The Role of Research for Vegetable Production Under a Changing Climate Future Trends and Goals

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1 Introduction

During the period of 1960–2018, the agricultural production is more than tripled due to invention of new Green Revolution technologies which enhance the productivity of agricultural crops and also the use of land, water and other natural resources got expanded for agricultural purposes. Despite this, in most of global countries malnutrition and hunger remain a major challenge and seems to persistent due to wider change in global climate and population scenarios. The current rate of progress of agricultural produce will not enough to feed the growing population by 2030, and not even by 2050 due to slow adoption of mitigation techniques for climate resilience.

Since, 1970s due to climate change natural disasters has increased fivefold. The natural environment got deteriorate day by day due to expanding of food production and economic growth. The level of groundwater is depleting at faster rate and deep erosion in biodiversity is another challenge (FAO 2017). The increased demand of

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agricultural product due to higher population growth put up the current agriculture under pressure (Ziervogel and Ericksen 2010; Godfray et al. 2010). At present, two main challenges to global food system are climate change and malnutrition and many studies have been attempted to achieve the global demand of food. Several studies have been conducted to find out the yield change due to climate change in major food crops and specific agronomic measures to counteract these impacts (Lobell et al. 2011; Lobell 2014).

Due to continuous climate change farmers will move away from low yielding crops and substitute them with better adapted crops to the new conditions due to continue progress in climate change (Seo and Mendelsohn 2008; Burke et al. 2009). The sensitive nature of agriculture produce and continuous changing climate are the major challenges.

Agricultural productivity, food security and other sectors affected by continuous change in climate. In tropical region, high temperature, declining rainfall patterns and increasing frequency of drought and floods are the expected future climate change (IPCC 2007; Mitchell and Tanner 2006). US National Centre for Atmospheric Research reported that in 2050 the rainfall trend is continuously declined and in compare to previous 50 years the region is expected to be 10–20% drier (Mitchell and Tanner 2006). The economic impacts of climate change on agriculture have been measured in various studies. Vegetables are usually succulent and sensitive plants therefore, severely affected by minor changes in the climate. The main focus of this chapter is to measure the effect of climate change in vegetable and role of research for vegetable production under changing climate. In developing countries vegetables are the main source of livelihood for most of communities because vegetables are loaded with several vitamins, carbohydrate, salts and proteins. Now a day's vegetables become an integral part of average household's daily meals because of increasing awareness towards their health.

2 Innovative Research Techniques for Vegetable Production Under Changing Climate

1. Organic farming
2. Irrigation management
3. Grafting techniques
4. Protected cultivation
5. Conservation tillage
6. Cropping system
7. Mulching
8. Post harvest technology
9. Genetic improvement
10. Biotechnology

3 Challenges of Vegetables Research During Climate Change

Climate changes pose several challenges and negative impacts upon both quality and production of vegetables. Several climate change especially temperature, rainfall, salinity, drought will reduce the productivity of vegetables. Vegetables are sensitive to these climatic changes, and sudden change in temperature and other climatic factors affects its growth, pollination, flowering, fruit development and thus reducing both average yields and quality of most major vegetables (Afroza et al. 2010). In potato, water stress during tuber formation stage, leads to higher susceptibility of tubers to postharvest black spot disorder (Hamouz et al. 2011). In carrot, preharvest water stress results in greater weight loss during storage (Shibairo et al. 1998). Smaller fruits with high soluble solids in tomato are due to high salinity condition of growing soil. Shelf life of leafy vegetables are affected by low light during growing period like in lettuce, shelf life of fresh cut lettuce grown in low light is much shorter than lettuce produced under optimal conditions (Witkowska and Woltering 2010). Vegetables are highly sensitive to drought condition which is the primary cause of crop loss and reducing average more than 50% for most of the crop (Sivakumar et al. 2016). Vegetative stage of chilli is not much affected by heat fluctuation but reproductive stage is most affected. Production and quality of vegetables are much affected by high temperature as high temperature affect flower and fruit set, length, width and weight of fruit, number of fruits per plant and ultimately overall fruit yield (Tables 1, 2 and 3).

