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Review Article

Mechanism of Heat Stress and their Management Strategies in Wheat

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ABSTRACT

Cumulative heat with resulting alterations to weather unfavorably disturb plant development, resultant in disastrous damage in wheat output. With one degree increase in temperature, wheat growth is projected to decrease by 6%. Comprehensive summary of morpho-physiological replies to wheat for temperature pressure might assist expressing suitable approaches in temperature pressure wheat yield development. Moreover, penetrating to conceivable managing approaches might elevate output and sustainability of rising wheat. Main conclusions after this review is follows: (1) temperature pressure meaningfully decreases kernel sprouting and seedling development, turgidness of the cell, water use competence of the plant; (2) During cellular level, temperature pressure interrupts cellular purposes over making unnecessary sensitive oxygen types, foremost towards oxidative pressure; (3) main replies to wheat for temperature pressure comprise improvement to senescence of leaf, decrease in photosynthesis, defusing of enzymes of photosynthesis, production of oxidative losses to chloroplasts; (4) temperature pressure too decreases number of grains and size via upsetting ounce setting, translocation of integrates and period and development proportion of grains; (5) actual methods to manage temperature pressure in wheat comprise screening accessible germplasm beneath field hearings and/or retaining marker aided assortment, claim to external protectants for seeds or plants, mapping quantitative trait locus discussing temperature confrontation and breeding; (6) Well combined genetic and agronomical organization choice might improve wheat acceptance for temperature. Though, achievement to apply numerous methods for temperature pressure organization needs better understanding of temperature acceptance topographies, molecular cloning, and description of genes. General achievement to multifaceted plant temperature pressure administration depends on intensive exertions to crop modelers, molecular biologists, and plant physiologists.

Keywords: *Germplasm, Temperature, Wheat, Crop*

INTRODUCTION

Numerous ecological pressures upsetting plant development and expansion reached thoughtful anxiety to setting of likely weather alteration. Modern agriculture aspects marvelous ecological weight crossways the sphere.

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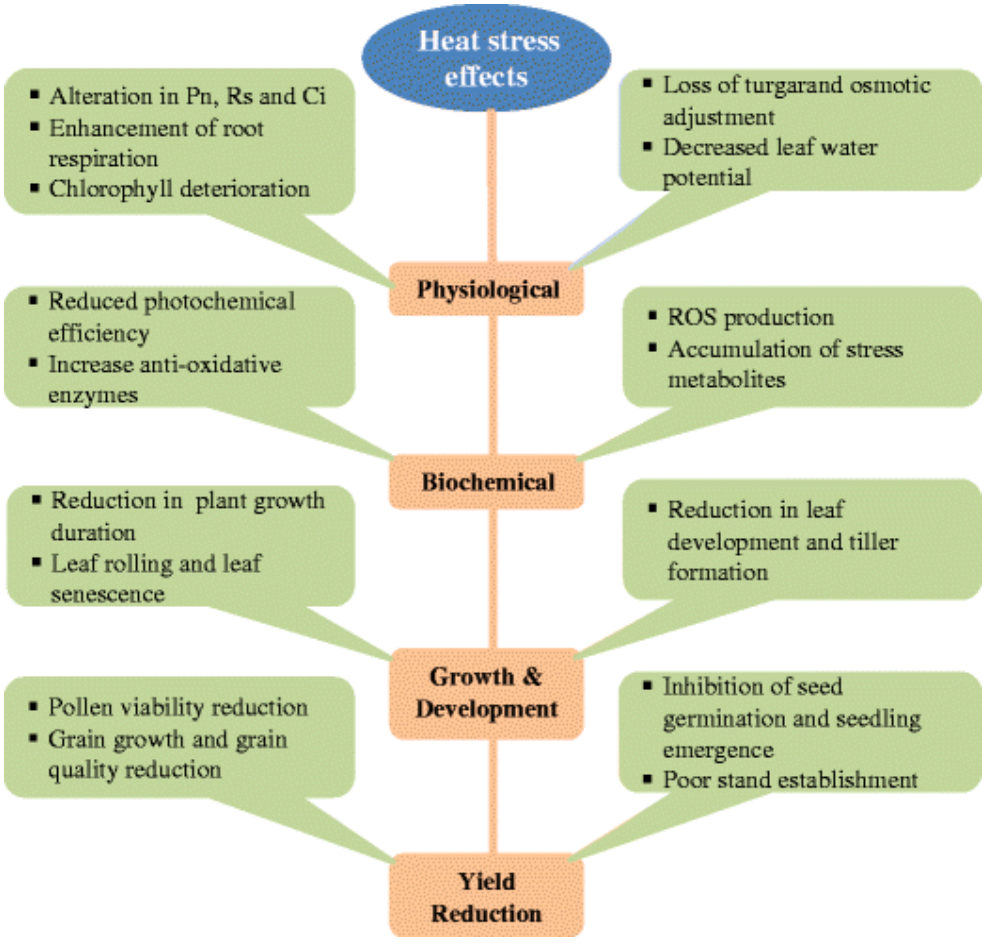
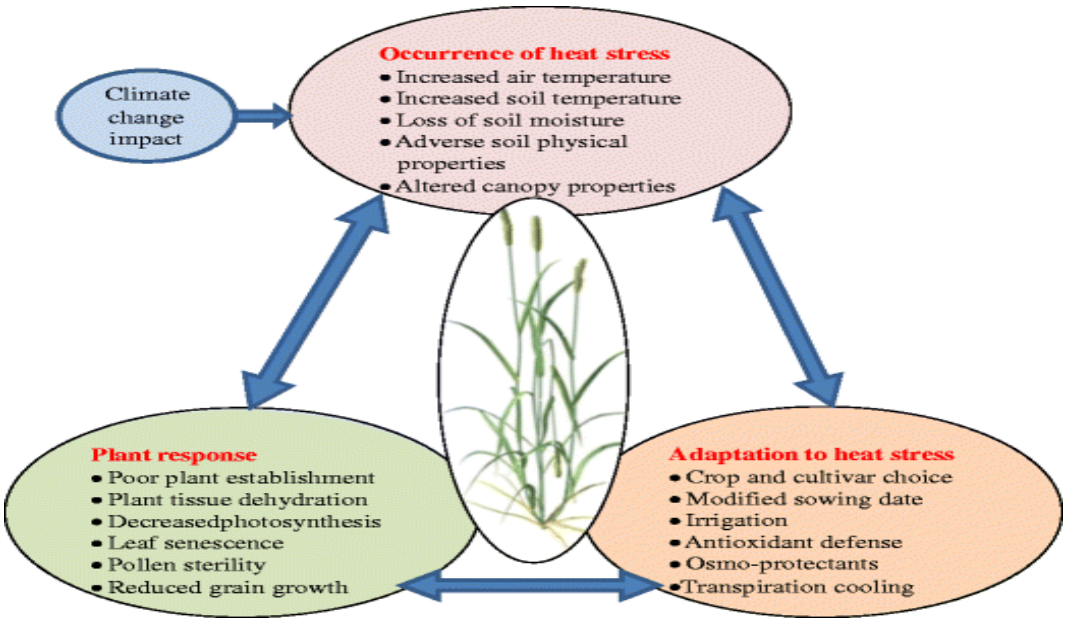
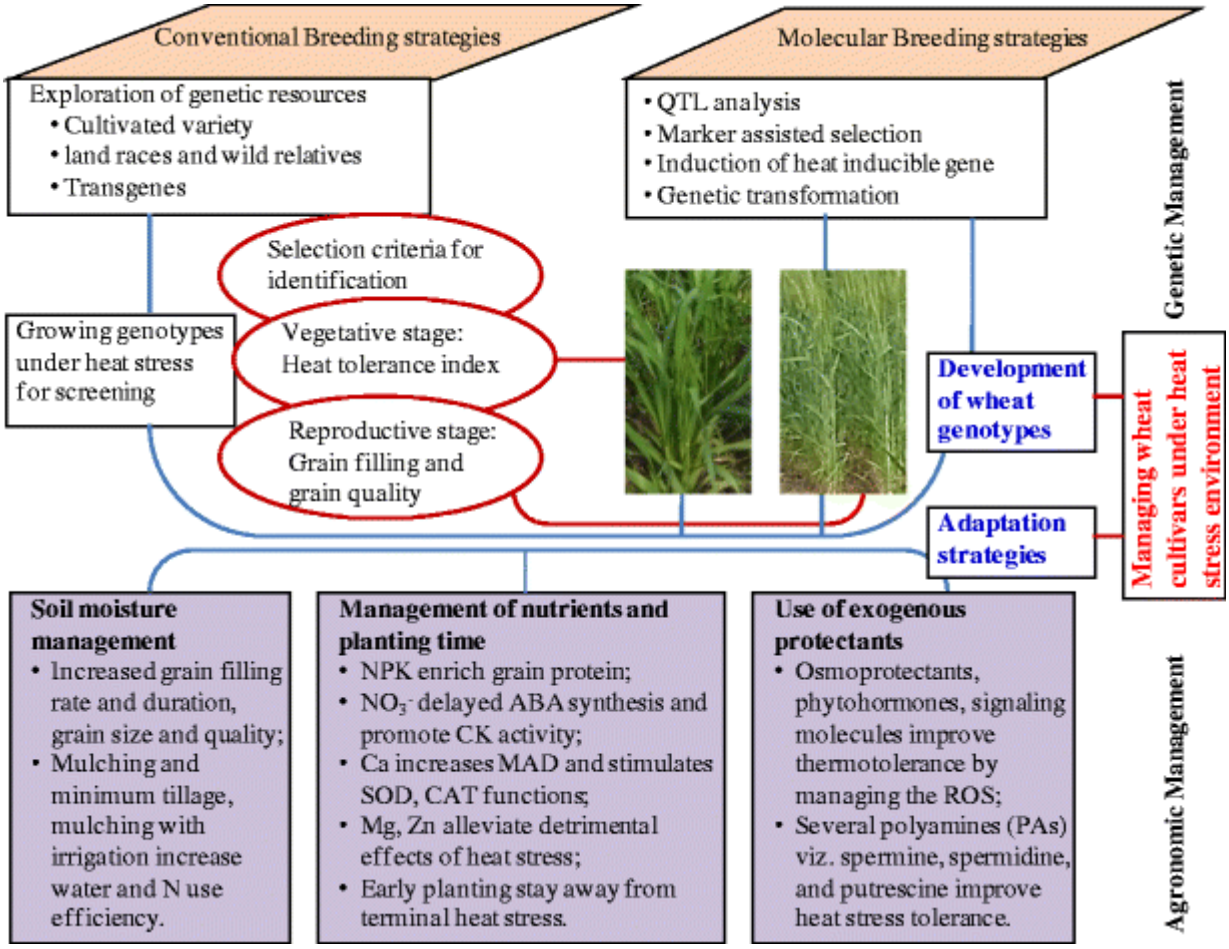
Foley et al. (2011) recommended numerous organizational choices counting preservation digging, accepting yield break approaches, cumulative cropping competences that would significantly operative to minimalize ecological influences and for maintainable crop manufacture. Though, utmost extraordinary ecological anxiety in agriculture is upsurge of worldwide fever. With respect to worldwide weather replicas, nasty ambient fever is forecast to upsurge by 1–6°C via end of twenty first era (De Costa, 2011). Such upsurge of worldwide fever might meaningfully effect on agricultural output in agreement with the harshness of the elevated heat, drought, salinity, waterlogging, and mineral toxicity pressures. Elevated heat persuaded temperature pressure is articulated as the increase in air heat outside a verge level for a passé adequate to root wound or permanent injury of crop plants in over-all (Teixeira et al., 2013). Temperature pressure condition is serious when earth heat elevates as a consequence of upsurge in midair heat related to weakening in earth dampness. Therefore, temperature pressure has seemed as a countless threat to fruitful yield manufacture around globe (Kumar et al., 2012; Lobell & Gourdji 2012; & Gourdji et al., 2013).

Wheat (*Triticum aestivum* L.), utmost extensively refined cereal harvest fitting with Poaceae family, is chief donor with approximately 30% of the biosphere ounce manufacture and 50% of the biosphere ounce skill. FAO projected, biosphere would need extra 198 million tons of wheat by 2050 to achieve upcoming stresses, for which crop manufacture essential to be augmented via 77% in the emerging states (Sharma et al., 2015). Though, heat irregularity delivery is altering near advanced fevers and irregularities are augmented (Hansen et al., 2012). This condition ended crop rising period has previously been stated for decreasing crop output in numerous areas of biosphere (Fontana et al., 2015; & Mueller et al., 2015).



Wheat is extremely amenable for temperature pressure (Gupta et al., 2013a). Little leeway regions, anywhere about 100 million hectares of crop are refined, are mainly temperature disposed to zones globally (Braun et al., 2010). Asseng et al. (2014) tested 30 crop replicas where unkind fevers for rising period reached from 15 to 32°C with false boiler. Consequences found designate that heating previously reduced ounce harvest at common of crop rising places. Replicated middle heat influence on deteriorating crop harvest diverse extensively, regular harvests to aeras between 1981 and 2010 reduced; reaching amid 1 and 28% crossways 30 places of globe; for an upsurge in fever of 2°C; and this worth design to between 6 and 55% for a heat of 4°C. Also, they projected that worldwide crop manufacture waterfalls by 6% for apiece 1°C of additional heat upsurge. Little freedoms presented a noticeable upsurge in replicated harvest erraticism with advanced heat than that experiential at elevated freedoms. This superior comparative harvest weakening was due to the advanced orientation of heat (Challinor et al., 2014). Mondal et al. (2013) specified that belongings of temperature pressure on plants are actual multifaceted resultant in modification of evolution and development, alterations in physiological purposes, and abridged ounce creation and harvest (Fig. 2). Temperature pressure reasons modification of herbal water relatives (Hasanuzzaman et al., 2012, 2013), discount of photosynthetic volume (Almeselmani et al., 2012; & Ashraf & Harris 2013), reductions of metabolic doings (Farooq et al., 2011) and variations of hormones (Krasensky & Jonak 2012), manufacture of oxidative reactive class (Wang et al., 2011), raise of ethylene manufacture (Hays et al., 2007), discount of pollen pipe growth, and upsurges of pollen humanity (Oshino et al., 2011) in wheat. In dated from 1880 to 2012, the Earth's scheme warmed by 0.85°C (IPCC, 2014). This heating dated would endure and is foretold to increase among variety of 1.5–4.0°C in upcoming (Wheeler & Von Braun 2013). Climatical issues, variations in fever, rain, CO_2, climate inconsistency, and earth dampness shortfall will have optimistic or undesirable belongings on crop manufacture (Joshi & Kar 2009). Harmful influences of weather alteration on crop production are challenging the food security of the world, and it is predicted that sustaining wheat manufacture would have wedged additional via cumulative heat (Tripathi et al., 2016). Weather alteration could powerfully touch crop manufacture, secretarial for 21% of nourishment and 200 million hectares of country universally (Ortiz et al., 2008).





Though, growth of temperature accepting crop diversities, production for better pre breeding resources for any breeding package in upcoming is critical in conference the nourishment safety (Ortiz et al., 2008). Proteomic and transcriptomic information are significant for classifying genes and proteins that answer to atmosphere, touches harvest and excellence of crop. Though, additional data concerning this is obligatory to grow crop diversity that can acclimatize to weather alteration persuaded elevated heat (Altenbach, 2012). This appraisal shelters an impression of latest effort described upon temperature persuaded opposing belongings and numerous critical administration policies for talking temperature pressure condition of crop.

Response to heat stress

Many processes of plants are affected by temperature stress foremost is morpho-physiological changes in wheat plants, stopping the expansion process and ultimately consequence hooked on excessive produce damage (McClung & Davis 2010; & Grant et al., 2011). The response of plant towards pressure of wheat diverge importantly with the scope and span of heat and some stages of growth stumbling the stress (Ruelland & Zachowski 2010).

Morphological response

Temperature stress have some primary effect in obstacle to kernel sprouting, some plants have deprived attitude system to numerous of the plants consisting wheat (Johkan et al., 2011; & Hossain et al., 2013). Embryonic cells are very much affected by terrain temperature around 45°C in wheat which affects kernel sprouting, appearance in impairment (Essemine et al., 2010). Plant meristems are usually affected by temperature stress and it damages the growth of plant by encouraging leaf senescence and abscission and by putting down the process of chemosynthesis (Kosova et al., 2011). When temperature pressure ranges between 28 and 30°C it may change span of development with limiting periods of maturity and germination

of seed (Yamamoto et al., 2008). Lower biomass is produced in warmer climates in comparison with optimum or low heat stress. Development of leaf and productive tiller formation might be severely affected in wheat plant when the temperature is around 30 and 25°C, respectively (Rahman et al., 2009). Though, in the reproduction stage of temperature stress its frequentness has been found much adverse in the production of wheat (Nawaz et al., 2013). Wheat plant suffers serious losses in yield with every one degree increase in average heat stress during phase of reproduction (Bennett et al., 2012; & Yu et al., 2014). Mitochondria is disrupted by increase in heat stress, altering the visible profiles of proteins, limiting gathering of ATP, and oxygen absorption in swigging embryos of wheat, consequence in additional betiding of misplacement of quality of seed bonding to germination, vigor and mass of seed (Balla et al., 2012; & Hampton et al., 2013). Seed mass is limited by increasing growth rate of seed and by limiting the period of grain filling in wheat 1–2°C rise in temperature (Nahar et al., 2010).

Physiological response

Aquatic relationships

Under the fluctuating climatic heat stress, status of plant water is normally come as much unpredictable. The tissues of plants are dehydrated due to high heat stress and due to this nourishment and development of plant consequently limited. To sustain status of water of a crop all through blossoming, heat of normally 31°C, appraised by way of higher hype (Atkinson & Urwin, 2012). As the leaf temperature increases by some hype, the potential of water and the relative water content of the leaves are limited due to exposure of wheat plants to the temperature stress, as it finally limits the productivity of photosynthesis (Farooq et al., 2009). Instantaneously, it harshly affects the transpiration rate and growth of plant. Almeselmani et al. (2009) observed that potential of water in wheat meaningfully reduces due to execution of high heat stress (35/25°C) and the genotypes that are vulnerable to temperature stress have higher reduction. In common, there is an association of various antioxidants with desiccation bearance and they are encouraged under the heat stress. All this is due to enhanced transpiration in the leaves that are under stress and tumbling of osmotic potential as well (Ahmad et al., 2010). Hydraulic conductivity of cell membrane is enhanced due to temperature stress and also tissues of plants mainly for enhanced activity of aquaporin (Martinez-Ballesta et al., 2009) with superior amount in limiting aquatic viscidness (Cochard et al., 2007).

Photosynthesis, photosystems, and leaf senescence

Utmost delicate physical occasion is photosynthesis and it leads to deprived performance of wheat in growth (Feng et al., 2014). Due to limitation of photosynthetic activity there is a much of temperature stress and that just results from the reduced expansion of leaf area, weakened equipment of photosynthesis, untimely foliage agedness, accompanying lessening inside crop making (Ashraf & Harris 2013; & Mathur et al., 2014). Stroma and chloroplast having thylakoid lamella are the reaction places of heat induced damage where occurrence of metabolism of carbon and photochemical reactions takes place, correspondingly. Membranes of thylakoid are disrupted by the temperature stress in wheat plant, thus by constraining the happenings of membrane related electron carriers and enzymes, in this way the rate of photosynthesis is limited eventually (Ristic et al., 2008). The photosynthetic rate of leaf may also decrease due to deactivation of chloroplast enzymes that are mostly encouraged by oxidative pressure. The main reason of the limitations of photorespiratory procedures are the temperature stresses that just limits the net photosynthetic activity (Ainsworth & Ort, 2010). Investigators berated, impairments to photosynthesis happenings are consequence for abridged solvable protein (Parry et al., 2011; & Hasanuzzaman et al., 2013). There is much alteration in Rubisco and Rubisco activase due

to exposure of wheat foliage towards elevated heat stress of approximately 40°C and under the dark scenarios these alterations are unalterable (Mathur et al., 2011).

Temperature stress is being responsive by photosystem-II in the tissues of photosynthesis (Marutani et al., 2012) nonetheless photosystem-I is comparatively unchanging (Mathur et al., 2014). First of all, temperature stress impairs the multifaceted phenomena of photosystem-II and furthermore, photosynthetic performance is changed due to this. Because of deactivation of Rubisco activase in wheat plant, temperature stress results in limiting of carbon collection. When the carbon collection limits, it results in reduction of ROS generation as well that in response limits the synthesis of proteins and stops mending of impaired photosystem-II (Murata et al., 2007; & Allakhverdiev et al., 2008). Prasad et al. (2008a) explicated compassion of photosystem-II as well where normally experimental factors are increasement in thylakoid membrane fluidity and electron transportation to temperature stress. This demonstrates, heat >40°C divorces bright reaping complex-II (Iwaia et al., 2010). Temperature pressure that just damages, disorders thylakoid sheaths are similarly accountable to termination for photophosphorylation (Dias et al., 2009a). During elevated heat, important supervisory enzymes are described for being separated which causes decrease to photosynthesis volume for foliage (Raines, 2011).

Most unique indication to temperature damage is senescence of leaf categorized by organizational alterations in the chloroplast shadowed by a vacuolar failure, and subsequently a damage in the integrity of cell sheath, meddling to cell balance (Khanna-Chopra, 2012). Consequently, there is an experience in temperature stress in wheat crop that have been found for senescence connected metabolic alterations (Ciuca & Petcu, 2009). Due to temperature stress the biosynthesis of chlorophyll breaks down under (>34°C) and it may hurry foliage agedness to crop (Asseng et al., 2013). Leaf senescence of crop is much increased due to exposure to temperature stress, emphasized damage to chloroplast honesty (Haque et al., 2014). Though, in crop a large diurnal dissimilarity in temperature is also accountable (Zhao et al., 2007).

Oxidative damage

The generation of disparaging ROS results to the plants that has much exposure to temperature stress which is accountable to produce oxidative pressure (Marutani et al., 2012; & Suzuki et al., 2012). Many plants results in notably elevated membrane peroxidation and reduced membrane temperature stability, example is wheat plant (Savicka & Skute, 2010). Nearly all proportions of the cell are reacted with hydroxyl radicals. Cell membrane may collect ROS in the plants due to regular stress of temperature and to depolarization in plasma sheath (Mittler et al., 2011). Miller et al. (2009) come to know, oxygen is elevated due to temperature stress, 68% manufacturing in the roots and malondialdehyde (MDA) mass inside foliage by 27% on initial phases, 58% on advanced phase to sprout expansion. Though, for the removal of ROS plants also have a mechanism called antioxidant mechanism.

Respiration

Respiration is affected by temperature stress by altering mitochondrial activities. Respiratory rate is elevated with the elevation of temperature but up to a certain limit, after that limit it moderates and results in destruction of respiratory gadget (Prasad et al., 2008b). The synthesis of ATP is lessened in the rhizosphere due to elevated rate of loss of respiratory carbon resulting from temperature stress and it elevates cohort of ROS (Huang et al., 2012). It was all just due to temperature stress touches the soluble ability in carbon dioxide with oxygen, and kinetics of Rubisco (Cossani & Reynolds, 2012). Almeselmani et al. (2012) detected, temperature susceptible types had a significantly elevated degree for breathing to the flag foliage in crop underneath temperature pressure whenever it is associated to regulator.

Grain development and expansion

Optimal heat ranges from 12 to 22°C for anthesis of wheat and filling of grains (Shewry, 2009). The main reason of reduction in yield of grains and overall yield is the exposure of plants to the temperature stress above >24°C during reproductive stage and it continues with like this (Prasad & Djanaguiraman, 2014).

Filling and quality of grains

Harvest index gets lower in wheat crop as the temperature stress limits the number of grains (Lukac et al., 2011). Though, the stages of growth that just encounters the temperature stress has a great effect on both the grain numbers and size of grains due to temperature stress. For instance, the growth of spike speeds up when the temperature gets elevated overhead 20°C in among beginning of spike, blossoming but decrease number of spikelet's and grains / spike (Semenov, 2009). Male sterility exerts due to temperature stress that unpleasantly affects pollen cell and microspore (Anjum et al., 2008). There can be complete sterility in wheat crop during the development of floret even at elevated temperature of above 30°C and it totally depends upon genetic constitution (Kaur & Behl, 2010). For crop, anther shaped below three times temperature pressure throughout blossoming was mechanically irregular, malfunctioning flowerets (Hedhly et al., 2009). Photoperiod elevated temperatures of 31/20°C might similarly reason lessening of ounces resultant after altering assemblies with aleurone coating (Dias et al., 2008).

Due to elevated temperature stage of grain filling becomes sensitive in wheat crop (Farooq et al., 2011). The rate of filling of grains is usually increased by the temperature stress and even it lessens the span of filling of grains (Dias & Lidon, 2009a). Though, in the plants that have various grain weight firmness the rate of growth of grains and span reduces (Vijayalakshmi et al., 2010). In wheat crop, with every 5°C rise in temperature above 20°C the span of filling of grains are reduced by 12 days (Yin et al., 2009). The responsiveness is more likely to rise with night temperature, as it shortens the span of filling of grains and eventually results in reduction of yield than that of day heat stress. The span of filling of grains is lessened by 3 to 7 days when the night temperature ranges between 20 and 23°C (Prasad et al., 2008a). Freshly, Song et al. (2015) detected momentous discount in ratio for fulfillment of grains in crop cultivars.

Quality of ounce in numerous cereals and pulses is disturbed by temperature stress, fundamentally due to the restriction of integrates and less remobilization of nutrients. In wheat crop concentration of protein is not much disturbed due to temperature stress (Lizana & Calderini, 2013), but a robust association detected among nitrogen mass of leaf and protein content of grain (Iqbal et al., 2017). Though, heat shock are accepted by the wheat plants as they are accomplished of that by emerging heat acceptance to enhancement for superiority of grains and produce afterwards (Sharma-Natu et al., 2010). Though, under the temperature stress there is no necessity of building up of the proteins in wheat grains, the dispensation superior characters are described significant. Li et al. (2013) found that by limiting the parameters that just relates to gluten strength temperature tends to reduce flour quality, lactic acid retaining volume and mixograph crowning period. Though, In the wheat plants the contents of proteins were quite high which just experiences the temperature stress at the stage of filling of grains (Castro et al., 2007). The association of sedimentation index and concentration of indispensable amino acids depends upon increased protein content of the grain. With diminished stages of amino acids, temperature pressure reduces the deposit catalogue (Dias et al., 2008).

Starch synthesis

60 to 75% starch of the total dry weight are present in grains of wheat (Sramkova et al., 2009). The biosynthesis of starch in grains of the wheat is meaningfully lessened by the temperature stress but produced a notable upsurge in entire resolvable sugar and protein (Sumesh et al., 2008; & Asthir & Bhatia, 2014). Liu et al. (2011) detected, there

is a momentous upsurge of starch in grains due to heat shock handling above 30°C and restricted the dry matter gathering in grain of wheat crop. At the temperature of 40°C nearly 97% of motion was misplaced just because of the reduction in soluble starch synthase, that just resulted in reduction of growth of grain and buildup of starch in crop (Chauhan et al., 2011). Elevated heat pressure (35/27°C) obligatory at plantlet phase meaningfully reduced resolvable sugar buildup and biomass produce of crop (Wang et al., 2014).

Translocation of photosynthetic products

The goods of photosynthesis for arrangement are fundamentally moved to multiplicative basins to kernel expansion. Growth and expansion of the crop plants are lessened just because of source and basin reductions under temperature stress circumstances. Setting of seed and its filling would too become limited via basis and basin restrictions (Lipiec et al., 2013). Temperature stress limits via the photosynthetic activity, stem assets all through pre blossoming passé are documented as foundation to carbon for secondary filling of grains (Mohammadi et al., 2009). In this crop, N remobilization is lessened by temperature stress. The filling of grain of wheat crop is extremely weakened by temperature pressure because of discount for present foliage and ear photosynthesis. In cause scenario, restriction in the temperature induction, plants pursue to discover substitute foundation of integrates to remobilize into the grains. At this period, for the support of growth of grain and its development stem assets of water soluble carbohydrate, its superior translocation towards multiplicative tissue is extremely imperative (Talukder et al., 2013). Though, at the elevated heat stress integrate translocation happening through together symplastic and apoplastic pathway is considerably abridged. Elevated heat stress at the span before anthesis augmented carbohydrate translocation from stem towards grain consequential in fewer discount of starch mass in ounces of crop at after blossoming stage of temperature pressure (Wang et al., 2012). For upcoming span, investigation guiding to integrate segmentation and phenotypic elasticity is recommended by Iqbal et al. (2017).

Managing heat stress

The nourishment and development of wheat crop is extremely disturbed by the temperature stress as a clear evidence. The solution for limiting these damages is fundamentally through creating genotypes of plants in accordance with modification of such crop agronomic observes (Asseng et al., 2011; & Chapman et al., 2012). For the production of temperature resistance genotypes numerous exertions have been utilized by exploitation of the knowledge increased until now on the replies of wheat crop to the stress of temperature. In the temperature stress places for the sake of maintainable wheat crop production, the two utmost authoritative approaches can be shadowed: (a) with the utilization of molecular and biotechnological approach's outline to genetically adapted or transgenic crop cultivars and it is done by working with conventional methodologies and (b) persuading numerous activities of agronomic crop organization so far undergoing stress of temperature administration under field circumstances.

Genetic management

In the altering environment breeding is just an adoptive reply of the crops. So, in future if the climate alters it just needs the assessment of genetic assortment for variation, and thus the assortment and introduction of pressure inducible genes of genetic possessions to emerge novel diversities in manufacture schemes (Chapman et al., 2012). Acceptance of temperature is still in initial phase in breeding and consequently, abundant consideration that gives to genetic development of crop to pressure of temperature. During current ages, numerous studies discover out crop genotypes accepting to pressure of temperature (Kumar et al., 2010; Sareen et al., 2012; Kumari et al., 2013; & Nagar et al., 2015).

Screening and breeding for heat tolerance

The scenario of breeding, Australia and several developing countries have been found appropriate in case of numerous physiological

scenarios. The procedure comprises screening genetic possessions to documentation of genetic centers for temperature acceptance in crops. After this, a novel plant type can be originate of our will following physiological crossing of novel trait mixtures, to battle upcoming weather that encompasses elevated heat proceedings (Reynolds & Langridge 2016). It is quite problematic to screen out genotypes of wheat under the situations of temperature stress inside numerous spatial climates. Consequently, no reliable selection standard has been recognized to assess varied genetic materials for temperature stress acceptance. Assortment standards and screening approaches to classify healthier crop genetic resources accepting to pressure of temperature are commonly loomed based on features related with advanced produce of grains below opposing temperature pressure condition.

Sharma et al. (2013) found dependable stricture a susceptible index though choosing wheat genotypes accepting to stress of temperature. Mason et al. (2010) have assumed stress at QTL planning of apiece produce characteristics like vulnerability directory with shared influence of it with temperature lenience with produce of grain constancy. Current information displays that thylakoid membrane constancy is extremely related with the temperature lenience volume of wheat crop. Mass broadcast by means of visit green charm might be complete aimed at temperature lenience with crops wheat genetic constitution. Kumar et al. (2010) shadowed the technique for assessing visit green mannerism with crop, originate an association of incurable temperature lenience in produce. Over-all, structural characters as initial shelter, progressing of leaf, mass, with numerous physical characters, like green contented of leaf, degree of photosynthesis, conductance of pores of the flag leaf, thermostability of the membrane, and also reserves of the stem with origination related in cells heat acceptance in crop. Current loans of scientific studies donated importantly, comprehend difficulty with pressure reply apparatuses below the pressure circumstances of temperature. Asthir (2015a, b) highlighted with information trails with defensive instruments for breeding temperature pressure accepting crop. Temperature acceptance is clearly controlled by many genes attribute, with overhead tackles too supports with examining foundation with crop heat acceptance. Wang et al. (2016) planned valuable operation with a few transcription features to recover manifold pressure acceptance of plant. Qtl planning with succeeding indicator aided assortment thru this conceivable with healthier thoughtful of the temperature acceptance in crop (Heffner et al., 2009). Fresh data disclose with numerous loci have been obtainable, it would castoff with emerging temperature lenience with crop. In instance, loci with temperature acceptance is recognized with mass of ounce and span of satisfying of grain (Mason et al., 2010; & Paliwal et al., 2012), senescence connected characters (Vijayalakshmi et al., 2010), and covering illness (Paliwal et al., 2012). Mason et al. (2010) too recognized loci connected with produce, produce characteristic behaviors with proposed, prickle of plant can castoff with placement of loci gene region with temperature lenience. Also, different documented loci with chromosome 2B, 4A and 5B for crop below temperature pressure circumstances (Pinto et al., 2010). Sap escape always a sign with abridged temperature requirement of wall with reproduces presentation with crop varieties exposed to inside the lab temperature shudder. Varieties making temperature tremor wave proteins would endure pressure of temperature because those defend sap from temperature pressure persuaded injury (Farooq et al., 2011). Gene alterations lenience with crop that dissimilar development phases too described (Kumar et al., 2013b; & Asthir et al., 2013). Answers too recommended profusion with minor temperature shudder sap, superoxide not mutase throughout cloudy bread phase acting an energetic character with synthesis with sap particle, it would assist for growing temperature accepting crop varieties comprising superior ounces. Humble, rapid,

with fewer expensive airing techniques are obligatory with greater amount in germplasms with grow temperature accepting plant varieties. Like, green rhythm would become useful with tall material broadcast in crop with temperature acceptance (Ristic et al., 2007).

Biotechnological method for temperature tolerance

Gene manufacturing tactics would improve opposing belongings with temperature pressure for refining temperature acceptance (Chapman et al., 2012). This includes combination with genetics concentration with wanted crop recovery crop acceptance for temperature pressure (Zheng et al., 2012). Though, difficulty in designing of genes types this problematic, investigate gene alteration with crop. Pressure of temperature with lengthier span upsurges sap amalgamation extension aspect with green portion that relates to temperature acceptance for crop. Constituent appearance with external crop endangered sap of leaf in contradiction of thermal collection, abridged thylakoid membranes disturbance, improved competence of photosynthesis, and struggled infective microorganisms contagion (Fu et al., 2012). Genes of crop accumulating are less EF-Tu depicted low temperature pressure and vice versa (Ristic et al., 2008). Freshly, numerous transcript influences elaborate with numerous pressures which is originated, plotted in recovering pressure acceptance with produces (Wang et al., 2016). Gene arrangements in numerous crops with newly produced with development for pressure acceptance. Clavijo et al. (2016) established 3 recognized, recognized 1 original gene reordering with crop. It is useful in comparatively cheap sequence skills, expected with investigators would utilize methods exemplified in sequencing manifold varieties of crop. It would transport the big gauge organizational variations which is recognized in showing main part with edition to crop in diversing tense surroundings.

Agronomic organization

The crop would also grow up effectively with heater atmosphere via operating roughly agronomical organization performs (Ortiz et al., 2008). Acceptance for numerous agronomical performs as aquatic preserve methods, suitable quantity with approaches in insemination, upholding appropriate period with approaches in spreading, claim for external protectants would efficiently lessen opposing influence in temperature pressure of crop (Singh et al., 2011b).

Preserving of soil dampness

Constant damping source, essential in supporting and satisfying of grains degree with period, magnitude of grain crop. It would never conceive with rainfed crop rising part, nonetheless now, covering with finest choice in upholding optimal wetness, current governments with earth scheme. Covering preserves dampness via dipping earth vanishing (Chen et al., 2007). Though, coverings are supported for evading harvest discount with crop, abridged digging becomes skillful (Glab & Kulig 2008). Growing efficiency crop by utilization of cover below temperature pressure, aquatic shortfall setting is described in another place (Chakraborty et al., 2008). Claim in carbon-based coverings conserves healthier earth dampness, recovers crop development, progress, afterward upsurges liquid, N_2 custom competence that might decrease (Singh et al., 2011b). Repetition is known extremely actual with crop manufacture below opposing temperature pressure circumstances in moderate hot zones.

Nutrient management and planting time

Satisfactory with stable source in inorganic saps are vital for crops unprotected in heat pressure (Waraich et al., 2012). Claim of N_2, P with K after blossoming span augments ounce sap during the heat pressure of 24 and 17°C, correspondingly, nonetheless belonging is invalidated during the elevated stresses. Foliar sprig in grains is extremely actual, it eases opposing result in temperature pressure in crop. Claim of inorganic sprig post blossoming can become another method in upsurging temperature acceptance in crop. It results in postponement with temperature pressure persuaded foliage agedness, improves ounce harvest (Dias & Lidon, 2010). The rewards of

nitrate ion via postponing abscisic cutting mixture and indorsing hormone action, likewise potassium ion persuaded cumulative photosynthesis doings, integrate buildup is fine documented in cumulative yield of ounce below temperature pressure atmosphere (Singh et al., 2011a).

Exogenic submission with Ca indorses temperature acceptance with crops (Waraich et al., 2011). Ca claim with procedure in calcium chloride, enthused doings of crop, that would show details with introduction in temperature acceptance. Genetic constitution of this crop, calcium buildup too appears in relation to an advanced acceptance with temperature pressure, perhaps since same sap would protect greenish in print obliteration, furthermore, it is able to uphold stomatal operationing, therefore attenuating the temperature pressure belongings via transpirational phenomenon (Dias et al., 2009b).

Satisfactory source with Mg recognized like actual nutritious approach for diminishing temperature pressure connected wounded to crop manufacturing. Mengutay et al. (2013) originated saying crops anguish from magnesium shortage remained vulnerable toward temperature pressure, adequate magnesium with procedure with magnesium sulphate efficiently lessened harmful result with temperature pressure. Zn lack, temperature pressure to disturb crop output via dropping grain development with chloroplast purpose (Peck & McDonald, 2010). Temperature pressure normally upsurges Zn attentiveness with ounce typically owing with removement after sprout (Dias & Lidon, 2009b). So, zinc too is established as actual refining temperature acceptance with crop.

Overall, after due date spreading of crops looks plain infection pressure, cuts title, old age period, eventually upsetting last produce and quality of grain (Hossain & Teixeira de Silva, 2012; & Hakim et al., 2012). So, this suggested with growth in tall springy crop varieties improved for semi-arid surroundings for choosing of genes for initial adulthood, comparatively extended period for header (Al-Karaki, 2012). Henceforth, initial establishing, genes for initial adulthood with comparatively extended period for header is supported to elude fatal temperature pressure, hasten ounce of grains (Khichar & Niwas, 2007; & Al-Karaki, 2012). So, to keep suitable planting period with significant agronomical performs with receiving best development of plant with crop harvest below temperature harassed surrounding (Kajla et al., 2015).

Alteration with establishing technique would lighten antagonistic influence in temperature pressure throughout imitation phase in crop. Everlasting crops zero digging at couch sowing to plant remainder holding is previously planned, likely resources to refine temperature pressure acceptance to crop to Mexican regions. Crop establishing to conservative digging via stubble covering augmented damp croft volume, carbon-based, entire N2 in earth that recovers digging volume consequential for alleviation of tall infection persuaded discount for ounce mass on late satisfying of grain phase (Tang et al., 2013).

External protectants

Current eras, externally useful numerous development indorsing defender like aquatic defenders, plant hormone, gesturing particles, drop essentials consume caused trendy possible for defending crops with counteracting damaging with opposing belongings to temperature pressure (Sharma et al., 2012; & Upreti & Sharma, 2016). Externally claims to materials recover temperature acceptance of crop below temperature pressure for handling (Farooq et al., 2011) by increasing antioxidant volume (Hemantaranjan et al., 2014). Giving heat delicate crops to numerous defenders, vitamin E is previously recognized its parts to heat acceptance. Outside claim for particles are bettering possessions in contradiction of oxidative pressure via stimulation of numerous enzymes e.g. catalase etc., non-enzymatic like tocopherol etc. (Ball et al., 2007). Lengthily utilized numerous crop controllers with

ornamental plants would also possibly castoff arena harvests counting crops, projections is today thrashed ready like developing pressure lessening skill with temperature pressure atmosphere (Ratnakumar et al., 2016). Under abiotic pressure situation, naturally happening numerous inside cellular amines, like spermidine, spermine and putrescine, would show energetic parts with maintainable plant manufacturing. Freshly, investigation focused on the way to part with nonliving pressure acceptances are acquisition importance (Gupta et al., 2013b; & Rangan et al., 2014).

Bacterial seed treatment

Variety development via upbringing packages is period intense with expensive, genetic alteration skill not so fine apparent via various investors. So, by means of biological regulatory agents such as fungi and bacteria are now well thought-out as an substitute technique of refining temperature acceptance (Raaijmakers et al., 2009). Crop development indorsing rhizo-bacterium is initiate with well-matched by consuming helpful result to development with crop below temperature pressure (Nain et al., 2010). Kernel action to rhizo-bacteria with sprig to numerous carbon-based, inanimate mediators improved temperature acceptance to crop (Yang et al., 2009). Kernel injection to rhizo-bacteria too meaningfully amended temperature acceptance to crop (Anderson & Habiger, 2012). Kernel action were too operative for upsurging temperature acceptance to crop sprouts (Abd El-Daim et al., 2014).

CONCLUSION AND FUTURE PERSPECTIVES

During current ancient, temperature pressure was found to central to massive damage of wheat efficiency universally. In spite of booming out rigorous studies on the harmful belongings of temperature pressure in wheat crop, in depth sympathetic of the device of temperature acceptance remainders indefinable. Consequently, temperature pressure acceptance device is energetic for emerging a prominent approach of wheat administration under temperature pressure and forth sighting environment alteration locations. To produce temperature accepting tall yielding crops, metabolic and growth procedures related with temperature pressure and vigor guideline must be methodically unspoken. Though a substantial development has been attained in understanding the temperature pressure belongings on wheat crop, thus far it is an essential to additional sympathy to biochemical, molecular foundation to temperature acceptance in development with produce in future heater surroundings. Information to reply, acceptance apparatuses for harvesting maintainable yield of grains should get examined. For identifying it, practical gene method can become helpful to answer crops temperature pressure.

Traditional with current heredity apparatuses at molecular level combined to agronomical managing observes would overwhelm difficulty for temperature condition. This is because dissimilar biochemical, molecular methods, agronomical choice is obligatory for discovering real belongings to temperature pressure at concluding crop yield. Furthermore, external requests to defender are exposed beneficial paraphernalia in temperature acceptance upgrading to crops. Smearing microbes appears valuable instrument with Agri sciences to upgrade the undesirable things to temperature pressure with plants, nonetheless additional educations are wanted for classifying and enhancement of limits tangled to fruitful bacterial act.

Therefore, conservative education, current biotechnology and molecular apparatus is a significant zone to upcoming investigations. Real foundation to smearing such approaches are either florae comprise temperature acceptance or not. These crop genomes show considerable level to temperature acceptance, though whole acceptance has not been found hitherto. Most disturbing is that no assortment standards of temperature acceptance have been recognized. Freshly, temperature compassion directories to

thousand seed mass with filling of grains period are industrialized.

Eventually, a close teamwork and exertions between biotechnologists, breeder and plant physiologists is obligatory. Scheme extensive phenomenon for genomic examination becomes obligatory for making conceivable a precise mapping of the trait, introgression to greater alleles, or duplicating main loci in case of temperature acceptance, these blends would allow for classifying genomes tangled for temperature acceptance, likewise associations among phenotypes with genotypes. To gain operative temperature acceptance, the transgenic method should be joint to marker aided breeding plans to temperature pressure connected genomes and loci.

Opinion prediction on worldwide heating, information connecting with biological foundation and device for acceptance is measured for covering method to engineer crops which would endure temperature pressure by giving acceptable produce. In spite of details of an opportunity to request of EF-Tu for emerging temperature accepting, virus resilient crop diversities to moderate appearance heights, added education is obligatory for travelling device of act of crop EF-Tu comparative with temperature acceptance. This becomes significant for noting that biological education encourages growing financial produce of crop, therefore complete possible produce appearance necessitates approximation for yielding at crop level. Thus, produce modelling scheme trainings are dynamic for improving temperature pressure acceptance and yield of grains in wheat crop.

REFERENCES

Abd El-Daim, I. A., Bejai, S., & Meijer, J. (2014). Improved heat stress tolerance of wheat seedlings by bacterial seed treatment. *Plant and soil*, *379*(1), 337-350.

Ahmad, P., Jaleel, C. A., Salem, M. A., Nabi, G., & Sharma, S. (2010). Roles of enzymatic and nonenzymatic antioxidants in plants during abiotic stress. *Critical reviews in biotechnology*, *30*(3), 161-175.

Ainsworth, E. A., & Ort, D. R. (2010). How do we improve crop production in a warming world?. *Plant physiology*, *154*(2), 526-530.

Al-Karaki, G. N. (2012). Phenological development-yield relationships in durum wheat cultivars under late-season high-temperature stress in a semiarid environment. *International Scholarly Research Notices*, *2012*.

Allakhverdiev, S. I., Kreslavski, V. D., Klimov, V. V., Los, D. A., Carpentier, R., & Mohanty, P. (2008). Heat stress: an overview of molecular responses in photosynthesis. *Photosynthesis research*, *98*(1), 541-550.

Almeselmani, M., Deshmukh, P., & Sairam, R. (2009). High temperature stress tolerance in wheat genotypes: role of antioxidant defence enzymes. *Acta Agronomica Hungarica*, *57*(1), 1-14.

Almeselmani, M., Deshmukh, P. S., & Chinnusamy, V. (2012). Effects of prolonged high temperature stress on respiration, photosynthesis and gene expression in wheat (Triticum aestivum L.) varieties differing in their thermotolerance. *Plant stress*, *6*(1), 25-32.

Altenbach, S. B. (2012). New insights into the effects of high temperature, drought and post-anthesis fertilizer on wheat grain development. *Journal of Cereal Science*, *56*(1), 39-50.

Anderson, M., & Habiger, J. (2012). Characterization and identification of productivity-associated rhizobacteria in wheat. *Applied and environmental microbiology*, *78*(12), 4434-4446.

Freeha, A., Abdul, W., Farrukh, J., & Muhammad, A. (2008). Influence of foliar applied thiourea on flag leaf gas exchange and yield parameters of bread wheat (Triticum aestivum) cultivars under salinity and heat stresses. *International Journal of*

agriculture and Biology, *10*(6), 619-626.

Ashraf, M. H. P. J. C., & Harris, P. J. (2013). Photosynthesis under stressful environments: an overview. *Photosynthetica*, *51*(2), 163-190.

Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., & Zhu, Y. (2015). Rising temperatures reduce global wheat production. *Nature climate change*, *5*(2), 143-147.

Asseng, S., Foster, I. A. N., & Turner, N. C. (2011). The impact of temperature variability on wheat yields. *Global Change Biology*, *17*(2), 997-1012.

Asthir, B. (2015). Protective mechanisms of heat tolerance in crop plants. *Journal of Plant Interactions*, *10*(1), 202-210.

Asthir, B. (2015). Protective mechanisms of heat tolerance in crop plants. *Journal of Plant Interactions*, *10*(1), 202-210.

Asthir, B., Bala, S., & Bains, N. S. (2013). