar

Organic manures are the sources of nutrients produced by decomposition of organic waste materials (crop residues, plant-based wastes from house/farm/market, etc., animal-based wastes like urine, dung, litter, excreta, etc.) through microbial actions. These are known as bulky organic manures (FYM, vermicompost, poultry manures, common compost, night soil, sewage and sludge, kitchen compost, etc.) as their requirements are high. Besides, there are concentrated organic manures like oilcakes, bone meal, blood meal, horn and hoof meals, fish meal, meat meal, etc. in which more nutrients are present and they, therefore, supply different nutrients relatively in large quantities from unit quantity applied than bulky ones. Apart from solid organic manures, there are various organic liquid manures/ITK formulations such as *Jiwamrit*, *Beejamrit*, *Amrit pani*, *Kunapajala*, *Panchagavya*, *Sanjeevani*, etc. are also used to improve soil health and thereby, crop growth.

Biochar is an excellent soil ameliorant produced under high temperature through controlled pyrolysis of organic substances. Quality of biochar depends on feedstock, temperature and pyrolysis conditions and time. Application of biochar improves plant growth and yield by reviving soil health.

4.2 Crop rotation and other agronomic practices

Crop rotation involves diversification of crops, that is, growing of different crops in succession on same field to avoid pest, disease and weed infestation, improve soil fertility, recycle nutrient reserves, utilize different resources properly, enhance crop productivity, profitability, etc. Besides, there are various other agronomic practices such as variety selection, land preparation, mulching, crop residue retention on soil surface, manure application, time and method sowing, seed rate, spacing and depth, physical, cultural or biological methods of weed, pest and disease control, timely and adequate irrigation, timely harvest and post-harvest operations, followed in organic farming to enhance crop productivity, quality and profitability in production.

4.3 Crop residue

Crop residue is the remaining left after harvesting and separating the economic part from the entire plants. These residues are often burnt leading to environmental pollution. There can be multiple uses of these crop residues like mulching materials, livestock feed, raw materials for manure preparation, substrates for mushroom cultivation, roof thatching, etc. Crop residues can conserve soil moisture, reduce weed infestation and promote crop protection.

4.4 Bio-fertilizers

These are the substances containing living organisms, that is, micro-organisms which are helpful for crop growth and productivity by improving soil health and fertility as well as uptake of nutrients and water by the plants. Seed inoculation or soil application of biofertilizer containing various bacteria (rhizobium, azotobacter, azospirillum, etc.), fungi (VAM, AMF, *Penicillium* sp., *Aspergillus awamori*, etc.), azolla, blue green algae, etc. can help the crop growth either by drawing nutrients and water near rhizospheric zone from distant area or by fixing atmospheric nitrogen in soil leading to enhancement of soil fertility.

4.5 Bio-pesticides and other protection measures

Bio-pesticides such as nicotine, pyrethrum, rotenone, subabilla, ryanin, margosa, neem, etc. are natural plant-based products containing secondary metabolites like alkaloids, terpenoids, phenolics and minor secondary chemicals. Besides, resistant variety selection, myco-pesticides, release of natural enemies or growing trap crop or plants which act as host for biocontrol agents can protect crops from disease and pest damages. Further, various agronomic approaches like mulching, soil solarization, stale seed bed technique, timely and line sowing, crop rotation, intercropping, smother crops, use of botanical extracts, etc. can suppress weed problem.

5. Different organic farming approaches to mitigate abiotic stresses

Over the years, organic farming has served as an eco-friendly approach to improve agricultural productivity in a sustainable manner. Further, it acts as buffer against various biotic and abiotic stresses which are often less highlighted. In the following section, different organic farming practices having the potential to mitigate various abiotic stresses are mentioned.

Mulching: In organic farming, mulching with straw, compost and other crop residues plays a key role in mitigating drought stress along with associated salt accumulation on soil surface. Further, it reduces the chances of loss of surface soil nutrients by restricting the soil erosion arising due to direct impact of rainfall or high runoff velocity. Mulch materials also act as insulators which keep the soil cool during warm weather and hot during winter months and thereby, solving the issues of heat and cold injuries to a high extent. Decrease of soil temperature by 1–2°C has been reported by Král et al. [43]. Apart from their role in soil and moisture conservation and checking different abiotic stresses, mulch materials like crop residues, compost, etc. can improve soil microbial activities and add essential nutrients through decomposition over the time [43]. In reality, abiotic stresses are most often associated with biotic stresses. Mulching, beside alleviation of various abiotic stresses, also suppresses various weed infestations in crop field. All these benefits are directly reflected to high crop growth, yield and quality under climate change scenario.