4 Role of Research Techniques

4.1 Protected Cultivation Technology: A Boon for Bio-technological Works

Under changing climate, cultivation of vegetables under protected condition is one of the best ways to protect our vegetables mainly from adverse environmental conditions such as temperature, hail, heavy rains, sun scorch, snow etc. It is an advanced agro-technology, which allow regulation of macro and micro environment, facilitating earliness, plant performance, duration of crop with higher and better quality yields (Gruda and tanny 2015). Nursery raising of vegetables under protected structures gives many folds benifits and also protects our crop from biotic and abiotic stresses (Sanwal et al. 2004). Better microclimate under polyhouse gives higher yield of different vegetables (Cheema et al. 2004). The yield and income of farmers increased as compare to open field conditions in tomato, capsicum (Kumar et al. 2016a, b). In comparison to open field condition, yield was increased by 80% under shade net and water saving of about 40% in covered cultivation (Rao et al. 2013). It provides an excellent opportunity to produce high value cash crops, vegetables and flowers and managed under controlled conditions with higher per unit productivity

Table 1 Impact of climate change on vegetable crops

Sl. No.	Climate change	Crops	Impact	References
1.	Heat	Tomato	Failure pollination, poor pollen production, poor viability of pollen, dehiscence, ovule abortion, abnormal reproduction, abnormal flower drop and at last failure to set fruit.	Hazra et al. (2007)
		Chillies	Affect fruit set *i.e*, fertilization, affect color development in ripe fruit, ovule abortion, flower drop, poor fruit set and fruit drop.	Arora et al. (2010)
		Cucumber, melons,	Germination affected, delay ripening of fruits and also reduce sweetness.	Kurtar (2010)
		Ash gourd, bottle gourd and pumpkin	Affect production of female flower	Ayyogari et al. (2014)
		Cauliflower	Bolting (not desirable for vegetable purpose)	Thamburaj and Singh (2011)
2.	Drought			
		Tomato	Flower abscission	Bhatt et al. (2009)
		Onion and okra	Affects germination	Arora et al. (2010)
		Potato	Sprouting of tubers	Arora et al. (2010)
3.	Salinity			
		Cabbage	Reduced germination, root and shoot length and fresh root and shoot weight	Jamil and Rha (2014)
		Chilli	Reduce dry matter production, leaf area, relative growth rate and net assimilation rate	Lopez et al. (2011)
		Cucurbits	Reduction in fresh and dry weight	
		Beans	Suppressed growth and photosynthesis activity and changed stomata conductivity thus reduces transpiration	Kaymakanova et al. (2008)
4.	Flooding			
		Tomato	Damage plants due to accumulation of endogenous ethylene	Drew (2009)
		Flooding + high temperature	Rapid wilting which results in death of plants	Kuo et al. (2014)
		Onion	Yield loss 30–40%	Kumar SN (2017)

and profitability (Choudhary 2016). In case of tomato indeterminate tomato hybrids (ID-32, ID-37, Rakshita, Himsona, Himsikhar, Snehlata, Naveen etc.) gives on an average 2–3 times higher quality yield and income as compared to traditional open farming systems (Table 4).

Table 2 Varieties of vegetable with various abiotic stress tolerance

Crops	Variety/lines	Tolerance to abiotic stress
Tomato	Pusa Sheetal	Set fruit at low night temperature *i.e,* 8 °C
	Pusa Hybrid 1	Set fruit at high night temperature *i.e*, 28 °C
	Pusa Sadabahar	Set fruit at both low and high night temperature
	Sabour Suphala	Tolerant to salt at seed germination stage
	Arka Vikas	Moisture stress tolerance
Chilli	DLS-10-02, DLS-20-11, DLS—160-1 and DLS-152-1	Heat tolerant
Eggplant	SM-1, SM-19 and SM-30	Drought tolerance
	Pragati and Pusa Bindu	Salt tolerance
Okra	Pusa Sawani	Salinity tolerant
Musk melon	Jobner 96-2	Tolerant to high soil pH
Spinach beet	Jobner green	Tolerant to high soil pH (upto 10.5)
Cucumber	Pusa Barkha	Tolerant to high temperature
	Pusa Uday	Grow throughout year
Bottle gourd	Pusa Santusthi	Hot and cold set variety
Onion	Hisar-2	Salinity tolerant
Carrot	Pusa Kesar	Tolerant to high temperature
Radish	Pusa Himani	Grow throughout year
Sweet potato	Sree Nandini	Drought tolerance
Potato	Kufri Surya	Heat tolerant upto 25 °C night temperature
	Kufri Sheetman, Kufri Dewa	Frost tolerance
Cassava	H-97, Sree Sahya	Drought tolerance
French bean	Arka Garima	Tolerant to heat and low and low moisture stress
Dolichos bean	Arka Jay	Tolerant to low moisture stress
Garden pea	Arka Tapas, Arka Uttam, Arka Chaitra	Tolerant to high temperature (upto 35 °C)
Carrot	Arka Suraj	Flowers and seeds sets under tropical condition.

Source: Koundinya et al. (2018)

4.2 *Molecular Breeding Approaches for Resistance Breeding*

In plant and animal breeding, use of DNA markers has opened a new realm in agriculture called molecular breeding (Rafalski and Tingey 1993). The use of DNA marker in this technology could speed up the selection process in comparison to traditional breeding method. Selection of primary trait link age between marker and trait is known as Marker assisted selection. It is an important tool to increase the

Table 3 Varieties of vegetables with various biotic stress tolerances

Sl. no.	Crops	Variety/F_1 hybrid	Abiotic stress
1.	Tomato	Arka Vishesh (H-391)	Triple disease resistance to tomato leaf curl, bacterial wilt and early blight
		Arka Apeksha (H-385)	Triple disease resistance to leaf curl, bacterial wilt and early blight
		Arka Abhed	Multiple disease resistance to tomato leaf curl, early blight, bacterial wilt and late blight
		Arka Rakshak	Triple disease resistance to ToLCV, BW and early blight
		Arka Samrat	Triple disease resistance to ToLCV, BW and early blight
		Arka Ananya	Combined resistance to ToLCV and bacterial wilt.
		Arka Alok and Arka Abha	Resistance to bacterial wilt
2.	Brinjal	Arka Unnathi, Arka Harshitha, Arka Avinash, Arka Neelkanth, Arka Nidhi, Arka Anand,	Resistant to bacterial wilt
3.	Chilli	Arka Khyati, Arka Harita, Arka Suphal	Tolerant to powdery mildew & viruses
		Arka Meghana	Field tolerant to viruses and sucking pest
4.	Capsicum	Arka Athulya	Tolerance to powdery mildew
5.	Watermelon	Arka Manik	Triple resistance to powdery mildew, downy mildew and anthracnose
6.	French bean	Arka Anoop	Resistance to both rust and bacterial blight
7.	Dolichos bean	Arka Sukomal	Rust resistant
		Arka Prasidhi	Resistance to rust
8.	Garden pea	Arka Ajit, Arka Karthik, Arka Sampoorna, Arka Priya	Resistance to powdery mildew and rust
9.	Carrot	Arka Suraj	Tolerant to powdery mildew and nematodes
10.	Onion	Arka Pitamber	Tolerant to purple blotch, basal rot diseases and thrips
		Arka Kirtiman, Arka Lalima	Field tolerance to diseases and pests

productivity of vegetables under changing climate condition. It increases the efficiency of selection by including various approaches like marker assisted backcross breeding (MABB), forward marker assisted selection, marker assisted recurrent selection (MARS) and genomic selection (GS).

Table 4 Vegetables varieties suitable for protected cultivation

Sl. No.	Crops	Variety/hybrids
1.	Tomato	ID-32, ID-37, Rakshita, Himsona, Himsikhar, Snehlata, Naveen, GS-600
2.	Coloured capsicum	Natasha, Swarna, Indra, Bombi, Orobelle, Bachata, Inspiration
3.	Parthenocarpic cucumber	Isatis, Kian, Hilton, Sun Star, Multistar, Fadia, Mini Angel
4.	Summer squash	Pusa Alankar, Pusa Pasand, Australian Green, Seoul Green, Kora, Yellow Zucchini, Himanshu
5.	Bitter gourd	Pusa Rasdar
6.	Musk melon	Pusa Sarda

4.3 SNP (Single Nucleotide Polymorphism) in Vegetable Crops

An individual nucleotide base difference between any two homologous DNA sequences representing the same locus in a genome is known as single nucleotide polymorphism. SNPs are the ultimate and most abundant molecular markers. It can be broadly classified into two ways namely hybridization based techniques and sequencing based techniques. In vegetable crops, SNPs can be widely used in tomato, carrot, potato, cucumber, brinjal etc.

4.4 Role of Biotechnology

Biotechnology plays a major role in the improvement of vegetables to make them suitable for altering climatic situation. Many biotechnology tools like tissue culture (micro propogation, meristem, endosperm culture, embryo, protoplast culture, haploid and callus & cell suspension), genetic engineering, genome editing and molecular markers of vegetables are useful tools that can cope with stress factors. Some of the important challenges which can be addressed by biotechnological tools are enlisted below:

1. In both biotic and abiotic stress condition its increases productivity of crop
2. Manage tolerance of herbicide
3. Manage diseases resistance
4. Improvement of genetic engineering technologies to enhance public perception

4.4.1 Biotechnology Based Approaches for Next Generation Agriculture

1. Tissue culture industry
2. Genomics
3. Molecular breeding

4. Genetic Engineering
5. Crops with novel traits

4.4.2 Need of Biotechnology for Vegetable Improvement

1. Eliminate unreliable phenotypic evaluation
2. There is no linkage drag.
3. Produced true to types
4. Overcome distant hybridization barriors (no species/genus gene transfer barrior)
5. Eliminates long term field trails
6. Shorten breeding cycles
7. 100% achievement of gene transfer

