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CLIMATE CHANGE: IMPACT, MITIGATION AND ADAPTATION

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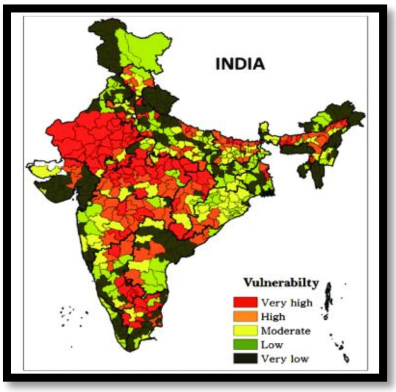
Vegetables are an important component of human diet as they are the only source of nutrients, vitamins and minerals. They are also good remunerative to the farmer as they fetch higher price in the market. Likewise other crops, they are also being hit by the consequences of climate change such as global warming, changes in seasonal and monsoon pattern and biotic and abiotic factors. Under changing climatic situations crop failures, shortage of yields, reduction in quality and increasing pest and disease problems are common and they render the vegetable cultivation unprofitable. As many physiological processes and enzymatic activities are temperature dependent, they are going to be largely effected. Drought and salinity are the two important consequences of increase in temperature worsening vegetable cultivation.

Introduction

For the past some decades, the gaseous composition of earth's atmosphere is undergoing a significant change, largely through increased emissions from energy, industry and agriculture sectors; widespread deforestation as well as fast changes in land use and land management practices.



GHGs trap the outgoing infrared radiations from the earth's surface and thus raise the temperature of the atmosphere. The past 50 years have shown an increasing trend in temperature @ 0.13 °C/decade, while the rise in temperature during the past one and half decades has been much higher.

The Inter-Governmental Panel on Climate Change has projected the temperature increase to be between 1.1°C and 6.4°C by the end of the 21st Century.

