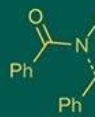
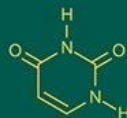


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Climate resilient vegetables: Breeding for heat stress tolerance

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Abstract

Global warming is becoming a serious threat to vegetable production as the temperature is rising above the optimal limits for most of the vegetable crops. Heat stress affects seed germination, vegetative and reproductive growth of the plants and leads to many morphological and physiological injuries in vegetables. Physiological processes such as photosynthesis, respiration, and membrane stability are mainly disturbed due to the oxidative stress created by excessive generation of Reactive Oxygen Species (ROS). In response to heat stress, plants have evolved different avoidance and tolerance-based mechanisms. The avoidance mechanisms which plants exhibit in conditions of heat stress are both morphological and physiological, which includes leaf orientation change, leaf pubescence, early maturing and membrane lipid alteration. The tolerance mechanisms involve osmoprotectants, antioxidant molecules, hormonal changes, transcription factors *etc.* Traditional breeding approaches including selection and hybridization have contributed significantly in developing heat tolerant cultivars, but the complexity of the trait and strong interactions between genotype and environment limits the progress. Genomic tools such as marker assisted selection, QTL (Quantitative Trait Loci) mapping, GWAS (Genome Wide Association Studies), recombinant DNA technology and genome editing are currently being used for the development of heat tolerant cultivars. Besides, advanced phenotyping platforms help breeders identify heat tolerant genotypes more accurately and faster by linking physiological traits with genetic data.

Keywords: Heat stress, heat tolerance, stress response, HSP, QTL, gene editing

1. Introduction

Global warming poses a serious threat to agriculture, particularly to vegetable crops, which are highly sensitive to heat because of their soft, succulent nature. Due to various anthropogenic activities, the global air temperature has been steadily rising over the past century. According to the IPCC's Sixth Assessment Report (2021) ^[1], global temperatures are expected to rise by about 1.5°C in the next two decades and by 4.5°C overall contingent on greenhouse gas emission trends. In addition to causing large yield losses, this temperature increase has had a negative effect on the growth and development of several crops. Every crop has a threshold temperature that it can withstand at a particular stage of growth. The plants may experience heat stress even with a slight increase or decrease beyond this threshold temperature. Heat stress causes numerous morphological and physiological harms to plants and has an impact on seed germination, vegetative growth, and reproductive development. Excessive Reactive Oxygen Species (ROS) generation induces oxidative stress, impairing essential physiological functions like respiration, photosynthesis, and membrane stability. Climate models estimate that in the second half of this century, crop plants may experience a 40 per cent increase in yield losses as a result of heat stress (Shahzad *et al.*, 2021) ^[2]. The extent of plant vulnerability under heat stress is determined by plant sensitivity and the intensity, duration, and magnitude of heat exposure (Jagadish *et al.*, 2021) ^[3].

Therefore, better vegetable cultivars that can withstand high temperatures are required. The development of heat resilient crops can be accelerated with use of new genomic technologies including genome editing, mutant breeding, and recombinant DNA technology.

Transgene free plants can be produced by combining genome editing and conventional breeding, which can help introduce or change the functionality of genes of interest in the crop. Understanding how vegetables react to heat stress and identifying genotypes that are heat resistant are also necessary to boost each vegetable's breeding program and fight the problems posed by high temperatures.

2. Impact of heat stress on vegetables

The growth, development, and productivity of many vegetables are negatively impacted by rising temperatures. It has been discovered that the germination and reproduction stages are extremely vulnerable to heat stress in vegetables.

2.1 Germination

At an early stage, heat stress has a negative impact on seed germination, which reduces the number of plants per unit area. Heat stress over time causes abnormal seedlings, reduced vigor, delayed germination, and restricted radicle and plumule growth (Hasanuzzaman *et al.*, 2013) [4]. A few vegetables, including okra, onions, spinach, and carrots, have been shown to have decreased seed germination as a result of heat stress (Abu-Rayyan *et al.*, 2012) [5]. At 40 °C, okra seed germination has been completely inhibited (Besma and Mounir, 2010) [6].

