A REVIEW ON HEAT STRESS RESPONSE IN DIFFERENT GENOTYPES OF TOMATO CROP (Solanum lycopersicon L.)

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ABSTRACT

Heat stress caused by amplified temperature is an agricultural dilemma in most of the areas of the world. Temporary or persistently higher temperature grounds an array of biochemical, morphological and physiological changes in plant species that affect plant growth and development and direct to a severe decline in economic yield. This unpleasant effect may be mitigated by developing crop plants with enhanced thermo tolerance by means of various genetic approaches. In the same way as tomato is the most important vegetable crop by its use. It is also affected by high temperature like flower dropage, dryness of anthers, less fruit set, fruit dropage and sunscalled are the major problems due to increase in temperature from its optimum level. Based on an absolute understanding of such mechanisms, potential genetic strategies ought to make to improve tomato crop for heat-stress tolerance that includes traditional and contemporary molecular breeding protocols and genetic engineering approaches. Addition to genetic approaches, crop heat tolerance could be improved by preconditioning of plants under diverse environmental stresses or exogenous use of osmoprotectants such as proline. By creating thermo tolerance is an energetic procedure by which significant amounts of tomato crop resources are converted to structural and functional protection to get away from the damage caused by heat stress, with biochemical and molecular aspects of thermo tolerance in tomatoes are comparatively well understood. The objective of our study was to collect and elaborate the work done by different scientists at different levels and approaches to create heat tolerance in tomato crop.

Keywords: Heat stress, Tomato, Yield components

Introduction

Heat stress is frequently defined as the increase in temperature beyond a threshold level for an interval of time sufficient to cause irreparable damage to plant growth and development. In general, an ephemeral elevation in temperature, generally 10–15 °C above ambient, is considered as heat stress or heat shock condition. Though, heat stress is a composite function of intensity (temperature in degrees), period, and rate of raise in temperature. The degree to which it occurs in specific climatic zones depends on the chance and duration of high temperatures going on during the day and/or the night. Heat tolerance is usually defined as the capability of the plant to grow and produce profitable yield under elevated temperatures. Though, while a few researchers consider that night temperatures are chief limiting factors others have argued that day and night temperatures do not affect the plant separately and that the diurnal means temperature is a better interpreter of plant response to elevated temperature with day temperature having a less important role (Peet and Willits, 1998). Heat stress by high ambient temperatures is a severe risk to crop production.
globally (Hall, 2001). Gaseous emissions due to different activities of human being are significantly adding to the already available concentrations of greenhouse gases, mainly CO₂, methane, nitrous oxides and chlorofluorocarbons. Diverse global distribution models foresee that greenhouse gases will progressively increase world’s average ambient temperature. According to a information of the Intergovernmental Panel on Climatic Change (IPCC), overall mean temperature will rise 0.3°C per decade (Jones et al., 1999) reaching to roughly 1 and 3 °C above the present value by years 2025 and 2100, respectively, and creating global warming. Increasing temperatures may lead to changed geographical distribution and growing period of agricultural crops by allowing the threshold temperature for the beginning of the season and crop ripens earlier (Porter, 2005).

Tomato (Solanum lycopersicon L.) is one of the most significant vegetables ever used all over the world. Requirements of tomato crop are relatively cool, dry climate for high yield and best quality. However, it can be grown to a wide range of climatic conditions from temperate to hot and humid tropical. The most favorable temperature for most varieties lies stuck between 21 and 24 °C. The plants can withstand a range of temperatures, but the plant tissues are damaged below 10 °C and above 38 °C. Tomato plants respond to temperature deviation during the growth cycle, for seed germination, seedling growth, flower and fruit set and fruit quality. If cool or hot climatic spells continue during flowering, production of pollen will be low. This will influence fruit formation (Wahid, et al. 2007). This assessment accentuates on tomato plant responses and adaptations to heat stress at the whole plant, cellular and sub-cellular levels, forbearance mechanisms and strategies for heritable enhancement of tomato crop with heat-stress tolerance.

**Heat-stress threshold**
Threshold temperature is the daily mean temperature at which a noticeable decrease in growth starts. Higher and lesser developmental threshold temperatures have been determined for tomato crop through controlled laboratory and field experiments. A lower threshold or a foundation temperature is one below which plant growth and development discontinue. Similarly, a higher developmental threshold is the temperature above which growth and development stop. Knowledge of lower threshold temperatures is important in physiological research as well as for crop production. Base threshold temperatures differ among plant species, but for cool period crops 0 °C is often the best-predicted base temperature (Miller et al., 2001). Cool season and temperate crops often have lower threshold temperature values compared to tropical crops. Higher threshold temperatures also vary for different plant species and genotypes within species. However, determining a reliable upper threshold temperature is difficult because the plant performance may vary depending on other environmental conditions (Miller et al., 2001). For the tomato crop the range of temperature requirements at different stages was suggested by Naika, et al. (2005) (Table 1).