Sea weed extracts: Sea weed extracts are now emerging as one of potential sources of nutrients in organic farming for crop production. They contain nutrients, plant growth promoting substances, enzymes as well as antioxidants which help the crop cope up with salinity, heat and drought stresses. Besides, the use of sea weed extracts for cold tolerance as well as associated nutrient deficiency is now emerging. Algal extracts trigger a number of pathways to enhance stress tolerance through scavenging ROS. These extracts improve soil properties to conserve water well and thus, allow crop to survive under drought. Earlier, the use of these extracts was successful on Kentucky bluegrass (*Poa pratensis* L. cv. Plush) to mitigate salinity stress also [44].

Organic manures and biochar: Organic manures as well as green manure plants contain various nutrients, growth regulators, micro-organisms, etc. which not only improve soil fertility by solving nutrient scarcity stress but also improve overall soil health to a high extent. Increasing soil porosity, aggregate stability, reduction of compactness, etc. increase water holding capacity of the soil and thereby, address the issues of drought stress. Further, moderation of soil temperature, greater aeration in root zone, beneficial micro-organisms' activities in soil improves crop growth and yield. It has been widely noted that organic matter through decomposition releases humic and fulvic acids which alleviate abiotic stresses.

Apart from the organic manures, biochar application can alleviate various abiotic stresses specially drought stress. Shashi et al. [45] observed positive result on maize from rice husk @ 20 t/ha biochar under drought condition by enhancing bacterial and fungal communities in soil. Biochar specially from poultry manure shows excellent properties to mitigate salinity stress by reducing Na and increasing CEC and SOC contents in soil. Further, biochar can protect plants from high and low temperatures as well as alleviates metal toxicity by immobilizing heavy metals, followed by reducing their mobility. Positive impact of biochar in mitigating different abiotic stresses in rice is summarized in **Table 2**.

Biofertilizers and bio-stimulants: Biofertilizer is known to improve soil fertility and overall soil health through accelerating beneficial micro-organisms' activities. Besides,

Abiotic stresses	Biochar type	References
Acidity	Sewage sludge	[46]
Salinity	Bamboo	[47]
Salinity	Rice husk	[48]
Nutrient deficiency	Rice straw	[49]
Saline-sodic stress	Wheat straw	[50]
Saline-sodic stress	Groundnut shell	[51]
Cold stress	Bamboo	[52]
Nutrient deficiency	Rice residue	[53]
Cold stress	Bamboo	[54]
Nutrient deficiency	Rice husk	[55]
Heat stress	Rice husk	[56]
Heat stress	Rice husk	[57]
Cd stress	Rice and maize residues	[58]
Cd and Pb stresses	Wheat straw	[59]

Table 2.
Positive impact of biochar in mitigating different abiotic stresses in rice.

biofertilizer is one of the key components of organic farming to alleviate various abiotic stresses. Various types of biofertilizer helps the crop to tolerate or overcome stresses resulting in good growth and productivity under stress situation. It has been also found that seed bio priming with micro-organisms alleviates various abiotic stresses through improving germination and early plant stand establishment [60]. Bio priming increases the osmolyte concentrations leading to high cell wall elasticity and turgid weight to dry weight ratio. Further, endophytic synthesis of alkaloids protects macromolecules through ROS scavenging activities. Plant growth promoting rhizobacteria (PGPR) improves drought responsive genes' expression through high ROS scavenging activities. It also synthesizes phytohormones like IAA, GA3, etc. resulting in high plant growth under stress. PGPR also synthesizes exopolysaccharides resulting in good soil structure and uptakes of nutrients and water. Various endophytic micro-organisms also confer abiotic stress tolerance in plants through activating host stress response as well as through synthesizing biochemicals against stresses. A specific category of microorganisms known as arbuscular mycorrhizal fungi (AMF) is well known to mitigate negative impacts of various abiotic stresses on crop by improving soil health and plant's defense mechanism. It makes symbiotic relationship with roots of around 90% of the plant types. Use of AMF as biofertilizer/bio-inoculant is an emerging strategy specially under climate change scenario. The fungal network extends as secondary root system and helps the crop to draw nutrients and water from distant areas. Further, it plays a key role in regulating anti-oxidant activities (CAT, POX, SOD, GST, etc.) of plants under specific or combined stress situation resulting in scavenging of ROS and improvement crop growth, yield and quality. Various stress alleviating properties of micro-organisms in the form of biofertilizers/priming are shown in **Table 3**.