2.2 Vegetative growth

Vegetable crops subjected to heat stress during vegetative growth often display morphological symptoms such as leaf and stem scorching, sunburning of aerial parts, and suppression of root and shoot development. According to Naik *et al.* (2017) [7], high temperatures cause cabbage and lettuce to have papery leaves and bleach their outer leaves. Heat stress in cauliflower and broccoli is also linked to a number of abnormalities, including raciness, buttoning, head discolouration, and bracting. Similarly, high temperature degrades carrot quality by causing hairy, deformed, and green shoulder roots. Heat stress causes blackheart in potatoes as well as other physiological abnormalities as bottlenecks, elongated tubers, and secondary growth (Moretti *et al.*, 2010) [8].

2.3 Reproductive growth

During the reproductive stage, heat stress alters blooming behavior and results in poor fruit set. High temperatures during the reproductive stage significantly impair fruit setting and development in solanaceous vegetables such as tomato, brinjal, sweet pepper, and hot pepper. The major factors contributing to reduced fruiting under heat stress include decreased pollen and ovule production, impaired dehiscence, ovule abortion, and reduced pollen and ovule viability. According to Müller *et al.* (2016) [9], exposure to heat stress in tomato plants results in antheridial cone splitting, increased anther spacing, and the formation of ovule like protrusions at the base of the anther. Similarly, Moretti *et al.* (2010) [8] reported that heat stress in tomato, hot pepper, and sweet pepper primarily causes fruit discoloration, blossom end rot, and fruit cracking.

2.4 Impact of heat on nutritional quality of vegetables

When Dark Red "Lollo" Rosso lettuce plants were grown for 30 days at 25°C and 33°C, the higher temperature led to a noticeable decline in both yield and quality, which also caused the bolting and bitterness process (Sublett *et al.*,

2018) [10]. The blossoms and sugar content of watermelon (*Citrulus lanatus* L.) and cucumber (*Cucumis sativus* L.) decreased at temperatures above 35° C (Lai *et al.*, 2018) [11]. High temperature (38°C) reduced flower and fruit number in hot pepper, while 40°C altered bulb size and increased sulphur content in onion (Ghai *et al.*, 2016) [12]. In tomato plants, exposure to temperatures above 25°C resulted in a reduction in the number of flowers and fruits, as well as a decrease in lycopene and carotene contents, leading to fruit discoloration (Karapanos *et al.*, 2008) [13]. Additionally, heat stress induced purpling of leaves, which became stiff and curled. Root growth was also adversely affected, with both fresh and dry biomass significantly reduced under high temperature conditions. Microscopic observations of root cross sections revealed increased lignin accumulation following heat treatment (Mathieu *et al.*, 2018) [14].

2.5 Impact of heat stress on physiological processes

Every morphological alteration brought on by heat stress during the vegetative and reproductive growth stages is the consequence of disruptions in physiological and biochemical cellular functions. An essential physiological mechanism for the cycling of carbon is photosynthesis. because it has a major impact on vegetable growth and yield. Nevertheless, under heat stress, leaves retain more light energy, which harms the machinery involved in photosynthetic processes and lowers the rate of photosynthetic activity (Abdalla *et al.*, 2020) [15]. The primary cause of the reduced photosynthetic rate is stomatal closure, which limits gas exchange following heat stress exposure. In many plants, mild heat stress results in a decrease in rubisco activation, which limits both stomatal conductance and photosynthetic rate (Asim *et al.*, 2021) [16]. Due to Rubisco's deactivation, which is caused by heat's detrimental effects on the electron transport system, the photosynthetic rate in cabbage dropped significantly (Lee *et al.*, 2021) [17]. Numerous studies have shown that heat stress reduced chlorophyll levels by preventing chlorophyll from being biosynthesised.

Internal water content is the most important factor in how plants react to temperature variations. In order to grow normally, plants typically maintain a balanced tissue water state. On the other hand, heat stress speeds up transpiration, which lowers water content and negatively impacts plant physiology (Demirel *et al.*, 2020) [18].

Heat stress triggers oxidative stress, causing damage to cellular macromolecules and membranes through the excessive generation of reactive oxygen species (O_2 , O_2^- , H_2O_2 , and $OH^\cdot$). Protein deterioration and fatty acid unsaturation are the primary causes of membrane breakdown (Kotak *et al.*, 2007) [19]. Fatty acid unsaturation causes membrane fluidity, which in turn causes electrolyte loss and membrane deterioration. The main criterion used to gauge the integrity of cellular membranes is leaf electrolyte leakage.

