

Designing a climate-smart brinjal that can withstand a variety of environmental conditions: A perspective

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Abstract: Brinjal is a beautiful vegetable crop with strong nutritional properties specifically folate concentration and total chlorogenic acid content. These vitamins and minerals are very much effective in building up the immune system, whilst chlorogenic acid content protects the human body against heart illnesses, liver issues and diabetes. The quantity of these chemicals changes from cultivar to cultivar largely based upon the location of growth and changing environmental circumstances. Many plant breeding strategies are used to alleviate the losses but have proved to be less successful. Whereas the use of molecular markers and other biotechnology technologies have created a road for creating climate smart brinjal with maximum yields and nutritious contents.

Keywords: Brinjal, Chlorogenic acid content, Climate smart, Breeding, Molecular markers.

Introduction:

Vegetables and fruit crops are a major group which are highly sensitive to climatic changes and exhibit varied changes not only in their physiology but also in their reproductive stages and show reduced yields. Climatic changes effect the farmers who grow vegetables and also fruits. Certain climatic changes may include drought, heat, cold, chilling conditions, rainfall, floods, mining and greenhouse gases emission [1]. As known so many crops depend upon climatic conditions and environment to complete their life cycle which includes vegetative stage, reproductive stage and fruit maturity stages which are the most important and vulnerable stages in the entire growth cycle of the crop. Sometimes the lifecycle or the growth stages of several fruits and vegetables are very much altered due to unfavorable climatic changes like dormancy of the seed, improper seedling growth and yield losses where if these climatic changes are in severe form, they may lead the crop towards death by showing some symptoms like drooping, yellowing of leaves, dry stems, dry leaves, withering etc [2].

These climatic changes have drastic effects on the crops by damaging their growth patterns where severe drought conditions would lead to drying of the crops and reduced growth. Lack of water conditions is a serious threat towards agriculture especially incase of fruit and vegetable crops where the crops tend to show certain symptoms. Also, high temperature conditions would affect the crop in different ways like damaging the internal properties of the plants by arresting certain physiological conditions. Also, high temperature conditions above 55°C would damage the crops by disturbing the natural cycles in the crop and also reducing the photosynthesis in the plants which in turn plants dies due to lack of proper nourishment [3]. In some cases, like chilling or cold conditions where the temperature falls up to -2 °C in chilling conditions and below 5°C -10°C in cold conditions which promotes higher production of certain hormones like ethylene which leads to improper growth of the plants, also in some cases chilling conditions would lead to pulp damage or pulp leakage in case of developed or developing fruits which will be a major loss by deteriorating the post-harvest quality. Along with these higher rainfalls cause flooded conditions in which plants are exposed to prolonged water stagnation where these plants lose their rigidity and the fruits become soft and useless for market purpose [4]. Above all certain greenhouse gases and some mining projects would affect the environment conditions which in turn spoil the crop growth environment. These damages caused by improper climatic conditions would not only affect the growth and development of the crops but also change their life cycle patterns which in turn reduces the yield of the crop [5].

Many agriculturally important vegetables and fruits are almost all prone to improper climatic conditions and are able to tolerate up to a certain level. But due to increased changes in the climatic conditions causing severities on the surrounding crop environment would affect the crop in a greater way by leading to the death of the crop [6].

Brinjal is considered as the most important vegetable due to its high nutritional qualities and easy adaptable nature. These species are the most important members of the family Solanaceae. This brinjal is of different types, shapes and color. Also, the fruit of brinjal can be used in different ways like chutney making, pickles, curries and fries. This fruit of the brinjal is also considered as the King of the vegetables as it occupies a major position as a main attractive dish in several occasions of South India. Apart from this Brinjal is a low calorie and high fiber plant having several health benefits and providing essential nutrients [7].

The peel of brinjal is high in anthocyanins and phenolic compounds which makes it the most important vegetable for eating. Also, several minerals make eggplants very important source for nutrition. This way the most important vegetable crop Brinjal is vital source of mineral, nutrients and fiber which is edible in different ways and can easily grow under normal conditions [8]. In our review we concentrated on the most important vegetable crop i.e., Brinjal and its adjustable nature during unfavorable conditions. The tendency of the brinjal under improper climatic changes is understood carefully and the important steps were considered for making the brinjal a climate smart crop [9].