Bio-stimulants are organic or inorganic substances rich in bioactive compounds and/or micro-organisms, which improve crop growth through developing root for

Microorganisms	Crop	Abiotic stress	Impacts	References
Sinorhizobium meliloti	Rice	Temperature stress	High endogenous hormone and photosynthesis	[61]
Rhizobium trifolii	Berseem	Salinity stress	High dry matter and nodulation	[62, 63]
Pseudomonas putida	Cotton	Salinity and alkalinity stress	High seed germination, plant height, fresh and dry weights through increased uptake of K^+, Mg^{2+} and Ca^{2+} and decreased uptake of Na^+	[64]
Pseudomonas alcaligenes, Bacillus polymyxa, Mycobacterium phlei	Maize	High temperature and salinity stresses	Calcisol produced by bacteria	[65]
Achromobacter piechaudii	Tomato, pepper	Salinity and water stresses	High biomass production	[66]
Pseudomonas mendocina	Lettuce	Salinity stress	High shoot production	[67]
Azospirillium spp., *Phosphobacteria* spp., *Glucanacetobacter* spp.	Rice, mangroves	Heavy metal (Fe) toxicity	Improvement in crop growth	[68, 69]
P. putida, Pseudomonas fluorescens	Canola, barley	Cd toxicity	Enhancement in IAA, siderophore and 1-aminocyclopropane-1-carboxylate deaminase	[70]
Pseudomonas sp.	Basil	Water stress	High antioxidant and photosynthetic pigments	[71]
Arbuscular mycorrhiza	Rice	Drought stress	High antioxidant and photosynthetic efficiency	[72]
Inoculation with AMF and PGPR	Date palm	Drought stress	High proline content and relative water content; low SOD, CAT, GST and POX activities in leaf	[73]
Glomus intraradices, P. mendocina	Different plants	Drought stress	Low SOD activity	[74]
Kluyvera ascorbata	Tomato	Ni, Pb, Zn toxicity	Reduction in accumulation of heavy metals in plants	[75]
Methylobacterium oryzae, Burkholderia sp.	Tomato	Ni, Cd toxicity	Less uptake and translocation of heavy metals	[76]
Pseudomonas brassicacearum, Pseudomonas marginalis, Rhodococcus sp.	Pea	Nutrient deficiency	Stimulation of root and high nutrient uptake	[77]
Rhizobium sp.	Pea	Zn and Ni toxicity	Enhancement of plant growth parameters	[78]
Arbuscular mycorrhizal fungi	Olive	Drought stress	High turgor potential and mineral nutrient uptake	[79]
Arbuscular mycorrhizal fungi	Soybean	Drought stress	High leaf area index, photosynthesis, growth and yield	[80]

Microorganisms	Crop	Abiotic stress	Impacts	References
Rhizophagus irregularis	Pangola grass	Drought stress	High stomatal conductivity, low lipid peroxidation	[81]
Glomus mosseae	Wheat	Drought stress	High chlorophyll, osmotic potential, antioxidant activities	[82]
Glomus etunicatus	Onion	Drought stress	High fresh and dry matter, phosphorus content	[83]
G. intraradices	Tomato	Salinity stress	High ion uptake, chlorophyll, growth and dry matter	[84]
R. irregularis	Tomato	Salinity stress	High root, shoot, leaf number, growth hormone synthesis	[85]
Claroideoglomus etunicatum	*Aeluropus littoralis*	Salinity stress	Stomatal conductance, root and shoot dry matter, sugar content	[86]
Glomus fasciculate	*Acacia nilotica*	Salinity stress	High root and shoot dry matter, Zn, Cu, P uptakes	[87]
G. mosseae	Cucumber	Salinity stress	High biomass, synthesis of antioxidant enzymes and photosynthesis pigments	[88]
R. irregularis, Glomus versiforme	Barley	Temperature stress	High survival rate	[89]
Funneliformis sp.	Maize	Temperature stress	Maintenance of PS II heterogeneity	[90]
R. irregularis	Cucumber	Temperature stress	High photosynthetic rate	[91]
Funneliformis mosseae	*Elymus nutans*	Temperature stress	High plant growth, chlorophyll and antioxidants, low oxidative damage	[92]
Glomus isolates	Maize	Heavy metal stress	High Mg, P and K contents in plants, dry matter	[93]
F. mosseae	*Trigonella foenum-graceum*	Heavy metal stress	High crop growth and yield	[94]
G. versiforme	*Lonicera japonica*	Heavy metal stress	Low Cd content in root and shoots	[95]
R. irregularis	*Populus alba*	Heavy metal stress	Low Zn and Cu toxicity	[96]
G. mosseae	*Trifolium pratense*	Heavy metal stress	Low root and shoot concentrations, Zn uptake	[97]
Acaulospora trappei, Glomus leptotichum	*Panicum hemitomon*	Flood stress	High P content in plant	[98]
G. intraradices	*Pterocarpus officinalis*	Flood stress	High growth and P content in leaves	[99]
Glomus geosporum	*Aster tripolium*	Flood stress	High sugar and proline content	[100]