3. Adaptation to heat stress

Different avoidance and tolerance based mechanisms have evolved in plants in response to heat stress. Heat tolerance refers to a plant's capacity to develop and yield economically in the face of heat stress, whereas heat avoidance encompasses all the tactics that plants adopt to prevent exposure to heat stress.

3.1 Avoidance mechanisms

Heat stress triggers avoidance mechanisms in plants such as leaf reorientation, stomatal closure, altered stomatal density, and changes in membrane lipid composition (Hasanuzzaman *et al.*, 2013) [14]. Plants may also generate tomentose hairs, which cover the cuticles and leaf surface in a thick layer, to protect themselves from heat. To reduce excessive light interception, leaves orient themselves parallel to the sun's rays; alternatively, they may roll or curl to minimize water loss under heat stress conditions (Zróbek-Sokolnik *et al.*, 2012) [20]. Smaller leaves are more heat tolerant than larger ones, as their reduced surface area facilitates more efficient heat dissipation from the interior to the surrounding environment. In addition, plants attempt to finish their reproductive cycle during times of optimal temperature in order to survive high temperatures.

3.2 Tolerance mechanisms

3.2.1 Osmoprotectant accumulation

Osmolytes are a key defensive mechanism against ROS generation under abiotic stress. Nontoxic chemical compounds called osmolytes build up in cells to maintain osmotic pressure equilibrium and shield internal organelles from harm. Through scavenging ROS and preserving the molecular membrane structure, osmolytes lessen the negative impacts of abiotic stressors. Osmolyte production and accumulation are triggered by a variety of signaling molecules that are generated under stressful situations (Jogawat, 2019) [21]. Proline is considered as the most crucial osmolyte for shielding plants from abiotic stress. It functions as a molecular chaperon, antioxidant, and its synthesis precursor is glutamate (Sharma *et al.*, 2019) [22]. Additionally, glycine betaine is essential for the plant's osmoregulation, which is crucial for shielding the plant from salinity, heat, and drought. It aids in maintaining photosynthetic equipment and membrane structure while halting ROS accumulation (Singh and Thakur, 2018) [23]. Because they stabilize the protein structure of membranes and maintain osmotic balance during abiotic stressors, carbohydrates and soluble sugars are also regarded as significant osmolytes (Zulfiqar *et al.*, 2020) [24].

3.2.2 Antioxidative defence

Plant antioxidant defense systems are broadly classified into two categories: enzymatic and non-enzymatic. The non-enzymatic antioxidants include ascorbic acid, glutathione (GSH), α -tocopherol, carotenoids, phenolics, flavonoids, and the osmolyte proline, which collectively scavenge reactive oxygen species. The enzymatic antioxidants comprise dehydroascorbate reductase (DHAR), superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), glutathione peroxidase (GPX), and glutathione reductase (GR), which play crucial roles in detoxifying reactive oxygen species and maintaining cellular redox homeostasis. An enzyme called dehydroascorbate reductase transfers electrons from reduced glutathione to dehydroascorbate, converting it to ascorbic acid and compensating for oxidative damage. This enzyme maintains the general redox status of plant cells by controlling the amount of ascorbic acid in the symplast and apoplast (Dar *et al.* 2017) [25]. Glutathione reductase (GR), a member of the flavoprotein reductase family, is a key antioxidant enzyme responsible for regenerating reduced glutathione (GSH) from its

oxidized form (GSSG), thereby maintaining the cellular redox balance. Ascorbate peroxidase (APX) plays a vital role in controlling the level of hydrogen peroxide (H_2O_2) within peroxisomes by utilizing ascorbic acid as a reducing substrate to convert H_2O_2 into water. Superoxide dismutase (SOD) represents the first line of defense against reactive oxygen species (ROS); it catalyzes the dismutation of the superoxide radical ($O_2^{\bullet-}$) into hydrogen peroxide and molecular oxygen, thus preventing oxidative damage to cellular components. Another essential antioxidant enzyme that reduces oxidative damage is catalase, which scavenges hydrogen peroxide and transforms it into oxygen and water. The essential feature of this enzyme is that it can dismutase reactions without the need for a cellular reductant.