This crop is highly advantageous due to its unique properties like having less fats which protects the heart, fights cancers, reducing anemia, maintaining bone health and very much useful during pregnancy [10]. But in recent years there are so many questions and discussions on proper growth and yield status of this crop because of improper climatic changes which proves to have a drastic effect on the growth of the crops from old, aged agriculture [11]. These climatic changes if are more than the tolerance level would reduce the usage and importance of traditional breeding methods which could pose a serious threat to the present-day agriculture and a really important problem to the farmers. This study deals with the proper understanding of the response in different stages of the crop towards varying climatic conditions and also the role of climatic changes in altering the nutritional qualities of the crop [12]. The medicinal properties and the other therapeutic properties were also known to be affected due to harsh environmental conditions thereby making the brinjal plants unfit for consumption [13].

Nutrition in Brinjal:

Brinjal is highly known for its nutritional properties and there a group a minerals, vitamins, carbohydrates and other essential elements in a required quantity for an individual who consume brinjals[14].

Table 1: Nutrition of brinjal (per 100g)[15]

TOTAL ENERGY	AMOUNT	MINERALS	AMOUNT	VITAMINS	AMOUNT
Calories	25 kcal	Calcium	10 mg	Vitamin A	1 µg
Total carbohydrates	6 g	Phosphorus	25 mg	Vitamin C	2.5 mg
Total fats	0.22 g	Potassium	230 mg	Vitamin K	3.7 µg
Total proteins	1 g	Magnesium	15 mg	Vitamin E	0.5 µg
		Iron	0.25 mg	Thiamine	0.041 mg
		Zinc	0.19 mg	Folate	22 µg

A total of 25 Kcal would be obtained by consuming 100 g of brinjal fruit where total carbohydrate is more compared to fats and proteins, which is about 6 gm and 0.22 gm of fats which is very less and thus makes the crop a good sources of weight loss. Along with this potassium is the most abundant mineral compared to other minerals in brinjal fruit which is about 230 mg which is very much helpful in protecting against several ailments, whereas zinc is very low compared to other minerals which is about 0.196 mg (Table 1).

Vitamins play major roles in regulating several mechanisms in human body which aids in healthy living [16]. All the vitamins are having several important roles that are beneficial for the growth of the plants and to the consumer as well [17]. The most abundant vitamin to be found in the brinjal fruit is Vitamin K which is about 3.7 µg and is

very much helpful in maintaining blood clots without the loss of blood. Whereas Thiamine is present in very less amount compared to other vitamins in brinjal which is about 0.0041 mg other than B complex [18]. Folic acid is the often known as Folate which is the most abundant vitamin in brinjal and is very much helpful for pregnant women. Brinjal known to be very helpful especially for pregnancy due to its several advantages of maintaining the embryo sac and assist in the development of the growing fetus [19,20]. This folate content is nearly about 22 µg (Table 1) which is more and abundant compared to other members of the Solanaceae family. This presence of important minerals and essential vitamins along with higher amounts of folate makes brinjal a unique crop for nutrition not only for proper health [21].

Effect of climate change on Brinjal:

Changes in the climate has brought several problems in case of many vegetables and fruits deteriorating the quality and nutrients. Severities in the environmental conditions brought about many changes in the growth stages of several vegetables arresting the growth of young saplings [22]. Especially in case of Brinjal which is a very important vegetable crop in the entire world is very sensitive to the changes in the climate which effects the growth of young seedlings and the yields of the crop [23].

Since brinjal is a very important vegetative used all over the world in different cuisines and plays a major role in important occasions in southern part of India. Also, this vegetable is famous for its taste and varieties. It can be used for making fries, stuffed curries and some continental dishes [24]. In some dishes very small brinjals are preferred which gives good texture and taste to the curry, whereas in some other curries long slender brinjals were preferred and most importantly for making curries short and stout brinjals are used which enhance the taste of the curry. Different colors of brinjal is also a very important consideration for preparing different cuisines as the purple colored brinjal fruits enhance the taste of the dishes compared to light green colored brinjals, because light green colored brinjals are slightly bitter compared to purple color. These light colored brinjals are somewhat similar to that of their wild parents and are almost similar in taste [25].

Different problems arising it climatic changes cause lots of problems in case of brinjal plants and its fruits. In tropical and sub-tropical regions of the world it was observed that the growth of the crop is arrested especially during fruit setting stages due to high temperature conditions [26]. The high temperatures above 55-60 °C are very problematic as they allow the dropping of the flowers and reduce the capacity of fruit setting. Along with these qualities it was also observed that the taste of the fruits under the influence of high temperature conditions is less and somewhat bitter [27]. The increasing temperature reduces the quality of the fruit by reducing the taste and size of the fruits which makes the fruits unfit for the consumption and there by reduces the economic value of the fruits [28].

Whereas in certain temperate regions where temperature falls below 5°C or less than 0 °C is highly problematic to the brinjal plants as the growth is arrested. Low temperature conditions damage the cells of the crops effecting the tissues of several plants and thereby reducing the nutritional status of the crops. The cold or chilling conditions of the crops alter the fruit growth by reducing the size of the fruits and makes them unripe and very unfit for consumption [29]. In some cases, it was observed thar the flesh in the fruits become hard and not fully developed. Thus, low temperatures play a major role in spoiling the entire cropping cycle of the plans and arresting the growth thereby leading to the loss of nutritional qualities of the plants [30].

Along with these severe climatic changes rainfall and floods are very much dangerous because they cause the uprooting of the crops from ground level which will be more disadvantageous as the entire crop is lost due to heavy water conditions [31,32]. In some cases, water stagnation and improper drainage conditions causes severe damage to the crops by cause rots in the root regions and stem regions. Leaves of the waterlogged areas are pale in color and underdeveloped which in turn would affect the photosynthesis and thereby reduces the nutrition in the plants through which the growth of the plants is arrested [33]. Also, greenhouse gas emissions from industries along with certain gas emission from other crop fields is also causing a major problem to the growth of the plants. The crops effected by gases would likely tend to become pale yellow to yellowish in color and show symptoms of

stunting and drooping of the leaves and stems. All the above conditions would affect the growth of brinjal plants by deteriorating the quality of the fruits or leading to the death of the plants under severe climatic changes [34].

Table 2: Effect of climate change in Eggplant [35]

Climate change	Percent effected
Rainfall and flooding	38%
High temperatures	29%
Chilling temperatures	12%
Snow falls and hail storms	3%
Greenhouse gases	17%

Brinjal is mostly affected by rainfall and flooding conditions where the percent effected is maximum and is about 38% and causes severe damage to the growing plants. This rainfall causes severe drooping of the leaves and stem of the crops, even though the fruits formed would not stand to the plants but gets detached and fall off from the plants. This is the major havoc caused by rainfall along with certain smuts and rots. Whereas, this brinjal is not habituated or cultivated in extreme low temperatures, but if any case these plants when exposed to lower temperatures would damage the plants by causing freeze injury and hardening the pulp of the fruits. This reduces the growing conditions of the crops and effects the crops at all stages by reducing the nutrition accumulation and retarding certain important plant growth pathways. The other climatic changes are also effective in the brinjal plants but causes low yields under extreme conditions. Thus, brinjal being a king of vegetable crops is damaged or mostly effected by drastic changes in the climate where it shows certain symptoms like rots, smuts, underdeveloped fruits and entire crop damage.

Brinjal Genome:

Brinjal is commonly known as Eggplant due to its oval shape and difference in size and it is so called in US, Australia and New Zealand, it is also called as aubergine in parts of UK, Ireland and Western Europe, whereas it is called brinjal in Asia and South Africa [36]. This plant is mostly known for its edible properties and its nutritional qualities. This vegetable crop belongs to the family Solanaceae and the fruit is known as Berry due to the arrangement of the seeds in the fruits [37].

The total set of genomes found in a particular plants or organisms is known to be genome size of the particular organism. The genome size of a particular organism can be analyzed as a single copy of entire set of genomes and can be well understood using picograms [38]. The maximum amount of DNA present in the organism together us called a genome and the larger the genome size the larger the time is taken for sequencing and replication and the smaller size of the genome takes very less time to complete the sequencing and replication where sequencing helps to understand the arrangement of nucleotides in a genome [39].

There are so many sequencing methods available so far and the methods are really quick. Compared to the old sanger’s method newest next generation methods are very much appropriate in giving the results through which the arrangement or the sequence of the nucleotides is clearly understood and also these methods pave way towards highly useful genome editing techniques which helps to alter the genomes of a particular organisms and making it more beneficial to the surrounding environment [40,41]. These genome editing techniques can be done using different enzymes, buffers, vectors etc. and its main aim is to resolve the areas where the genomes are not proper and which cause disease can be resolved so that alteration can happen and is highly beneficial to the humans as well. This mechanism of genome editing is possible in variety of organisms and species [42].

As known brinjal is a very important vegetable crop all over the world due to its taste and especially colors and different shapes this vegetable occupies a main role in vegetable kingdom and so-called king of the vegetables [43]. Therefore, proper studying and understanding the genomes of this crop is very much important so that the nutritional qualities of this crop may be enhanced and can be very much beneficial for consumption. Also, the

different genes that are responsible and express during different stress conditions [44]. Certain genes like HSP's, WRKY, MYB etc. are highly responsive under serious heat conditions like temperatures above 50°C. Also, certain genes like CAT and PPO genes are highly responsive during extremely lower temperatures and chilling conditions. Whereas under saline conditions certain genes like SOS, KAT 1 are highly responsive and are upregulated under stress conditions [45]. The above genes that are responsive to heat, salt and low temperature conditions were also observed in some members of the Solanaceae family. These genes are known to be upregulated in certain crops like chili peppers, tomatoes etc[46].

Like tomatoes and chilies which share the same family with brinjal where brinjal is an autogamous diploid having 12 chromosomes i.e., $2n=24$, where the maximum estimated genome size of haploids is about 1.21 Gb [47,48]. Whereas the bell peppers which belong to the same family have the genome sizes more than brinjal which is about 3.5 Gb where these genomes contain mostly repetitive elements which occupies more than 80 % of the total genome of the bell peppers [49]. Also, this important crop Brinjal is having nearly 560 accession specific families having more than 1000 genes out of which nearly 111 genes are functionally annotated [50].

Therefore, the brinjal which was studied extensively has several gene families where certain genes are shared with the members of the family. These studies help one to understand the importance of gene sequencing and genome editing for the enhancement of nutritional qualities in the plants and also developing brinjal varieties that are highly tolerant to different stresses and making them capable to tolerate differences in climatic conditions through which smart crops [51].

Organellar genomes of eggplant:

Along with nuclear DNA certain amounts of organellar genomes are known to be present in any plant and are known to play important roles in hereditary. These genomes are well known as extracellular genes and are present outside the chromosomes in certain cell organelles. The plant cell is composed of several organelles which play major important roles in the functioning and the development of the cells as well as the entire organism [52]. Some of these organelles are known to carry certain amount of genetic matter which is very much useful in understanding the hereditary nature of the organisms. The genome sizes of these organelles are very much less compared to the nuclear DNA but are known to be powerful in gene transfer from one generation to next generation. Though there are many cell organelles like Endoplasmic reticulum, Golgi apparatus, vacuoles, Peroxisomes etc., these two organelles play a vital role in maternal inheritance due to the presence of small amounts of genetic material that is transferrable from one generation to another generation [53].

Usually, the genome sizes of these organellar DNA is very small which is about 25- 20,000 genomes per cell and are very neatly arranged in an organized manner. It was observed that the complete mitochondrial genome of eggplant is about 498,136 bp, linear along with 4 rRNAs and 30 tRNAs. This entire sequencing of eggplant genome was done by using next generation sequencing method [54]. These sequences were also known for their GC content which is around 44% which is a really good amount for proper bondage between the bases of the genetic material. After proper sequencing of the mitochondrial genome, it was also cross checked using phylogenetic tree by comparing the genomes of brinjal. It was observed that the mitochondrial genomes eggplant was almost all similar to that of the potato and tomato belonging to the same family [55].

It was also observed that the complete chloroplast genomes of eggplant were around 26,000 bp which was divided into large copy and small single copy. Also, the GC content of the mitochondrial genome was known to be about 38% which was a good amount for maintaining stability between the bonds. These complete chloroplast genomes were collected from whole genome sequencing project from which the sequences were retrieved, and the sequences were properly filtered by Blast n, which is a nucleotide blast where the similarities between the sequences were searched [55,56]. The chloroplast genomes that were generated from the eggplant were compared to that of the chloroplast genomes belonging to their species in the same family. It was observed that the sequences of eggplant are nearly similar to the sequences obtained from solanum nigrum which is a European night shade plant [57, 58].

This transfer of organellar genomes is mostly maternal, sometimes paternal and rarely bi-parental. The study of these organellar genomes has gained much importance in the recent years due to their importance in inheritance and their effective functions[59]. It was also known that these genomes replicate in a semiconservative way proving that there is proper exchange of segments in between the genomes. Therefore these organellar genomes play major important roles in the proper transfer of information from one generation to next generation. Also, these studies are going on extensively for different plant under Solanaceae like tomato, chilies, potatoes, different peppers etc. to observe the important characters in organellar genomes of eggplant and their roles in maintaining the nutrient qualities of the plants under adverse climatic conditions [60].

Challenges, Priorities and Prospect of Plant Breeding in Eggplant (Limitations of Traditional Eggplant Breeding)

Brinjal is a very important crop of Indian culture as it plays a major role in many auspicious events in Southern part of India. The vegetarian meals in Indian ceremonies include Brinjal as main dish as it is considered a King of vegetable crop [61]. The fruits of eggplants were known to contain low fats and can be used as low- diet for extensive weight loss. Along with these properties eggplants are known to reduce the risk of heart strokes and helps in controlling the blood sugar levels [62].

The growth of eggplants is normal in case of traditional breeding methods compared to that of the non-conventional breeding methods where the yields are expected to be more. Brinjal can be well grown in almost all the soils like sandy loams, clay loams, silt loams etc., but clay loams are preferred mostly. This crop usually takes 5 months to complete fruiting and the maturity of the fruits will be completed at the end of 5 months. To obtain higher yields the soils are to be well maintained, well drained and are to be fertile for proper yields where the pH of the soil should be in between 5.0-6.0[63].

The germination of the seeds and the fruit setting stages of brinjal are the most sensitive growth stages that are most vulnerable to climatic changes. Mostly the sowing of this crop is done in two seasons one in summers and other is early winters till spring[64]. These seasons are ideal for proper growth and development of the crops. Irrigations should be given every alternative day before the soil becomes very dry. A maximum of 60cm gap should be given between the seeds of brinjal for proper growth of the plants so that the plants occupy required space for extending their stems. Whereas 300-500 gm of seeds is required for one acre of land. Only high-quality seeds that are previously treated with fungicides should be used for sowing[65].

Eggplants are very much sensitive to biotic and abiotic stresses to mitigate these losses several fertilizers, fungicides and pesticides are used at each and every stage of the crop to increase the yields. But the usage of these harmful chemicals has caused severe problems in plants and ultimately humans. The continuous use of chemicals causes loss of soil nutrients and sometimes effect the growth of soil microbes [66].

In ancient times to reduce these losses traditional methods were employed for proper growth and development of the crops. But the application of traditional breeding methods is quite problematic and a lot time taking. Also, there were not really promising yields after the usage of the traditional plant breeding methods. Traditional plant breeding includes a series of several steps right from the beginning of selecting the parent plants up to the release of new varieties. Although there are several ways in which eggplants are affected by the environment certain crops like rice release methane into the environment which causes severe damage to the air quality thereby affecting the eggplant crops. Also, there are several other reasons for which the changes in the climatic conditions are adverse, all these account to the improper productivity of the crops [64,65].

It was observed that the normal temperature conditions for egg plant crop is around 25°C where this temperature is optimum for germination and well growth of the crops. But due to changes in the climatic conditions which causes increased heat i.e., more than 45°C is problematic for germination, flower germination as well as fruit development. Also, it was observed that the fruits that are set during high heat conditions are lack of taste and somewhat bitter than usual. Sometimes the eggplant fruits are less developed or show smaller sizes compared to

the actual size of the fruit. Under such circumstances sowing of crop in the late season or using heat tolerant hybrids as an alternative is advised under traditional breeding methods to reduce the damages caused by high temperature conditions [67].

In some places with low temperature conditions i.e., below 10C where the proper conditions for growth is less and the plants show wilting symptoms. Also, the growth of the crops are arrested where the plants exhibit stunting and underdeveloped stems and fruits. In certain rainfall areas the plants show certain rotting symptoms where the fruits of the eggplants become soft and oozes water from inside. In such cases of low temperatures and rainfall conditions the crops are sown in the later season, mixed cropping is employed sometimes or growing of the eggplants in green houses under controlled environmental conditions is the possible way to fix the changes in the climate [67].

Not only these effects but also drought causes severe damage to the crops and causes severe yield losses where the drought tolerant varieties that are developed through plant breeding are used for protecting the crops from the harmful effects of the climate [68]. Although these solutions of employing certain plant breeding techniques under adverse climatic conditions is not pretty much successful due to its laborious methods and time-consuming procedures. But following these methods like late sowing of the crops, early sowing of the crops before the season, short duration crops etc. would reduce the drastic yield loss effects caused by climate changes in brinjal and other crops belonging to the same family [69].

Table 3: Eggplant varieties suitable for adverse climatic changes[70]

Eggplant Varieties	Tolerance
Arka Harshitha	Tolerant to high temperatures
Arka Neelanchal Shyama	Early variety suitable for rabi season
Pusa Kranti	Suitable for high and very low temperatures
Pusa Syamala	Suitable for waterlogging conditions
Niranjan Bhata	Resistant to insects and pests
Diamond eggplants (Russian)	Highly drought tolerant

Different eggplant varieties are known to possess different characters suitable for different climatic conditions. These varieties are derived from extensive plant breeding techniques where they are tested both in field and laboratory conditions. There are some varieties (Table 3) where they are tolerant to high and low temperature conditions like Arka Harshitha, Arka Neelanchal and Pusa Kranthi. Also, some varieties like Pusa Symala and diamond eggplants are tolerant to waterlogging and drought conditions respectively. The most important variety like Niranjan Bhata was known for its tolerance against pests and diseases where it does not show any yield losses under severe disease and pest attack like other brinjal varieties. Therefore, proper cultivation of certain important eggplant varieties which are able to tolerate climatic changes is very much important for the development of climate smart brinjal.