Fig 1. Rise In Sea Level

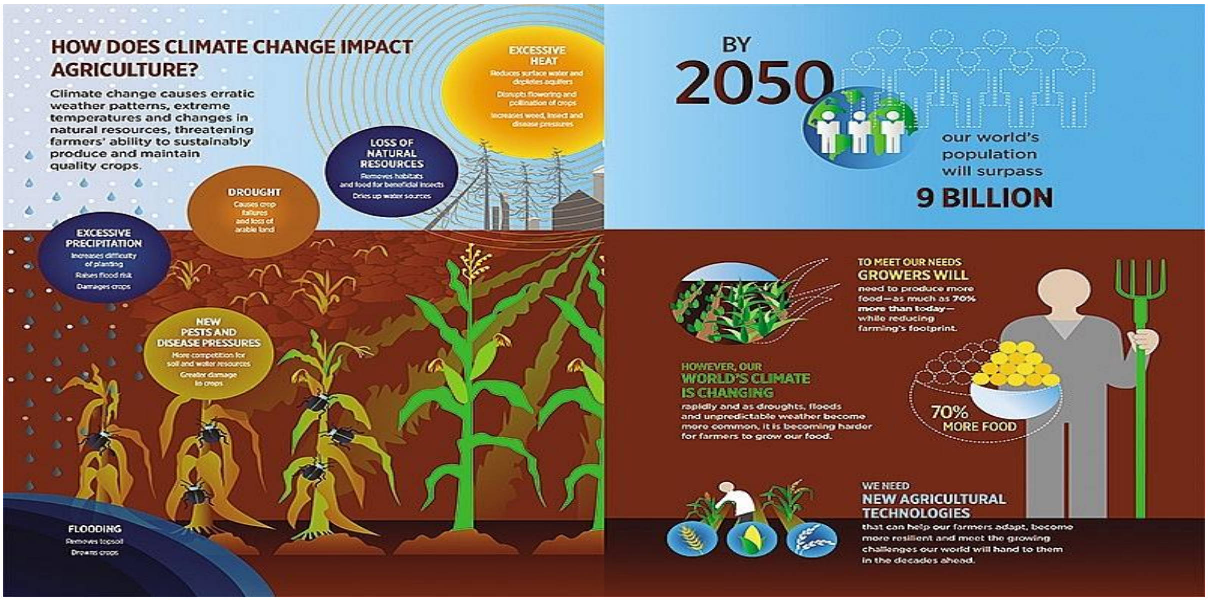
Fig 2. Bushfire in Australia

Concerted efforts are required for mitigation and adaptation to reduce the vulnerability of agriculture to the adverse impacts of climate change and making it more resilient. The adaptive capacity of poor farmers is limited because of subsistence agriculture and low level of formal education. Therefore, simple, economically viable and culturally acceptable adaptation strategies have to be developed and implemented. Furthermore, the transfer of knowledge as well as access to social, economic, institutional, and technical resources need to be provided and integrated within the existing resources of farmers.

Environmental Constraints Limiting Vegetable Productivity

- Climatic changes will influence the severity of environmental stress on the vegetable crops. Moreover, increasing temperatures, reduced irrigation-water availability, flooding, and salinity will be the major limiting factors in sustaining and increasing vegetable productivity. Plants may respond similarly to avoid one or more stresses through morphological or biochemical mechanisms.
- Environmental interactions may cause stress response of plants more complex or influence the degree of impact of climate change.

- Measures to adapt to these climate change-induced stresses are critical for sustainable vegetable production.



Impact on Agriculture

Some of the important environmental stresses which affect vegetable production have been reviewed below.

(A) High Temperature

Heat stress due to increase in temperature is a major agricultural problem in many areas of the world. A constantly high temperature causes an array of morpho-anatomical changes in plant which affect the seed germination, plant growth, flower shedding, pollen viability, gametic fertilization, fruit setting, fruit size, fruit weight, fruit quality etc. Heat stress above 35 ºC has become a major limiting factor for seed germination, seedling and vegetative growth, flowering & fruit setting, and ripening in tomato.



Fig 3. Tip Burn In Lettuce **Fig 4.** Black Heart In Potato **Fig 5.** Buttoning In Cauliflower

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High temperatures also interfere with floral bud development due to flower abortion.

VEGETABLES	SYMPTOMS
Asparagus	High fibre in stalks and spears, feathering and lateral branch growth
Beans	High fibre in pods
Carrot	Low carotene content
Cauliflower	Blindness, buttoning, ricyness
Cabbage	Bleached and papery outer leaves
Lettuce	Tip burn, bolting at >30^{o}c
Tomato	Sun burn, sunscaled
Potato	Black heart

Table 1: Physiological Disorders Due To Temperature

(B) Chilling injury in Tomato

The cultivated tomato genotype (*Solanum lycopersicum*, earlier known as *Lycopersicon esculentum* L.) displays limited growth and development at temperatures under 12 ºC. At temperatures between 0 and 12ºC, plants are damaged by the chilling stress. The severity of damage is proportional to the length of time spent in this temperature range.

(C) Drought stress

The water requirements of vegetable crop range from about 6 inches of water per season for radishes to 24 inches for tomatoes and watermelons. Precise irrigation requirements can be predicted based on crop water-use and effective precipitation values. Lack of water influences the crop growth in many ways and the effect depends on the severity, duration, and time of stress in relation to the stage of growth. Nearly all vegetable crops are sensitive to drought during two periods: flowering and two-to-three weeks before harvesting.

Fig 6: Fruit cracking

Fig 7: Quick bolting

Fig 8: Blossom end rot

VEGETABLES	SYMPTOMS
Brinjal	Reduced extension of main stem, reduced number of branches per plant
Beans	Few flowers, delayed flowering, low seed protein
Potato	Decreased starch
Cauliflower	Leafy, loose, yellow, small and hard curds
Tomato	Blossom end rot, fruit cracking
Lettuce	Bitter taste, accelerated development of tip burn
Spinach beet	Quick bolting

Table 2: Physiological Disorders Due To Water Stress

(D) Salinity

20% of cultivated lands and 33% of irrigated agricultural lands worldwide are afflicted by high salinity. In addition, the salinized areas are increasing at a rate of 10% annually; low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices are the major contributors to the increasing soil salinity.

(E) Flooding

Most vegetables are highly sensitive to flooding and genetic variation with respect to this character is limited, particularly in tomato and early cauliflower. In general, the damage to vegetables by flooding is due to reduction of oxygen in the root zone, which inhibits aerobic processes.

- Flooded tomato plants accumulate endogenous ethylene that causes damage to the plants. The rapid development of leaves is a characteristic response of tomatoes to waterlogged conditions and the role of ethylene accumulation has been implicated. The severity of flooding symptoms increases with rising temperatures; rapid wilting and death of tomato plants is usually observed following a short period of flooding at high temperatures.

Mitigation Strategies to Climate Change

To mitigate the possible impact of climatic change on vegetable production as well as on national economy, several initiatives have been undertaken.

These include:

- Selection of better adaptable genotypes,
- Genetic manipulation to overcome extreme climatic stresses,
- Measures to improve water and nutrient-use efficiency and
- Biological nitrogen fixation as well as exploiting the beneficial effects of CO_2 enhancement on crop growth.

Adaptation Strategies to Climate Change In Vegetable Crops

To deal with the impact of climate change, the potential adaptation strategies are:

- Developing cultivars tolerant to heat and salinity stress and resistant to flood and drought
- Modifying crop management practices
- Improving water management,
- Adopting new farm techniques such as resource conserving
- Resource-conserving technologies (rcts)
- Crop diversification
- Improving pest management
- Better weather forecasting and crop insurance

A. Water Management

There are several methods of applying irrigation water and the choice depends on the crop, water supply, soil characteristics and topography. Surface irrigation methods are utilized in more than 80% of the world's irrigated lands, yet its field level application efficiency is often 40-50%. To generate income and alleviate poverty of the small farmers, promotion of affordable, small-scale drip irrigation technologies are essential.

- Drip irrigation minimizes water losses due to run-off and deep percolation and water savings of 50-80% are achieved when compared to most traditional surface irrigation methods. Crop production per unit of water consumed by plant evapo-transpiration is typically increased by 10-50%. Thus, more plants can be irrigated per unit of water by drip irrigation, and with less labour.



Fig. 9: Drip irrigation **Fig. 10:** Protected cultivation **Fig. 11:** Relay cropping

- The water-use efficiency by chilli pepper was significantly higher in drip irrigation compared to furrow irrigation, with higher efficiencies observed with high delivery rate drip irrigation regimes.
- For drought-tolerant crops like watermelon, yield differences between furrow and drip irrigated crops were not significantly different; however, the incidence of *Fusarium*wilt was reduced when a lower drip irrigation rate was used.

B. Cultural Management

- The use of organic and inorganic mulches is common in high-value vegetable production systems. These protective coverings help reduce evaporation, moderate soil temperature, reduce soil runoff and erosion, protect fruits from direct contact with soil and minimize weed growth



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Fig. 12: Red plastic mulch **Fig. 13:** Raised bed & plastic mulch **Fig.14:** Paddy straw mulch

- During the hot rainy season, vegetables such as tomatoes suffer from yield losses caused by heavy rains. Simple, clear plastic rain shelters prevent water logging and rain impact damage on developing fruits, with consequent improvement in tomato yields. Fruit cracking and the number of unmarketable fruits are also reduced.

- Another form of shelter using shade cloth can be used to reduce temperature stress. Planting vegetables in raised beds can ameliorate the effects of flooding during the rainy season

C. Grafting of Vegetables for Stress Management

- Grafting of susceptible plant (scion) on tolerant plant (rootstock) helps to grow plant successfully under stress conditions, especially under salt and drought stress conditions. Grafting of vegetables has been used primarily to control soil-borne diseases affecting the production of vegetables such as tomato, eggplant, and cucurbits.
- It provide tolerance to soil-related environmental stresses such as drought, salinity, low soil temperature and flooding if appropriate tolerant rootstocks are used.
- Melons grafted onto hybrid squash rootstocks were more salt-tolerant than the non-grafted melons.
- Grafted plants are also able to tolerate low soil temperatures. *Solanum lycopersicum*x *S. habrochaites* rootstocks provide tolerance to low soil temperatures (10°C to13°C) for their grafted tomato scions, while eggplants can be grafted on wild brinjal (*S. integrifolium)* as rootstocks to overcome low temperatures (18°C to 21°C).