3.2.3 Hormonal changes

As stress hormones, ethylene (C_2H_4) and abscisic acid (ABA) function as signal molecules that regulate a variety of physiological characteristics. ABA induction has a significant role in thermotolerance under field circumstances, where heat and drought stressors typically coexist. This indicates that ABA plays a role in the biochemical pathways essential for survival during heat induced desiccation stress. Other research indicates that one way ABA provides thermotolerance may be through inducing a number of HSPs, such as HSP70. A class of steroids known as brassinosteroids (BRs) is mostly present in plants and produces an impressive growth response. In addition to enhancing antioxidants, it has been shown to be protective against heat stress.

3.2.4 Signaling cascade

When plants are under stress, they interpret both internal and external cues through a variety of separate or connected pathways that control diverse reactions and help them gain tolerance. Multiple routes are involved in the intricate, integrated circuits that plants use to respond to stress. Cofactors and signaling molecules must interact in order to produce a response in particular cellular compartments or tissues to a given stimulus. Genes that respond to stress are activated by signaling molecules. Stress responsive gene activation involves various signal transduction molecules, depending on the plant species and stimulus type, such as CDPKs, MAPKs/MPKs, nitric oxide, sucrose (as a signaling molecule), and phytohormones. Stress responsive genes are activated by these substances in conjunction with transcriptional factors (Jha *et al.*, 2014) [26].

3.2.5 Transcription factors

Transcription factors (TFs) are proteins that bind to specific DNA sequences to regulate the transcription of genetic information from DNA to mRNA (Haider *et al.*, 2022) [27]. Heat stress transcription factors (HSFs), along with other heat induced TFs, act as the final components of the signal transduction cascade, controlling the expression of heat shock proteins (HSPs). Under heat stress, monomeric HSFs translocate from the cytoplasm into the nucleus to initiate this response. In the nucleus, HSF monomers assemble into an active trimer that binds to specific regions of heat shock genes (HSGs), such as promoters or heat shock elements (HSEs). This binding triggers effective transcription, translation, and post translational modifications, leading to the production of functional heat shock proteins (HSPs), which confer heat stress tolerance and protect the plant cell.

3.2.6 Heat Shock Proteins (HSPs)

Heat stress typically triggers the up regulation of numerous heat inducible genes, commonly called heat shock genes (HSGs), which encode heat shock proteins (HSPs). The active products of these genes are crucial for plant survival under severe heat stress. Under normal conditions, HSPs act as molecular chaperones, regulating protein synthesis, folding, maturation, and degradation. Additionally, molecular chaperons help proteins refold and stabilize proteins and membranes under stress. The five main families of heat shock proteins (HSPs) or molecular chaperones are Hsp70, Hsp60 (chaperonins), Hsp90, Hsp100, and the small Hsp (sHsp) family. Stabilizing proteins, preventing their aggregation, and ultimately keeping them in a state necessary for later refolding which is carried out by Hsp 60, Hsp 70, and Hsp 90 are all accomplished by sHsps and Hsp 70. Hsp 100 can be used to resolubilize proteins that have been denatured or misfolded, and then refold them. According to research by Usman *et al.* (2015) [28], heat tolerance in chili genotypes is closely linked to the expression of the HSP70 protein. While susceptible plants exhibit low levels of this protein under thermal stress, tolerant genotypes demonstrate an overexpression of HSP70, which serves to improve the thermostability of their cell membranes.

4. Heat tolerance through conventional breeding

A suitable and practical adaptation to heat stress is the breeding of cultivars that are resistant to heat. The development of heat tolerant genotypes is typically carried out in naturally hot climates or under artificially induced

heat stress in growth chambers or greenhouses. By screening high yielding cultivated varieties for heat tolerance, the indirect technique can also be utilized to identify genotypes that are heat tolerant.

4.1 Limitations in conventional breeding

- Environmental variation has a significant impact on stress tolerance features, which are complicated and governed by multiple genes. As unpredictable environmental factors negatively impact the precision and reproducibility of such experiments, direct selection in the field is typically challenging.
- Since heat stress may or may not occur in the field, field nurseries frequently cannot guarantee constant high temperatures.
- Abiotic stress tolerance is stage specific and developmentally regulated; tolerance at one stage of plant growth does not necessarily confer tolerance at other stages.
- Heat tolerance is frequently linked to some undesired horticultural or agronomical traits in certain plant species. For instance, tiny fruit and a limited foliar canopy are two unfavorable traits frequently seen in genotypes of tomatoes that are heat tolerant.
- Identifying genetic resources with characteristics of heat tolerance. Many plant species, like tomatoes, have few genetic differences within the cultivated species, making it necessary to identify and exploit wild accessions.

Table 1: Heat tolerant cultivars through conventional breeding

Crop	Varieties	Method	Institute
Tomato	Thar Anant	Mutational Breeding	ICAR-CIAH, Bikaner
	Kashi Adbhut, Kashi Tapas	Hybridization	ICAR-IIVR, Varanasi
	Pusa H 1	Hybridization	ICAR-IARI, New Delhi
Potato	Kufri Surya	Hybridization	ICAR-CPRI, Shimla
Brinjal	Punjab Chamkila	Selection	PAU, Ludhiana
Musk melon	Thar Mahima	Selection	ICAR-CIAH, Bikaner
Pumpkin	Thar Kavi	Selection	ICAR-CIAH, Bikaner
Okra	Anand Kranti	Hybridization	AAU, Gujarat
Eggplant	Pusa Bhairav	Selection	IARI, New Delhi
Cucumber	Pusa Bharkha	Selection	IARI, New Delhi
Watermelon	Arka Manik	Hybridization	IIHR, Bangalore
Cauliflower	Arka Kanti	Selection	IIHR, Bangalore
Cabbage	Pusa Ageti	Selection	IARI, New Delhi

5. Heat tolerance in the genomic era

5.1 Quantitative trait loci mapping for heat tolerance

It is a statistical technique that uses marker based data to connect the complicated phenotype and genotype. To identify the number and chromosomal locations of genes or QTLs associated with desirable traits, as well as their individual and combined effects, various molecular markers

such as SSRs, Amplified Fragment Length Polymorphisms (AFLPs), and SNPs can be used. These markers are linked to target genes or QTLs through linkage or pleiotropy. Table 2 lists some of the QTLs for heat specific characteristics that have been found, along with the chromosome location of each.

Table 2: QTLs mapped in vegetables for heat tolerance

Crop	Specific traits targeted for heat tolerance	Number of QTLs	Chromosome location	References
Common bean	Yield under high temperature	32	1,2,3,4,5,8,9,10	Vargas <i>et al.</i> (2021) [29]
Potato	Tuber yield under high temperature	3	5	Trapero-Mozos <i>et al.</i> (2018) [30]
Bottle gourd	Relative electrical conductivity	7	1,2,5,6,7,8	Song <i>et al.</i> (2020) [31]
Broccoli	Head color, size, shape and smoothness	5	2, 3, 5, 7, 9	Branham <i>et al.</i> (2017) [32]
Cucumber	Heat tolerance at adult stage	1	1	Liu <i>et al.</i> (2021) [33]
Tomato	Reproductive traits	22	1,2,4,6,12	Gonzalo <i>et al.</i> (2020) [34]

5.2 Marker assisted selection

Conventional plant breeding could be greatly enhanced by marker assisted breeding, which could increase its accuracy and efficiency. Extensive QTL mapping studies across various crop species have generated a wealth of information on DNA marker trait associations. Plant genes that regulate heat stress tolerance can be found using these marker trait relationships. Breeding is twice as quick as phenotypic based breeding because plants with the appropriate markers are chosen for additional breeding.

5.3 Genetic engineering

The term genetic engineering describes methods that directly introduce the advantageous gene or genes across taxonomic boundaries to produce desired phenotypes in the crop of interest. Genetically modified organisms (GMOs), or transgenics, are plants created by genetic engineering. Genes involved in the production of antioxidants, osmolytes, and other regulatory or signaling pathways have been modified to enhance heat tolerance (Table 3).