Genetic Resources of Eggplant: Diversity, Characterization and Utilization

Solanum melongena which is the most important and famous crop in almost every part of India. In general, this plant requires warm climatic conditions for proper seed germination, seedling growth, flower development, fruit setting and fruit maturation up to physiological harvest which takes nearly about 5-6 months' time[71]. The soil should always be well drained to avoid the fungus invasion and all the rots which would reduce the fruiting of the plants. In general eggplant can withstand a temperature up to 40oC but not more than that, however plants if exposed would show certain symptoms like discoloration and drying flesh of the fruits. This makes the plants look frowzy and they do not appear well. Depending upon these conditions different varieties are used in different areas depending upon the changes in the climatic conditions of that particular area[72].

Table 4: Popular varieties in different regions of India[73]

Regions of India	Popular varieties
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North Indian Region	Pusa Barsati, Pusa Anmol, Pusa Syamala
South Indian Region	APAU Shyamala, Co-1, MDU 1
East Indian Region	Swarna Shree, Swarna Mani
West Indian Region	Janak, BSS-793

Different parts of India cultivate different varieties of eggplants depending upon their climates and other important aspects like soil health, seed vigor etc. The popular varieties like Pusa Barsat, Pusa Syamala is grown in most of the areas of North India (Table 4) whereas APAU shyamala along with other varieties is most common in South India and Swarna Shree and Janak are the important varieties of East India and Western India respectively. These varieties are so cultivated depending upon the areas of high productivity due to less chances of losing yields and also the tolerant nature of these varieties towards climatic changes is maximum.

This eggplant is mainly known for its nutrient content, vitamins especially folate and importantly chlorogenic acid. The contents of these economically important vegetable crop is of high nutritional values and is suitable for weight loss programme. This chlorogenic acid is very much useful for maintaining sound health especially reducing the risks of heart attacks, blocks insulin and reduces the accumulation of fats in liver.

Table 5: Total chlorogenic acid content in important cultivars of eggplant [74]

Varieties of eggplants	CGC content (g/kg)
Scarlet variety of eggplant	1.03
S. Aculeatum	1.03
S. macrocarpon	1.99
S. dasyphyllum	4.9
Gboma variety of eggplant	2.5

Different varieties of eggplant show differences in the chlorogenic acid contents where the maximum amount of chlorogenic acid is found in S. dasyphyllum (Table 5) variety of eggplant which is the native of middle eastern countries and is very beneficial for health due to its high chlorogenic acid content which is proven to have several nutritional characters. Whereas, the Gboma variety of eggplant which is native to south Africa is also having good amount of chlorogenic acid which is about 2.5g/kg (Table 5) which is also a very beneficial for human health. The rest of the important varieties are also having chlorogenic acid but in less amounts i.e., nearly 2 g/kg.

Due to its several important characters like nutritional status, low fats, high chlorogenic acid contents, vitamins, minerals etc. eggplant is a wonderful vegetable crop which should be involved in our daily food intake. Consumption of eggplants on a regular basis has proven benefits like maintaining good body shape and health of the person and also proper liver functioning and most importantly keeps heart risks at bay. But the cultivation of these plants under unfavorable conditions is quite a problem which may result in heat stress, cold stresses, damages caused by through rainfall and flooding and harmful gaseous effects.

To avoid all these unnecessary circumstances or yield losses of the crop, proper care should be taken for sowing of the suitable variety under suitable conditions and proper soil maintenance.

Table 6: Different climatic changes and tolerant cultivars [75]

Climate changes	Cultivars
Heat tolerant	Nadia, Florida Highbush, Traviata
Cold tolerant	Rashika, Sheetal, HABH-8
Rainfall and waterlogging	CO-1, CO-2, MDU, PKM-1
Drought tolerant	Azad kranthi, Azad Keshav, Pusa Hybrid 5

The most important climate changes in any area is heat, cold, rainfall and drought where the use of tolerant varieties like Nadia, Traviata etc., for heat, Sheetal, Rashika etc., for cold conditions, CO-1, CO-2 etc., under rainfall conditions and Azad kranthi, Azad Keshav etc., for drought is very much advisable to avoid all the yield losses caused by such unfavorable environmental conditions.

Therefore different varieties of eggplants have tolerance towards different climatic changes, these varieties are developed by prolonged breeding methods where the trials are properly conducted and time taking procedures were followed. Out of many available cultivars of eggplant present in India and around the world having several medicinal and therapeutic properties along with high chlorogenic acid content and folate contents and quality fruits with proper yields and pretty much tolerant to changes in climatic conditions making this crop climate smart [76].

Development and Application of DNA Markers in Context to Brinjal

DNA markers are very useful and very much important segments of DNA where they were used to detect the polymorphisms different genotypes for a particular sequence in a gene pool or a large population. It helps to identify the exact location of the known segment of DNA which can be used as a reference sequence for important studies [77].