<table>
<thead>
<tr>
<th>Stages</th>
<th>Temperature (° C)</th>
<th>Optimum range</th>
<th>Max.</th>
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<tbody>
<tr>
<td>Seed germination</td>
<td>11</td>
<td>16-29</td>
<td>34</td>
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<tr>
<td>Seedling growth</td>
<td>18</td>
<td>21-24</td>
<td>32</td>
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<tr>
<td>Fruit set</td>
<td>18</td>
<td>20-24</td>
<td>30</td>
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<td>Red color development</td>
<td>10</td>
<td>20-24</td>
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**Response of tomato genotypes to Heat-Stress:**
**Morphological response**
Heat stress harmfully affects the vegetative growth and reproductive development of the tomato plants and eventually reduces yield and fruit quality. The response of vegetative growth to temperature differs significantly between glasshouse and field studies. This may be due to differences in the
environmental factors like wind speed and light intensity, as well as biotic factors like insects and diseases. Consequently, the comparative stimulation in response to temperature in the current glasshouse was much larger than that observed under open field conditions. Tomato plants grown under glasshouse heat tolerant genotype showed a high rate of vegetative growth as compared to the heat sensitive genotypes. The difference may be attributed to the genetic make of these genotypes (Hussain et al., 2001) as compared to that of field situation, due to high temperature under field conditions noticeably decreased the leaf area, foliar curling, yellowing and stunting of the plants (Gomez et al. 2004, Abdelmageed, et al. 2009). The discovery showed that selection for stress tolerance at early stages is effective same as that of late stages. Total flower bud and flower production, mainly at the first four russes, may be a consistent criterion for heat tolerance selection. Reproductive processes in tomato crop also susceptible to high temperature than the vegetative ones. (Lahar, and Peat, 1998, Abdelmageed, et al. 2003, Alsadon, et al. 2006).

It is observed that tomato plants can develop an acclimated mechanism in opposition to super optimal thermal stress caused at 35°C, temperature well above the optimal growth temperature that is 25°C, this acclimated method in tomato plants appear to consist of the addition of phenolic compounds as a feasible form of adapting to this stress. It can be possible, by manipulating characters concerned with the bioactivity of phenolic compounds, to make active acclimated mechanisms in plants under stress caused by temperature (Rivero, et al., 2001).

The metabolism of phenolic compounds as well includes the performance of oxidative enzymes as, Peroxidase and Polyphenol oxidase that catalyse the oxidation of phenols to quinones. A number of studies have reported that these enzyme activities rise in reaction to diverse types of stresses (Thyphyapong, et. al., 1995).

**Physiological responses to heat stress**

Although a limited number of germplasm was assessed by Saeed, et al. 2007. They evaluate that the genotypes appeared to have great difference to tolerance heat stress. Some genotypes showed high level of tolerance to the heat stress that shows the potential exists for breeding tomato genotypes with improved tolerance to heat stress to sustain tomato production in the hot circumstances. Greater tolerance to heat stress shows higher membrane thermostability and lowest ratio of flowers shed at the same time producing maximum fruit yield during hot period. There was positive relationship between fruit yield with membrane thermostability but negative relationship was found for number of flowers shed (Rahman et al., 1998).

There was a significant difference between transgenic and normal genotypes for electrolyte leakage. In the leaf disks of transgenic lines the electrolyte leakage was 50% less as that of normal genotypes. Transgenic tomato plants provide better defense against heat stress, UV-B and Sunscald. This elevated enzyme activity could play a significant role in increasing stress tolerance against fruit sunscald (Chen and pan., 1998, Wang, et al. 2006).

Hazra, et al., (2007) summarized the symptoms causing by which fruit set stoppage at high temperatures in tomato; it includes bud drop, irregular flower development, reduced pollen production, dehiscence, and viability, ovule abortion and meager viability, less availability carbohydrate, and other reproductve abnormalities occur. It is reported that heat shock proteins (HsfA2 and Hsp17-CII) are activated early on in the tomato diploid pollen mother cells prior to the microspores develop and that their expression is constant under extended HS conditions until mature dry pollen is formed. It is recommended that HsfA2 can be directly involved in the activation of defense mechanisms in the tomato anther for the period of hs and, thus, might contribute to tomato fruit set under unfavorable temperatures. Higher temperature can potentially interrupt tomato fruit set by causing injury to developing pollen grains. Genes for heat shock protein are also induced in a number of developmental pathways, like seed maturation, embryogenesis, and/or fruit maturation, in different genotypes (Volkov, et al., 2005; Kotak, et al., 2007, Giorno, et al., 2010)

Lapidot and Friedmann (2002) concluded from their studies that plants have evolved abundant self-protective strategies to distinguish and cope with violent behavior by pathogens, together with insects and viruses. The cultivated tomato is extremely prone to geminiviruses transmitted by whitefly, such as TYLCV. Early contaminated plants stop to grow,

*International Journal of Modern Agriculture, Volume 2, No.2, 2013*
produced symptoms like leaf yellowing and curling, and can not yield fruit. Breeding efforts have been made in the development of resistant lines and commercially used cultivars that present ameliorated symptoms and a lower titer of virus than plants prone to disease. Patterns of proteins known to be involved in defense-like (PR proteins) and stress-like (HSPs and MAPKs) responses on whitefly invasion and whitefly mediated immunization of TYLCV in RT and SF tomato lines issued from the same breeding plan. Now it became possible that these proteins participate in the augmented tolerance to whiteflies and TYLCV, not only in laboratory situations but also in the field, by minimizing the compensation insect feeding and viruses can induce (Zarate et al. 2007; Gorovits, et al. 2007).

Genetic improvement for heat-stress tolerance

The extraordinary management of the heat-stress response from bacterial to plant cells includes the structure and function of the heat-stress proteins as well as the organization of their stress-dependent appearance Southwestern selection of a agtI cDNA expression collection of tomato (Lycopersicon peruvianum) resulted in the separation of three diverse HSF clones. In association with hsf genes of other organisms, individual of the tomato genes (hsf8) is constitutively expressed. But expression of the two others (hsf24, hsf30) is accelerated by heat stress. The hsf24 cDNA sequence was available before (Scharf et al., 1990). This description concerns the cDNA sequences of hsf8 and hsf30 and some structural features of the equivalent proteins (Nover, 1991, Scharf, et al., 1993). It is declared that HsFA2 and Hsp17-CII are activated early on in the tomato diploid pollen mother cells prior to the microspores develop and that their expression is constant under extended heat stress conditions until mature dry pollen is formed. It is recommended that HsFA2 can be directly involved in the activation of defense mechanisms in the tomato anther during heat stress and thus, may contribute to tomato fruit set under unfavorable temperatures. It is suggested that some genotypes under field situation would not be related with tolerance of photochemical functions and SOD activity. Still, the fast and reversible revival of the event injury during elevated temperature can explain its tolerance, if it is considered that plant recovery capacity determines the possibility of plants to survive under unfavorable conditions (Camejo, et al., 2005). Altogether, these markers correspond to cause 32.82% of the phenotypic variation for the traits. The accumulative ratio explained by the different experiments on QTL varied from 30 to 70%, depending on a number of factors, as well as on the cross under study (Beavis et al. 1991), the traits evaluated (Edwards et al. 1992), the experimental design, and map resolution in terms of number of markers. As in maize, using an F2 population with 1700 plants and an error level of 5%, one QTL was detected that contributed with only 0.3% to the phenotypic trait variation (Edwards et al. 1987). The greatest possible line of attack was used for this analysis and the recombinant frequency as distance unit; QTL related with tomato fruit set were detected in the linkage groups. The occurrence of QTL was measured only in the cases where LOD peaks were obtained for every linkage group. It is indicated from the different expressions QTL controlling fruit set is being carried by polygenic nature of the traits. The detection of such QTL has the enormous weightage, because we can use them in assisted selection in improvement programs for tomato fruit set, based on the progenies evaluated, by this heat-tolerant plants can be chosen quickly, which improves tomato fruit set. Grilli, et al., 2007.

Villarez and Lai., 1979 found that heat tolerance is mainly controlled by recessive genes and transfer generation to generation in a multifaceted fashion with low heritability, which is distinctive for polygenetic traits. They also recommended that the heat tolerant genes are easily prejudiced by environment. In another observations made by AVRDC, 1988 it was suggested that heat tolerance in tomato may not be as complex as had been reported earlier by Villarez and Lai. The optimum day/night temperatures for fruit set in tomato is in the range of 26-32°C/15-20°C (Kuo et al., 1979). Yet, there typically found genotypic differences in their fruit setting capability to high temperature (Charles and Harris, 1972). In the tropical regions, the tomato is usually grown in the period of the cool season for the reason that high temperature in the hot season prevents fruit set. Temperatures higher than 34/20°C (day/night) or 4 hour treatment of 400°C before anthesis for 9 days generally cause flower drop in most of the genotypes (El-Ahmad and Stevens, 1979). The findings of Hanna et al., 1982 shows, where the highest day temperature ranged between 32.40 to 36.10°C and the lowest night
temperature ranged between 22.60 to 25.30°C found that the crosses of some genotypes with maximum GCA values gave the higher percentage of fruit set. This showed that some parents transmitted superior fruit setting capability to its progenies. Stevens. 1979 observed by his study that percent fruit set is under the control of mainly additive genetic system with modest heritability under higher temperature So we can select general combiner parents and specific combiner crosses can be used for better parents and F1s respectively for early highest yielder for late summer tomato cultivation (Ahmad, et al., 2009). The similar set of tomato lines were evaluated and characterized by the pollen performance and fruit-set traits at higher temperature and observed resemblance among genotypes differed depending on the characters studies (Soylu and Comlekcioglu, 2009; Comlekcioglu and Soylu, 2010). Though genotypes characterized in this study showed a huge variation morphologically, they appear to have a comparatively restricted polymorphism level of RAPD and SRAP primers. We consider that both morphological-agronomic characters and molecular description is desirable in the quantification of diversity and inequity. The indigenous genotypes might be an important source of heat tolerance genes for the genetic improvement of tomato crop. Molecular description of breeding materials is necessary for breeders. The recognition of different genotypes provides a standard location for the identification of any genotype, in spite of any factors that limit or influence phenotypic characterization (Comlekcioglu, et al., 2010).

