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Mitigation of Temperature, Drought and Viral Diseases Stress in Vegetable Crops

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Abstract

Vegetable crops are more prone to temperature stress, drought and viral diseases as compared to other crops. Each vegetable has special range of temperature for its growth and fruit setting. On account of fruit as an economical part of vegetables especially belonging to Cucurbitaceae, Solanaceae, they require mild temperature (12-29˚C). Temperature extremes not only hinder plant growth but also halt fruit setting. Additionally vegetable crops require continuous availability of medium moisture therefore drought causes severe reduction in growth as well as fruit yield. As vegetables possess succulent leaves therefore these crops are more susceptible to insects. Additionally insects also act as a vector for transmission of viral diseases. Considering aforementioned threats various approaches could be adopted for ameliorating the effect of these stresses. In addition to long term approach like stress breeding, short term approaches like protected nursery sowing, tunnel cultivation, mulching with plastic, lowering of temperature by using cooling pads and foggers use of insect net, drip irrigation, uses of fruit setting hormones and vegetable grafting could also be adopted.

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Introduction

Temperature both low as well high, water scarcity and viral diseases are causing serious threats in vegetable production. Due to climate severities there are considerable reduction in suitable temperature period for getting optimum vegetable production. Almost all vegetable crops require mild temperature for their normal production. Optimum temperature range for growth and quality of garlic, leek and onion is 12-24˚C, for beet root, broccoli, broad bean, brussels sprouts, cabbage, kohlrabi, radish, spinach, turnip, cauliflower, carrot and pea is 15-18˚C, for pumpkin, squash, vegetable marrow, cucumber, musk melon and sweet melon is 18-24˚C, for sweet paper and tomato is 21-24˚C, for chili, eggplant, okra, sweet potato and watermelon is 21-29 ˚C.

High temperature not only cause reduction in growth but also it causes reduction in female flower in cucurbits and flower shedding in solanaceous crops especially in tomato and chili (De Koning, 1989; Bouzo and Küchen, 2012). High temperature stress could be alleviated by using cooling pads, foggers and by selecting proper location keeping in view temperature threshold. On the other hand low temperature causes reduction in growth and extreme low temperature causes frost injury. Considering frost sensitivity, a grouping of different vegetable crops has been made namely, very tolerant (asparagus and turnip), moderately tolerant (cauliflower, cabbage and snow peas), tolerant (beet root, broccoli, carrot, onion, peas, garlic and radish), sensitive (sweet potato), very sensitive (beans, capsicum, cucumber, egg fruit, pumpkin, tomato, zucchini and button squash).

For the control of low temperature stress, installation of plastic covered low, high and walk-in tunnels are best options. Additionally mulching with black plastic also helps in improving soil temperature especially during low temperature days. Considering water situation there has been severe reduction in per capita water availability which may cause severe threat to vegetable production as almost all vegetable crops are moisture loving on account of high yield. Per capita water availability was 5300 m^3 in 1951, which has been reduced drastically to 1,040 m^3 for a population of 190 million approximately in 2010. The present situation is further expected to escalate and expectedly per capita water availability in Pakistan could decrease to 800 m^3 by the end of 2025 (Mustafa *et al.*, 2013). Water scarcity could be tackled in two ways. The excellent and most beneficial option is construction of water reservoirs. However as a short term approach drip irrigation could be adopted for different vegetable crops. In addition to these abiotic stresses, prevalence of viral diseases is another threat especially for vegetables belonging to Cucurbitaceae, Solanaceae and Malvaceae families. Since most of viral diseases are not seed born therefore their spread is totally dependent on prevalence of insect vector which remain variable in terms of population dynamics. In order to control the spread of viral diseases, use of fine insect net is an excellent short term approach. As a long term approach various breeding techniques and biotechnological tools could also be exploited for incorporation of characters like temperature stress tolerance, drought tolerance and virus tolerance. For this purpose tolerant indigenous vegetable varieties and their wild relatives could be used for incorporation of favorable traits.

Approaches for mitigation of stresses

Approaches for mitigation of stresses can be categorized as follows;

Stress breeding

As a long term approach one can breed varieties as well as hybrids of vegetable crops possessing stress tolerance. In our country considerable germplasm possessing specific traits like high temperature tolerance are available. For example in cucumber, variety namely “Kheera Local” (Fig. 1a) (Amin *et al.*, 2018) and in muskmelon, varieties like Ravi and T-96 posses fairly high degree of high temperature tolerance. Additionally wild relatives of different vegetable crops could also be used through pre plant breeding and embryo rescue technique for incorporation of stress tolerant genes for example bitter apple (*Citrullus colocynthis*) (Fig. 1b) could be

used for incorporation of traits like drought tolerance and high yield and resistance against diseases (Al-Zahrani and Al-Amer, 2006; Alsadon *et al.*, 2014). Wild brinjal (*Solanum incanum*) (Fig. 1c) could be used for incorporation of various stress traits (Liu *et al.*, 2015).

Non-breeding approaches

Various short term and non-breeding approaches could also be used for mitigation of temperature as well as viral diseases and drought. These innovations are not only short term but are also most effective and efficient. These approaches are as follows;

Plastic sheet covered tunnels

In Punjab province and others provinces of Pakistan excluding Sindh temperature during winter months (December and January is extremely low which not only cause reduction in growth and fruit setting but crops are also at risk of severe frost injuries. Use of plastic sheet covered tunnels helps in creating favorable environment for the growth of crops like tomato, cucumber, sweet pepper, watermelon, muskmelon (Singh *et al.*, 2005; Gunadi *et al.*, 2007).

These tunnels are of three types 1) Low tunnel (Fig. 2a) 2) Walk-in tunnel (Fig. 2b) 3) High tunnel (Fig. 2c). Use of these tunnels not only saves the crop from frost injury but also helps in extending the vegetable availability period.

Table 1. Temperatures for various stages in tomato crop production.

Stages of plant development	Temperature ˚C		
	Minimum	Optimum	Maximum
Germination	11	16-29	34
Vegetative Growth	18	21-24	32
Fruit set (night)	10	14-17	20
Fruit set (day)	18	19-24	30
Red color development	10	20-24	30
Yellow color development	10	21-32	40
Chilling damage		6>	
Frost damage		1>	
Lethal temperature		-2	

Protected nursery raising

There are some adverse conditions for the nursery raising in open field conditions. During continuous heavy rainfall condition seedling should be raised in the glass house, under shade or poly-house in small structure like earthen pot, polythene bags and nursery trays (Fig. 3a) by using soil, sand and compost mixture. During the raining hours these plots are to be kept at the protected place. During too low or too high temperature condition the artificial temperature regimes can be created in the glass house or poly-house for seed germination and raising the seedling successfully to catch the early market by producing the early crop (Schrader 2000; Parish 2005). A net-house (Fig. 3b) can be recommended in dry regions where high rainfall and humidity is not a problem and when the investor requires a lower cost structure that still provides protection against the environment and complete protection from pests and diseases.

Fig. 1a Kheera local.

In summer season to avoid viral diseases and attack of sucking insects it is necessary to cover the seedling beds with 50 or 64 mesh nylon net prevent the entry of white fly. If the finer mesh is not available, use

coarser (20-30) mesh and spray neem based pesticide on net.

Fig. 1b. Bitter Apple.

Fig. 1c. Wild brinjal.

Plastic sheet mulch

Use of black plastic sheet as a mulch on prepared beds not only suppresses weed growth but it also helps in moisture conservation (Fig. 4). Additionally in winter it keeps the soil warm on account of its black color and improves soil temperature around root and stem zone (Albert *et al*., 2010). Vegetables grown without support in the open field or in plastic tunnels could profit from covering the soil with a mulch of polyethylene film.

The film might be transparent, black or yellow according the purpose for which the mulch is needed (Rudich, 1979; Garnaud, 1981; Benoint *et al*., 1984). However, in our country black plastic sheet is used as mulch. Mulching can have various effects on the soil and the plant. Moisture distribution in the upper soil layer is more uniform compared to un-mulched soil. In saline soils or when brackish water is used for irrigation, soil mulch would reduce salt concentration inside the mulched area because of low evaporation.

Fig. 2a. Low tunnel.

Fig. 2b. Walk-in tunnel.

Drip irrigation

Drip irrigation (Fig. 5) has been found to be the most efficient. It is independent of weather conditions and the water flow can be easily regulated by suitable pressure regulators. The penetration of water into soil can be easily controlled to the optimum depth and moisture. Irrigation can be applied at any time of the

day with nearly 100% efficiency. Top dressing with suitable fertilizer can be done easily through the irrigation system if necessary.

Fig. 2c. High tunnel.

If the drip irrigation systems are independent from drinking water supply herbicide, systematic fungicides or pesticides can be applied through them (Tiwari *et al.*, 2003). The Drip irrigation remarkably reduces the occurrence of fungal and bacterial diseases and also certain mites (Srivastava *et al.*, 2003).

Fig. 3a. Plastic trays for nursery.

Yellow and blue sticky traps or cards

Use of yellow and blue sticky traps or cards not only helps in reducing pest attack but they also helps in monitoring of insects population (Fig. 6). Yellow sticky traps can trap white flies, leaf miner and winged aphid. Blue sticky traps can trap thrips. Most commonly 3×5 inch sticky card/traps are used in poly-house. Small cards are excellent for monitoring while large cards are good for mass trapping.

Fig. 3b. Net house.

When traps are to be used for pest suppression in nursery structure, as a guideline use at least one trap/m², increasing or decreasing depending upon the severity of problem.

Fig. 4. Plastic sheet mulch.

Foggers and Cooling Pads

Foggers provide optimal cooling and humidity in poly-house and green house (Fig. 7). Vegetables can be grown in summer season in green houses by using foggers (Villarreal-Guerrero *et al.*, 2012). Use of foggers provides mild temperature in hot summer season and thus cultivation of vegetable crops becomes possible in summer season. A mechanical

sensor is usually a screen placed in the plant canopy that collects moisture and turns off a solenoid valve when it gets heavy. Two kinds of sensors are available in the market namely, temperature dependent that triggers the functioning of foggers when the temperature crosses the set limits and relative humidity dependent that triggers the fogger when humidity levels decrease. There are different types of foggers prescribed by different irrigation companies. Additionally, in order to lower the temperature during summer months, cooling pads and exhaust could also be used. However, these could only be used for raising high value crops on account of high energy cost.

Fig. 5. Drip Irrigation.

Fig. 6. Yellow and blue sticky traps or cards.

Plant hormones

High as well as low temperature not only disturbs plant growth but also disturbs fruit setting and flowering behavior. For example in tomato there is quite narrow range of temperature for fruit setting while the range of growth is quite wide (Table 1). The use of fruit setting hormones especially 4CPA (4-chlorophenoxy acetic acid) is quite helpful for fruit setting at low as well as at high temperature (Iwahori, 1968; Ozguven *et al.*, 1997; Gemici *et al.*, 2006). It is in commercial use in many countries of the world and it could be used at a concentration of 50 to 75 ppm quite successfully. Use of plant growth hormones like gibberellin, auxin and cycocel trigger fruit growth in different vegetables when used at different concentrations. In capsicum, naphthalene acetic acid at 60 ppm conc. gave maximum per plant number of flowers (11.83), weight of fruit (169.66g), per plant number of fruits (9.87) and per plant yield (1.67kg) (Singh *et al.*, 2017). Islam *et al.* (2017) found that in cabbage use of GA3 at 120 ppm gave highest marketable yield (65.5 t/ha) while minimum yield was recorded in GA3 at 0 ppm (41.2 t/ha).

Fig. 7. Fogging system in green house.

Vegetable grafting

The use of grafted vegetable seedlings has been popular in many countries during recent years (Lee *et al.*, 2010). The cultivated area of grafted Solanaceae family including a number of important annual fruit-crops such as tomato, eggplant, pepper and Cucurbitaceae such as melon, cucumber and watermelon has increased in an effort to obtain resistance to soil-borne diseases (Crinò *et al.*, 2007), tolerance against abiotic stresses (Savvas *et al.*, 2010), to improve the sustainability and profitability of organic vegetables cultivation (Janse and van der

Wurff, 2011) and to increase yield and fruit quality (Colla *et al*., 2008).

Fig. 8. Watermelon grafting on root stock of bottle gourd.

In cucurbits, grafted mini-watermelons on a commercial pumpkin rootstock revealed higher yields (more than 115% total and 60% marketable) when grown under conditions of deficit irrigation, compared with un-grafted plants (Rouphael *et al*., 2008) (Fig. 8).

Conclusion

Vegetables are succulents and much prone to abiotic and biotic stresses. Climate change factors like rise in temperature, extremely low temperature and drought situation and viral diseases are major limiting factors in sustainable vegetable production.

A constantly high temperature and drought cause an array of morpho-anatomical changes in plant which affect the seed germination, plant growth, flower shedding, fruit setting, fruit size, fruit weight, fruit quality etc. Low temperature causes reduction in growth and extreme low temperature causes frost injury. Occurrence of viral diseases is another hazard especially for vegetables belonging to Cucurbitaceae, Solanaceae and Malvaceae families. These problems can be minimized in vegetables by using breeding approaches and non-breeding like protected nursery sowing, tunnel cultivation, mulching with plastic, lowering of temperature by using cooling pads and foggers, use of insect net, drip irrigation, uses of fruit setting hormones and vegetable grafting.

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