D. Use of Heat- and Cold-Tolerant Genotypes

- The key to achieving high yields with heat-tolerant cultivars is the broadening of their genetic base through crosses between heat-tolerant tropical lines and disease-resistant temperate or winter varieties.

E. Drought Tolerance

- Most of the vegetables are sensitive to drought; however brinjal, cowpea, amaranth, and tomato can tolerate drought to a certain extent.
- Transfer and utilization of genesfrom these drought-tolerant species will enhance tolerance of tomato cultivars todry conditions, although wide crosses with *S. pennellii*produce fertile progenies.

F. Salt Tolerance

- Screening for salt tolerance in the field is not a recommended practice because of the variable levels of salinity in field soils.Screening should be done in soil-less culture with nutrient solutions of known salt concentrations.
- A few vegetables like, beet palak, tomato, etc. can tolerate salt to some extent.
- Most commercial tomato cultivars are moderately sensitive to increased salinity and only limited variation exists in the cultivated species.
- Genetic variation for salt tolerance during seed germination in tomato has been identified within the cultivated and wild species.
- Wild tomato species, *S. cheesmani*, *S. peruvianum*, *S pennellii*, *S. pimpinellifolium*, and *S. habrochaites*are the potential source of salt tolerance.
- Attempts to transfer quantitative trait loci (QTLs) and elucidate the genetics of salt tolerance have been conducted using populations involving wild species.
- Elucidation of mechanism of salt tolerance at different growth periods and theintrogression of salinity tolerance genes into vegetables would accelerate development of varieties that are able to withstand high or variable levels of salinity compatible with different production environments.

G. Use of Biotechnological Tools in Stress Management

- Use of molecular technologies has revolutionized the process of traditional plant breeding. Combining of new knowledge from genomic research with traditional breeding methods has enhanced our ability to improve crop plants.
- Several QTLs have been identified to stress tolerance in tomato, i.e. for water-use efficiency in *S. pennellii and S. pimpinellifolium*as source of salt tolerance. Only a few major QTLs account for the majority of phenotypic variation, indicating the potential for marker-assisted selection (MAS) for salt tolerance.
- Integration of QTL analysis with gene discovery and modelling of genetic networks will facilitate a comprehensive understanding of stress tolerance, permit the development of useful and effective markers for marker-assisted selection, and identify candidate genes for genetic engineering.

1. **Development of Heat Tolerant Varieties**

CROPS	GENETIC MATERIAL
Tomato	PusaSadabahar, Pusa Hybrid-1, Pusa Hybrid-8, ArkaMeghali, ArkaVikas
Brinjal	KashiSandesh, KashiTaru
Potato	Kufri Surya
Okra	Kasha Pragati, Kasha Kranti
Cauliflower	PusaMeghna
Bottle Gourd	TharSamridhi, PusaSantushti
Cucumber	PusaBarkha
Radish	PusaChetki
Carrot	PusaKesar

Table 3: Heat Tolerance

2. **Development of Drought Stress Tolerant Varieties**

CROPS	GENETIC MATERIALS
Tomato	ArkaMeghali, ArkaVikas
Brinjal	Supreme, Kasha Sandesh
Chilli	Samrudhi, Kasha Anmol
Potato	KufriSindhuri, KufriSheetman
Carrot	Ooty-1

Table 4: Drought Tolerance

3. **Development of Salt Tolerant Varieties**

CROPS	GENETIC MATERIALS
Tomato	Pusa Ruby, Best Of All
Lettuce	Calmar
Okra	PusaSawani
Onion	Punjab Selection
Pea	Market Prize
Cucumber	Pi-177361

Table 5: Salt Tolerance

Conclusion

- A holistic approach is required to over stress tolerance rather than a single method.
- For reducing malnutrition and alleviating poverty in developing countries through improved production and consumption of safe vegetables will involve adaptation of current vegetable systems to the potential impact of climate change.
- Vegetable germplasm with tolerance to drought, high temperatures and other environmental stresses, and ability to maintain yield in marginal soils must be identified

to serve as sources of these traits for both public and private vegetable breeding programmes.

- These germplasms will include both cultivated and wild accessions possessing genetic variation unavailable in current, widely-grown cultivars.

Refrences

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