Table 3.
Micro-organisms in the form of biofertilizers/priming against abiotic stresses.

high absorption and assimilation efficiency of nutrients, regulating proper water balance in plants as well as tolerating various abiotic stresses by synthesizing proline, simple sugars, alcohols, abscisic acid, osmotic compounds and antioxidants (to scavenge ROS) [101]. Role of bio-stimulants in plants is shown in **Figure 5**. It increases the contents of carotenoids, phenolic compounds and other secondary metabolites in plants as defense against stresses. It is applied as soil drench (directly/through irrigation) or foliar spray or treatment of seeds. Mitigation of various abiotic stresses by bio-stimulants is listed in **Table 4**.

Crop rotation and various agronomic interventions: Crop rotation is one of the key principles of conservation agriculture. It is always suggested to add leguminous crop in rotation to revive soil fertility after cultivation of a soil exhaustive crop through fixing atmospheric nitrogen. Further, biomass incorporation in soil results in addition of SOC content and thereby, causes improvement of soil porosity, water holding capacity, soil fertility, etc. leading to protection of plants against drought, salinity, high temperature stress as well as nutrient deficiency. Growing a shallow rooted crop after deep rooted crop helps in utilization of nutrients and water from various depths of soil profile so that plant can't experience nutrient and water scarcity.

Various other agronomic practices also can protect the crop from being affected by abiotic stresses under climate change scenario (**Figure 6**, **Table 5**). For instance, proper selection of resistant/tolerant crop and varieties under a prevalent abiotic stress is one useful strategy. To achieve this, breeding activities should include identification of responsive genes. Grafting is another one, which is widely used in horticulture to counter various abiotic stresses specially, salinity, nutrient or water deficiency, heavy metal toxicity, etc. Here, scion susceptible to stress is grafted to stress tolerant root stock. Exogenous application of plant components such as amino acid, sugars, etc. and phytohormones such as ABA, GA3, jasmonic acid, salicylic acid, brassinosteriods, etc. protects crop from abiotic stresses. Application of citric acid and vitamin C exhibit antioxidant properties which inactivates heavy metals such as Cu, Pb, Al, etc. as well as helps crop to overcome salinity and drought stresses through ROS scavenging activities. Soil and foliar applications of humic substances, beneficial fungi, bacteria, chitosan, sea weed extracts, etc. can combat abiotic stresses. Tillage also plays key role in conserving moisture and nutrients as well as breaking hard pan and high percolation of water and thereby, mitigates drought, flood and salinity. Keeping the land fallow for a season or year can rejuvenate the soil fertility and

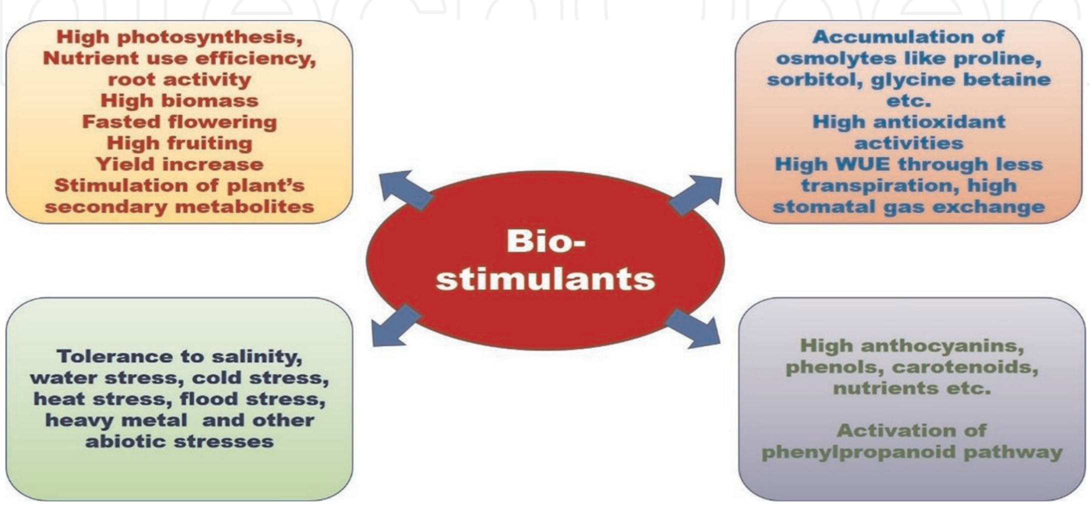

Figure 5.
Role of bio-stimulants in plants.