In case of crop improvement programmes with respect to the time taking breeding methods DNA markers play a major role in identifying the purity of the seeds, hybrid testing, diversity studies, linkage analysis, QTL mapping and MAS studies. Also, markers help one to understand the differences clearly between the available gene and genes of interest. All these studies are very much important for understanding the nature of the hybrid variety that will be useful in crop improvement [78].

Especially in case of eggplant several DNA markers were used to assess the genetic variability and diversity studies to isolate the important varieties that are suitable for crop improvement programmes.

Table 7: Molecular markers: Use in Eggplant [79].

Markers	Usage in eggplant
SNP	Used in genome wide analysis and helps in identifying or differentiating plant varieties.
SSR	Maximum genomic abundance was observed along with comparative genomic analysis studies
EST-SSR	These are detected in non-coding regions, useful in gene targeting and marker assisted selection.
ISSR	These microsatellites are useful in identity studies of strains, genes and parents.
RAPD	Highly useful in studying the genetic variability between different genotypes.

Different markers were used in eggplant studies to achieve proper yields and hybrids in plant breeding programme. These markers one way or the other are very much useful in multitasking in plant breeding programme in a way of identifying the unique characters in plants of same species along with understanding proper parentage of the released hybrids. Mostly SSR's and RAPD markers are well used in case of eggplant studies where SSRs are useful in comparative genomic studies as well as RAPD markers identify genomic variability between genotypes (Table 7). Along with these markers other types like SNP's, EST-SSR's and ISSR's were also well used in studying different strains and MAS studies in different species or in between the varieties of the same plants especially for genomic studies in case of eggplant.

Genome-Wide Approaches

The variations in the genomes are very well understood using genome wide approaches. This is achieved by properly scanning the entire genomes of a particular organism to identify any genes that are disease causing or any malformations in the plants so that the alterations can be made to protect the plants from the diseases and death. These approaches are gaining much importance these days due to their accuracy and benefits in plant breeding programmes, where several losses can be reduced [80]. These studies are done to identify the desirable

and undesirable traits of the plants so that only the desirable traits are concentrated to the next generation to achieve maximum yields. This is highly beneficial as the unwanted traits were eliminated and plants can be protected from unwanted diseases. The characters of the plants can be observed both phenotypically and genotypically so that the nature of the plants was well understood [81].

This technique has gained much importance because of its unique nature in identifying the cause of the diseases which may be known or new. By studying these genes that are responsible for causing such diseases are altered and the transfer of diseases from one generation to the next generations is greatly arrested so that the plants are protected, yield losses are greatly reduced and ultimately very much beneficial to humans [80,81]. In general, these studies are based on population studies where there were comparisons between different species of same plant populations and their growth characteristics were carefully observed. Most importantly these studies are dealt with the usage of linkage disequilibrium map and association mapping along with knowing the ancestry of particular species and studying their wild relatives. The quantitative percentages of the populations along with the knowledge of ancestors is the very important step for genome wide studies which is achieved by comparing the individuals between two populations or within the same population.

Genome wide studies especially in case of egg plant which contain more than 1500 species is well known for its different types based on shapes and colours is very much popular with its wild relatives. Out of all the cultivars in brinjal three are of main importance which are common brinjal *S.melongena* which is round, egg shaped plants which are round *var.esculentum* and small in shape and also long, slender fruits *var.depressum* are well known varieties having many important characters [82].

These studies should be done properly to understand the diversity studies of the genotypes, ancestral characters analysis, population studies and especially sequencing of the eggplant genome. With the help of this sequencing the eggplant genotypes the entire genes were studied carefully so that any unwanted or undesired segment of genes can be improvised through genetic engineering techniques and molecular tools which can make the plants resistant towards the undesirable disease conditions. Therefore it was well understood that the genome wide studies are very much important in identifying and altering the genes that cause severe damage to the crop by yield reductions in plants which can be altered by using molecular biotechnology approaches [83].

Transcriptomic Approaches:

The total set of RNAs in a particular cell is called its transcriptome. The proper understanding of the transcriptomes is very much important in all the living organisms especially in vegetables. To achieve climate smart eggplants in agriculture proper understanding of the genes that are expressed in different conditions of the plant is very much important to achieve maximum yields and to reduce maximum losses [84].

The transcriptomic analysis is a hybridization technique and works with the help of sequence-based approach where DNA microarrays were involved to detect the genes that are compared with other genes for further analysis. This is the major step for hybridization where many genes were compared at a time and the useful genes were recorded for further usage [85]. Whereas in sequence-based approaches multiple sequences or two sequences are compared so that the similarities between the sequences can be understood. This can be done using multiple sequence alignment and Blast software from Clustal omega and NCBI respectively. The mRNA sequences can be collected from the NCBI of all the species of eggplants where all the sequences can be compared to understand the expressions of genes [86].

Especially in case of eggplant which is the most important vegetable crop having several nutritional properties, proper analysis of genes and studying their functions is very much important [87]. The expressions of different genes under different stresses are to be observed carefully so that the growth of the plants can be estimated. Since eggplant is not tolerant to extreme high or low temperatures where certain genes like WRKY and CAT are responsive respectively [88]. The regulation of these genes would help the plant from unfavorable conditions. These genes protect the plants up to a certain level by controlling the reduced yields and death of the plants. Along with these genes some other genes like DREB and SmADC genes were responsive under severe drought

conditions thereby protecting the plants from maximum yield losses and death which is possible only when the genes are upregulated [89]. Therefore, this study of RNA expression for plant protection is Transcription profiling or expression profiling through which different functions of different genes can be made known along with the responses of the genes during unfavorable climatic conditions can be analyzed. This knowledge of differential expression levels of the genes under different environmental conditions are analyzed to protect the plants from severe yield losses [90].

Conclusions and Future Prospects:

Brinjal which is also known as the King of vegetables was a perennial, herbaceous and tropical plant with a height of 80-100 cms when fully fruited and having a short lifecycle of 5-6 months has a smooth skinned berry fruit with many seeds is used as a famous dish in Indian occasions due to its different sizes, shapes and colors.

This fruit is very famous for its nutritional properties which help to maintain good heart health, liver health, maintaining proper body weight, reducing diabetes and many others. Especially the fruits of eggplants contain maximum amounts of minerals and vitamins where folate is abundant of all. This folate is highly useful for pregnant women as it helps in maintaining the amniotic fluid and aids in protecting the growing embryo. Along with these it also contains many polyphenols and very important compound called chlorogenic acid which has several health benefits. This CGC varies from one cultivar to another cultivar which also depends upon the climatic conditions.

Climate plays a major role in proper growth and development of all the plants especially in vegetables the sowing season and the climatic conditions are very important to obtain maximum yields. But due to increasing pollutions and global warmings there is a drastic change in the climate which makes the crops susceptible and leads to death. There are several climatic changes which influence the growth of the plants in which high and low temperature conditions, drought conditions, rainfall and water logging conditions and release of harmful gases into the environment. All these conditions create many problems for cropping and thereby reduce the yields. Eggplant being very much sensitive to extreme climatic changes shows drastic yield losses when exposed to a longer period of time. Although several breeding programmes are employed to reduce the losses caused by climatic changes in eggplant, they are not very successful due to time consuming methods and high labor requirements. These methods did not solve the problems completely but help in maintain the plant growth to a certain level.

To avoid these losses and to save money and time new approaches that are more advanced compared to breeding programmes like molecular breeding approaches and biotechnology were employed. These studies help to understand the sequences of the entire genome of the plants so that any unwanted genes can be altered or removed which can protect the plants and thereby maintain the yields. Also, certain methods of molecular breeding were also employed to escape the harsh environmental conditioned and the detailed phenotypic and genotypic characters were studied to protect the plant from death.

Future Prospects:

1. Developing high yielding varieties with good amount of chlorogenic acid.
2. Development of elite lines
3. Development to new hybrids with multiple stress responsiveness
4. Increased nutritional qualities in the fruits
5. Encouraging transgenic crops that are both biotic and abiotic stress tolerant
6. Employing advanced crop management practices with improved molecular biology tools
7. Designing stress responsive genes that are heritable to generations
8. Developing cost effective methods of plant growth
9. Designing climate adaptable varieties
10. Promoting good health at affordable price

Since eggplant being a wonderful vegetable crop having several nutritional qualities is well known for its high folate and chlorogenic acid contents which are highly beneficial for human consumptions so that several body

functions are regulated and maintained. These nutrients help in protecting the human health and also helps in regulating the weight of the body. But the yields of eggplants are reduced drastically due to severe climatic changes by which the yields of the crops are reduced greatly. Many plant breeding programmes accompanied by molecular markers and biotechnology tools would help to maintain yielding of the crops and make the crops tolerant to different stress conditions up to a certain level so that the crops will be protected but do not die. Considering all these nutritional qualities of eggplant the protection of the plant and maintaining its productivity in the present situation where climatic conditions are changing drastically so that their yields may not be reduced and the nutrition of the crops can be maintained up to generations so that the climate smart eggplants can be produced and supplied to the farmers, where these cultivars would be able to withstand changes in the environment.

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