Table 3: List of vegetables possessing transgenes to combat heat stress

Source	Trans host	Gene	Remarks	References
<i>Escherichia coli</i>	Tomato	<i>TPSP</i> (trehalose-6-phosphate synthase/ phosphatase) gene	HsfA1, HsfA2, and HsfB1	Lyu <i>et al.</i> (2018) ^[35]
<i>Arabidopsis thaliana</i>	Pea	<i>HsfA1d</i>	Higher SOD and APX activities, and elevated proline levels.	Shah <i>et al.</i> (2020) ^[36]
<i>Cucumis sativus</i>	<i>Cucumis sativus</i>	<i>CsCaM3</i>	Higher SOD, CAT, POD, APX, HSP70 and HSP90	Yu <i>et al.</i> (2022) ^[37]
<i>Solanum habrochaites</i>	Tomato	<i>sha-miR319d</i>	HsfA1a, HsfA1b, Hsp90	Shi <i>et al.</i> (2006) ^[38]

5.4 CRISPER/ Cas 9 mediated genome editing

Breeding is greatly accelerated by CRISPR based genome editing, which allows for exact modifications at particular genomic sites. In Solanaceae, parthenocarpic plant growth offers a means of achieving yield under heat stress. Using the CRISPR Cas9 system, mutant plants of the *SIAGL6* (Slagamous-like 6) gene have recently been developed. Because heat stress kills pollen, which significantly impairs

fertilization dependent tomato fruit setting and such CRISPR Cas9 edited plants can set fruit despite experiencing stress. Recessive monogenic *Slag16* mutant plants are capable of producing parthenocarpic fruit that is normal in size and weight without compromising their ability to reproduce sexually (Klap *et al.*, 2017) ^[39]. Other CRISPR based studies on vegetables is given in Table 4.

Table 4: Summary of CRISPR based genome editing for heat tolerance in vegetable crops

Crop	Target gene	Gene function	Outcome	References
Tomato	<i>SIHyPRP1</i>	Proline rich protein	Heat stress tolerance	Tran <i>et al.</i> (2023) ^[40]
	<i>SICPK28</i>	Protein Kinase	Heat stress tolerance	Hu <i>et al.</i> (2021) ^[41]
	<i>SIMAPK3</i>	Protein Kinase	Heat stress susceptibility	Yu <i>et al.</i> (2019) ^[42]
Lettuce	<i>LsNCED4</i>	Enzyme for abscisic acid biosynthesis	Seed germination at a higher temperature	Bertier <i>et al.</i> (2018) ^[43]
Cucumber	<i>CsSPT</i>	Transcription factor	Heat stress susceptibility	Liang <i>et al.</i> (2023) ^[44]

6. High Throughput Phenotyping (HTP)

High throughput phenotyping (HTP) technologies have become essential tools, enabling rapid and non-destructive assessment of key traits such as root architecture, chlorophyll content, and canopy temperature in both controlled and field environments (Angidi *et al.*, 2025) ^[45].

High throughput phenotyping (HTP) involves the automated collection of large scale data on plant traits using advanced imaging, sensing, and computational technologies. Common approaches include hyperspectral imaging, thermal infrared imaging, chlorophyll fluorescence imaging, and unmanned aerial systems (UAS) employing satellites and drones.

Table 5: Image analysis programs and phenotyping platforms

Software	Primary Function	Key Advantage	Real World Application
RootTrace	Root morphology measurement	High speed analysis of root length and branching	Assessment of root vigor in crop breeding programs
Root Reader 3D	3D root system architecture	3D visualization for structural analysis	Modeling root growth under stress conditions
HTPheno	Shoot and leaf trait measurement	Designed for high throughput plant phenotyping	Large scale plant screening in breeding program
LemnaTec 3D Scanalyzer	Leaf color, shape, size, and architecture	Fully automated phenotyping system	Precision agriculture and stress detection

7. Future prospects

- Understanding the signaling cascades and the specific genes activated in response to heat stress
- Transcriptomics, proteomics, metabolomics to identify candidate genes/QTLs for heat tolerance
- Use of crop simulation models to predict performance of heat tolerant genotypes under future climate scenarios

8. Conclusions

Vegetable growth and development have been severely impacted by heat stress, which poses a serious threat to vegetable productivity in the approaching age eat tolerance in vegetables is primarily developed through conventional breeding methods. While the mechanisms underlying heat tolerance have been studied in many crops, aspects such as heat avoidance or escape equally relevant under field conditions have received less attention. Only in a few

vegetables, contemporary genomic techniques as GS, QTL mapping, GWA research, and marker assisted selection were used. So, in order to create heat tolerant vegetable varieties, genome editing and transgenic techniques must be used in conjunction with traditional and marker assisted breeding methods. This will produce observable, useful results that will raise the quality and yield of vegetables.

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