Abiotic stress	Crop	Bio-stimulants	Impacts	References
Cold stress	Coriander	Asahi SL @0.1%	High chlorophyll *a* and carotenoids	[102]
	Tomato	*Flavobacterium glaciei, Pseudomonas frederiksbergensis, Pseudomonas vancouverensis*	High shoot and root length and biomass, low electrolyte leakage, lipid peroxidation, proline accumulation, SOD, CAT, APX , POD and GR activities	[102]
	Strawberry	Pepton 85/16 @ 2 L/ha or 4 L/ha	New root initiation, more flowering and fruiting	[103]
	Lettuce	Pepton 85/16 @ 04, 0.8, 1.6 g/L	High fresh and dry weights, relative growth rate	[104]
	Lettuce	Terra-Sorb Foliar	High root fresh weight, green cover %	[105]
	Chilli	5-Aminolevulinic acid	High chlorophyll, relative water content, shoot and root biomass, SOD activity, low membrane permeability	[106]
	Pepper	*Serratia nematodiphila*	High plant growth and regulation of endogenous GA4, abscisic acid, jasmonic acid and salicylic acid	[107]
Drought stress	Tomato	Megafol @ 2 ml/L	Increased leaf area	[108]
	Spinach	*Ascophyllum nodosum* @0.50%	Increased leaf area, fresh and dry weights	[109]
	Pea	*P. putida, P. fluorescens*	High root and shoot lengths, pods/ plant, chlorophyll content and grain yield	[109]
	Tomato, chilli	*A. piechaudii*	Low ethylene synthesis, high fresh and dry weights of seedling	[110]
	Tomato	*A. nodosum* @0.33%	High relative water content, plant growth, foliar density, proline and sugar contents, chlorophyll content, low lipid peroxidation	[111]
	Mustard	*A. nodosum* + amino acids	Increase in chlorophyll activity	[112]
	Tomato	VIVA	High shoot and root biomass	[113]
	Basil	*Pseudomonades, Bacillus lentus, Azospirillum brasilens*	High CAT, GPX and chlorophyll activities	[114]
	Pumpkin	Moringa leaf extract	High growth, harvest index, water use efficiency, low electrolyte leakage	[115]
	Soybean	*Sphingomonas* sp.	High growth, chlorophyll content, amino acid, sugar, low ABA and JA	[116]
	Wheat	*Bacillus subtilis*	Enhancement in IAA, decrease in ABA	[117]
	Lucerne	*Enterobacter ludwigii* and *Bacillus megaterium*	Low electrolyte leakage, ABA level, high growth, chlorophyll content, relative water content, nutrient concentrations	[118]

Abiotic stress	Crop	Bio-stimulants	Impacts	References
	Foxtail millet	*P. fluorescens*	ACC deaminase production, high seedling growth	[119]
	Potato	*B. subtilis*	High tuber weight, soluble sugar and CAT, POD, SOD activities	[120]
	Tobacco	Arbuscular mychorrhizal fungi and PGPR	High growth, chlorophyll content, phenol and flavonoid levels	[121]
	Finger millet	*P. fluorescens, P. palleroniana*	High plant growth, nutrient contents, leaf pigment and proline contents, SOD, CAT, GPX activities, low lipid peroxidation	[122]
	Maize	(*Bacillus pumilus, Bacillus cereus*, *Pseudomonas* sp., and *Proteus* sp. and protein hydrolysates	High ABA, IAA, GA, relative water content, protein content, photosynthetic pigments	[123]
	Rice	Commercial seaweed extract (*A. nodosum*)	High plant biomass, yield, leaf area index, chlorophyll content	[124]
	Tomato	Protein hydrolysate	High plant growth, pollen viability, leaf water potential, lycopene content	[125]
Flood stress	Sesame	*Pseudomonas veronii*	High fresh and dry biomass, root and shoot length, chlorophyll content	[126]
	Wheat	*Trichoderma asperellum*	Low ethylene synthesis, high seedling growth	[127]
Heat stress	Common bean	Brassinosteroids @ 25, 50 and 100 ppm	High plant growth, leaves, branches and shoots/plant, fresh and dry weights, nutrient contents	[128]
	Green gram	Glutathione @ 0.5 Mm	High chlorophyll, proline contents, low ROS	[129]
	Chick pea	Proline @ 5, 10, 15 Mm	High germination, shoot and root lengths, proline content, chlorophyll synthesis, low electrolyte leakage, lipid peroxidation	[130]
	Chick pea	Abscisic acid @ 2.5 Mm	High shoot length, chlorophyll content	[131]
	Tomato	*B. cereus*	High growth, APX, SOD, GSH activities, ion uptake (Fe, P, K), chlorophyll content.	[132]
	Chinese cabbage	*Bacillus tequilensis*	High shoot, leaf developments, JA and salicylic acid production, low ABA	[133]
	Rice	Brassinosteroids, amino acids, nitophenolatres, or botanical extracts	High photosynthesis, stomatal conductance, low lipid peroxidation and proline content	[134]
	Tomato	Commercial seaweed extracts	Improved root system, chlorophyll content, high growth	[135]
Fe deficiency	Strawberry	Actiwave (*A. nodosum*) @ 10 ml/20 ml water	High vegetative growth, chlorophyll content, stomatal density,	[136]

Abiotic stress	Crop	Bio-stimulants	Impacts	References
			photosynthesis, fruit production, berry weight	
NPK deficiency	Tomato	Amino acids @ 0.1, 0.2 ml/L water	High plant growth, root and leaf	[137]
	Okra	Kelpak (*Ecklonia maxima*) @ 0.40%	More number of leaves, roots, stem thickness, shoot weight, root weight, leaf area	[138]
	Garlic	Bio-Cozyme @ 2 kg/ha	High bulb yield, plant height, nutrient in leaves	[139]
Salinity	Lettuce	*A. brasilense*	High germination, seedling growth, chlorophyll, dry mass	[140]
	Chilli	*A. brasilense/Pantoea dispersa*	High plant dry weight, carbon di oxide assimilation, nitrate concentration	[141]
	Pea	*Rhizobium leguminosarum*	High plant growth	[142]
	Pumpkin	*Bacillus pumilis, Trichoderma harzannum, Paenibacillus azotoformans*	High fresh weight, potassium uptake, low sodium uptake	[143]
	Common bean	Humic acid@ 0.05%, 0.1%	High nitrogen and phosphorus, plant root and shoot growth, low electrical conductivity, electrolyte leakage	[144]
	Strawberry	Acadian (*A. nodosum*)	High growth and yield	[145]
	Lettuce	Super Fifty (*A. nodosum*) @ 0.4, 1, 2.5, 10 ml/L	High root, stem and total plant biomass	[146]
	Lettuce	Protein hydrolysates @ 2.5 ml/L	High plant shoot and root growths, fresh yield, low oxidative stress	[147]
	Tomato	*A. piechaudii*	High fresh and dry weights, uptakes of phosphorus and potassium, water use efficiency, low ethylene production	[148]
	Cucumber	*A. nodosum* @ 1, 2 g/kg	High fruit yield	[149]
	Common bean	Licorice root extract @ 0.50%	Plant growth, yield, relative water content, total soluble sugars, low electrolyte leakage	[150]
	Common bean	Propolis and maize grain extract @ 1%, 2%	High germination, seedling growth, proline, total soluble sugars, low electrolyte leakage, ABA, lipid peroxidation	[151]
	Common bean	Moringa oleifera	High shoot and root growths, total soluble sugars, proline, SOD, APX, GR activities	[152]
	Chick pea	*Sargassum muticum* and *Jania rubens* @ 1%	High chlorophyll, carotenoids, plant growth, soluble sugars, CAT, SOD, POD, APX activities, low MDA	[153]
	Tomato	*Dunaliella salina* exopolysaccharides @ 0.1 g/L	High protein, chlorophyll, low proline	[154]

Abiotic stress	Crop	Bio-stimulants	Impacts	References
	Onion	Bee-honey based bio-stimulant @ 25–50 g/L	High water use efficiency, bulb yield, antioxidants, photosynthetic pigments	[155]
	Chilli	Humic acid @ 50, 100, 150 mg/kg	High fresh and dry weights, nutrient uptakes, low membrane damage	[156]
	Pea	*Acinetobacter bereziniae, E. ludwigii, Alcaligenes faecalis*	Low electrolyte leakage, high proline, chlorophyll, total soluble sugar, plant growth	[157]
	Tomato	*Pseudomonas oryzihabitans*	Increase plant growth and photosynthetic characters	[158]
	Ground nut	*Stenotrophomonas maltophilia*	High growth, auxin and total amino acids, low proline, electrolyte leakage, lipid peroxidation	[159]
	Common bean	*Aneurinibacillus aneurinilyticus*	High root and shoot length and weight, chlorophyll content	[160]
	Soybean	*Arthrobacter woluwensis, Microbacterium oxydans, Arthobacter aurescens, B. megaterium, B. aryabhattai*	High antioxidant (SOD, GSH) activities, chlorophyll content	[161]
	Wheat	*Trichoderma reesei*	High plant biomass, chlorophyll, carotenoids, uptake of nutrients, low Na, ABA contents	[162]
	Wheat	*Trichoderma longibrachiatum*	High root and shoot length and weight, relative water content, chlorophyll content, antioxidant (SOD, POD, CAT) activities	[163]
	Soybean	*Porostereum spadiceum*	High seedling growth	[164]
	Cucumber	*C. etunicatum*, *Rhizophagus intraradices*, and *F. mosseae*	High biomass, SOD, CAT, APX and GR activities, JA, SA contents, low lipid peroxidation, electrolyte leakage	[88]
	Maize	Humic acid	High photosynthesis rate, plasma membrane proton pumps activity	[165]
	Rice	Panchagavya	High plant growth, chlorophyll, carotenoid, anthocyanin contents, low CAT, SOD, POX activities	[166]
	Tomato	Seaweed extract (*Ulva lactuca*)	High plant growth, soluble sugar, total protein, chlorophyll content, carotenoids, low hydrogen peroxide, APX activity	[167]
	Wheat	*Exiguobacterium aurantiacum*	High plant growth, nutrient content, proline contents, CAT and POD activities	[168]
Heavy metal stress	Rice	*E. ludwigii* and *Exiguobacterium indicum*	High growth, chlorophyll content, SA, low ABA, Ni and Cd	[169]
	Cucumber	*Pseudomonas psychrotolerans*	High growth, chlorophyll content, IAA and GA	[170]

Abiotic stress	Crop	Bio-stimulants	Impacts	References
	Soybean	*B. cereus*	High shoot and root growth, SA, chlorophyll content, low ABA, POD activities, low Cd accumulation	[171]
	Sunflower	Arbuscular mycorrhizal fungi	High growth, antioxidant activities, fatty acid contents	[172]

Table 4.
Mitigation of abiotic stresses through various bio-stimulants.

Figure 6.
Abiotic stress mitigation through various organic farming practices.

moisture content for next crop. Timely and properly sowing, adequate seed rate, spacing and depth, seed treatment also allows the crop to grow and utilize resources properly resulting in surviving and withstanding of climate change scenario. For instance, wheat, if sown on time, can escape terminal heat stress. Further, adequate and timely water, nutrient and interculture (weeding) managements accelerate crop growth by conservating water, nutrients, light, etc. which otherwise could be utilized by weeds and thereby, mitigate drought, salinity, nutrient deficiency, etc. Tall variety is susceptible to lodge by high wind velocity, while dwarf, robust variety can withstand the wind stress. Shelterbelt also protects the crop from high wind. Sometimes, crop suffers from hot sunlight and requires shading from tall growing crop and thus, intercropping or agroforestry is beneficial. On a contrary, shading of tall weeds on crop affects crop growth and therefore, timely weed management is needed. Under saline condition, frequent flooding with irrigation water or irrigation to root by drip method, scraping of surface salts, application of plant growth promoting bacteria, etc. are the key mitigation practices. PGPB alleviates salinity through hydraulic conduct, osmotic accumulation, toxic sodium removal, higher osmotic activity. Further, use of organic product such as brewer's spent grain as soil amendment not only improves soil

Abiotic stresses	Agronomic management practices in organic farming	Abiotic stresses	Agronomic management practices in organic farming
Drought	• Use of resistant/tolerant variety • Mulching or cover cropping or inter/mixed cropping to reduce evaporation loss of water (moisture conservation) • Sowing in ridge and furrow bed • Alternate/skip furrow irrigation or partial root drying • Skip row planting • Use of sprinkler/drip or any other micro irrigation/water saving options • Less application of manures • Use of bio-fertilizers and seed priming • Nipping or pinching apical portion to arrest shoot growth and consequently, transpiration rate	Flood	• Use of resistant variety • Drainage of excess water • Growing of water loving crops • Double transplanting in rice • Growing tall plants to avoid complete submergence
		Salinity	• Use of resistant/tolerant variety • Incorporation of green manure crop in soil before sowing • Exogenous applications of non-synthetic ABA and/or jasmonic acid • Seed treatment with non-synthetic polyamines viz., putrescine, spermidine, spermine, etc.
High temperature	• Use of resistant/tolerant variety • Shading on the plant canopy • Use of mulch or residue retention to avoid heat stress at early growth stages • Application of non-synthetic salicylic acid or glycine betaine or ethylene or gibberellic acid • Irrigation on the canopy to restrict sun scorching • Drip irrigation to reduce soil temperature at root zone depth • Timely sowing of winter crops to avoid heat stress during anthesis and seed formation phases	Low temperature	• Use of resistant/tolerant variety • Seed treatment with non-synthetic gibberellic acid or proline • Use of non-synthetic cryoprotectants, ABA, paclobutrazol, uniconzole, etc. • Timely sowing of monsoon crops to avoid terminal cold stress
		Heavy metal toxicity	• Construction of wetlands • Reduction of chemical based intensive farming approach • Substitution of chemicals with biofertilizer, compost and bio-pesticides
		Wind velocity	• Use of windbreaks/shelterbelts • Use of dwarf crop varieties
Low light	• Use of sun loving or tall varieties	Excess chemicals and nutrients	• Promotion of organic farming practices • Growth of nutrient exhaustive crops
High light	• Use of shade loving or dwarf varieties	Nutrient scarcity	• Application of nutrients through manures to correct the deficiency

Table 5.
Agronomic management practices in organic farming to mitigate specific abiotic stress.

fertility but also alleviates heavy metal, nutrient deficiency, salinity, drought stresses, etc. Intercropping/Mixed cropping also conserves soil and water, suppresses weeds, reduces salt accumulation on surface through evaporation and thereby, alleviates various stresses. Sometimes, allelopathic potential of many crops on weeds are utilized to suppress weeds resulting in conservation of resources and good crop growth. Under the scarcity of water, precise and wise use of water, clipping of leaves (to reduce transpiration water loss), organic anti-transpirants (like wax, panchagavya) application, broadcasting of seeds, closer spacing, more plant population/hill, double transplanting, etc. are useful. Apart from drainage, double transplanting is also beneficial for flood condition where main field is too flooded to transplant seedlings on time. It is well known fact that various biotic stresses like pest, disease and weeds trigger abiotic stresses. Addressing these biotic stresses by botanical extracts, biopesticides, release of natural enemies or living organisms, trap cropping, etc. can help the crop to avoid various abiotic stresses.

6. Conclusion

Abiotic stress is creating detrimental effect on living organisms specially on plants since long. Its negative impact on crop is becoming prominent in recent days in the context of climate change scenario. In most of the cases, an abiotic stress combines with other abiotic or biotic stresses to exert combined impact on crop growth, yield and quality and the extent of impact on crop varies from mild to severe resulting in hampering crop growth accordingly. Although plants adopt some internal defensive mechanisms to counter these stresses, in most of the times, they require external stimuli/practices/inputs to mitigate abiotic stresses. Due to population rise, crop yield loss through abiotic stresses cannot be accepted at this moment or future and therefore, suitable agronomic and breeding interventions are highly needed. Since chemical-based farming is a barrier against sustainable agricultural production as it deteriorates soil health and is hazardous to the environment due to toxic chemical footprint, organic farming is emerging as its potential alternative. Various organic farming inputs such as organic manures, biofertilizers, bio-priming with microorganisms, bio-stimulants (seaweed extracts, humic acid, micro-organisms etc.), mulches, biochar etc. have the potential to mitigate abiotic stresses under climate change scenario. Further, organic farming practices like crop rotation, inter cropping, tillage, time and method of sowing, nutrient, water and intercultural operations, use of PGPB, organic formulations, grafting, selection of resistant/tolerant varieties and other scientific/wise uses of organic inputs can help the crop to mitigate/escape the detrimental effects of various abiotic stresses to a great extent. Still, there is need on proper research or study on the abiotic stress potential of organic farming further. Available organic farming technologies as well as information/awareness about them are very also scanty at this moment. Therefore, proper multi-locational research experiments, transfusion of modern practices/awareness through strong extension services, policy interventions and advanced breeding approaches are highly required to address harmful abiotic stresses as well as to get high crop growth, yield and quality. Various strategies should be jointly implemented rather than using individually to get the best result from organic farming in making crop to cope up successfully with climate change scenario.

Author details

Saikat Biswas[1], Rupa Das[2]* and Lay Lay Nwe[1]

1 Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

2 Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

*Address all correspondence to: rupadasbiswas18@gmail.com

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