5 Improvement of Vegetable Through Genetic Engineering

Alteration of genome of an organism by introducing one or few specific foreign genes is known as genetic engineering. The crop which is modified by this tool is known as transgenic crops or genetically modified crops and the gene introduced is referred as transgene. Genetic modified crops are resistance to various biotic stresses (disease and insect resistance) and abiotic stresses like drought resistance, salt resistance, heavy metal resistance, cold tolerance, frost tolerance etc. Nutritional content of potato *i.e.,* protein and essential amino acids is increased by a seed-specific protein, AmA1 (amaranth seed albumin) of Grain Amaranthus (*A. hypochondriacus*) (Chakraborty et al. 2000). Beta carotene precursor of vitamin A increased more than three times than normal control.

6 Grafting

Under this climate change situation, various environmental stress became more crucial for vegetable production. Grafting of commercial cultivars onto selected rootstock offers an adoptive mechanism to overcome several biotic and abiotic stresses (Koundinya and Kumar 2014). This technique is widely exploited in comparison to relatively slower breeding methods to enhance environmental- stress tolerance of fruit vegetables (Flores et al. 2010). Now a days, grafting techniques has increased in crops like Tomato, brinjal, pepper, melon, cucumber, watermelon and pumpkin (Lee et al. 2010). Heat stress tolerance in temperature sensitive tomato was achieved by grafting onto more resistant rootstock (Abdelmageed et al. 2014). High yield of brinjal was achieved by grafting onto *Solanum torvum* because it enhances fruit size (Moncada et al. 2013). Grafting of eggplant (S. *melongena* cv. Yuanqie) onto a heat-tolerant rootstock (cv. Nianmaoquie) prolonged its growth stage and also give upto

10% increase in yield (Ahmedi et al. 2007). Grafting increased not only fruit production and marketable fruits but also gave higher phenolic antioxidant content (Sabatino et al. 2016).

In Tomato, for adjusting under suboptimal root-temperature cold tolerant rootstock gives higher capacity to their root/shoot (Venema et al. 2008). Bacterial wilt and flooding tolerance in tomato was achieved by grafting onto *Solanum melongena* (Palada and Wu 2007).

7 Tissue Culture

For improvement of vegetable crops, tissue culture industry is a fast growing sector. Micropropagation of superior genotypes is being practiced in India for the last three decades across a variety of vegetable crops such as potato, carrot, broccoli etc. For multiplication of plants by embryogenesis, organogenesis and by non-adventitious shoot proliferation mainly in vitro techniques is widely used (Table 5).

8 Embryo Rescue Technique

In horticultural crops to overcome the post-zygotic barriers such as endosperm abortion and embryo degeneration, embryo rescue technique is widely used and several hybrids have been developed in several vegetable crops like capsicum, tomato, muskmelon etc. (Kumari et al. 2018). In this technique, immature seed is harvested and induced to germinate on culture medium, with or without the addition of plant growth regulators, to negate the waiting time for seed to mature. In lettuce, haploid plants were developed through embryo culture techniques (Zenkteler and Zenkteler 2016). Hybrids in between *Lycopersicum esculentum* X *Lycopersicum peruvianum* were developed by using embryo rescue.

Table 5 Achievements of tissue culture in vegetable crops

Sl. No.	Crops	Purpose/ Achievement	Refs.
1.	Onion/ Shallot	Elimination of onion yellow dwarf virus	Walkey et al. (1987)
2.	Pea	Elimination of pea seed borne mosaic virus	Kartha and Gamborg (1978)
3.	Brinjal	Elimination of mosaic virus	Raj et al. (1991)
4.	Chilli	Haihua 3 variety	Li and Jiang (1990)

9 Conclusion

The main significant cause of yield loss in plants is abiotic stress which reduces yields by as much as 50%. In last five decades, India has achieved a lot in terms of agriculture but the major challenge is to feed its growing population. Due to continuous change in climate, abiotic stress becomes a major area of concern for plant scientists, affecting both production and quality of crop worldwide. Heat stress directly changes the physical properties of bio-molecules. The change in climate is one of the biggest worries because as most of the India's farming is still depend on the monsoon. Various breeding programme in different crops helps to cope up with these challenges. The first most important goal of any researcher is to develop resistant varieties which give high quality production under any conditions. By adopting advanced technologies farmers get higher yield and better quality that ensure more income for improving livelihood and nutritional security. But to cope with these challenges some technological inventions are seriously needed for the drastic improvement in the crop production scenario.

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