Significant differences between studied genotypes were observed for pollen viability, osmotic pressure, fruit setting and total yield plant-1, in addition to higher heritability (h2 bs) for these traits were also found (Grilli et al., 2003). From the results discussed may be concluded that the high tolerant genotypes possess higher values for traits studied and vise versa, susceptible heat genotypes have low values for considered traits. Saeed, et al., 2007 observed that genotype, that can produce improved yield under high temperature circumstances, would be suggested as heat tolerant. Abdul-Baki in 1991 assessed fruit yield of tolerant and susceptible tomato lines and cultivars under field condition at high temperature. The heat tolerant genotypes give higher fruit yield as compared to heat sensitive cultivars. Peter et al., 2002 observed that high temperatures fruit set (heat tolerance) was a critical trait of tomato. It is confirmed that by using pollen viability as a choice standard for high temperature tolerance was genotype effect as well as heat stress due to decrease in number of pollen grains in heat – sensitive cultivars, resulted reduced fruit set. Though, in heat tolerant genotypes, number and quality of pollen grains, number of fruit set were least affected by higher temperatures (Adul-Baki and John, 1995, Firon et al., 2006).

Furthermore Lin, et al., (2006) recognized random amplified polymorphic DNA (RAPD) markers associated to heat tolerance characters in tomatoes under heat stress by using the bulked segregant analysis. This bulked segregant study was used to classify RAPD markers related to high temperatures they used F2 tomato plants, segregating population for the detection of ISSR markers coupled to fruit associated characters in the tomato (Chague et al. 1997, Lin et al., 2010). From the results it is observed that only two RAPD and one ISSR markers were linked to heat tolerance. Thus, BSA permitted us to target the gene in a straight line, as confirmed by Michelmore et al.(1991).The stage of polymorphism showed in molecular marker followed by marker-assisted selection (MAS) has been verified to be excellent substitution process of the agronomic selection, where it make available to plant breeders with environmental- self-governing genetic markers for certain profitable characters (Kamel, et al., 2010).

Conclusion and future prospects
Tomato crop exhibited a variety of responses to high temperatures, which are depicted by symptomatic and quantitative changes in morphology and growth. The capability of the plant to handle with or adjust to the heat stress varies within specie as well as at different developmental stages. Though high temperatures manipulate plant growth at all developmental stages, later phenological stages, in particular anthesis and fruit development, are normally more prone. Pollen viability is the main issue in tomato crop at high temperature. Some genotypes showed resistance against high temperature and have maximum pollen viability while some shows susceptibility and affected adversely. In reaction to stress due to heat, plants manifest plentiful adaptive changes. The initiation of signaling cascades leading to reflective changes in precise gene expression is considered a significant
heat-stress adaptation. Evidence on synthesis and addition of some other stress-related proteins is also available. Such stress proteins are thought to function as molecular chaperones, helping in folding and unfolding of necessary proteins under stress, and ensuring three-dimensional structure of membrane proteins for constant cellular functions and endurance under heat stress. In addition to genetic means to developing plants with enhanced heat tolerance, attempts have been completed to induce heat tolerance in a range of plant species using diverse approaches. These include precooling of tomato plant to heat stress and exogenous applications of osmo-protectants or plant growth-regulators on seed or whole plant. Results obtained from such applications are shows potential and further research should impending. In addition, even as some prominent progress has been reported as to the development of crop plants with enhanced heat tolerance by means of traditional breeding, the vision for engineering tomato plants with heat tolerance is also good considering accumulating molecular information on the mechanisms of tolerance and contributing traits. Additionally, genomics applications, trascriptomics and proteomics approaches to a better consideration of the molecular basis of tomato plant response to heat stress plus plant heat tolerance are very important. The knowledge of response and tolerance mechanisms at molecular level will pave the way for engineering tomato crop that can tolerate heat stress and might be the foundation for production of tomato crop which can produce profitable yield under heat-stress conditions.

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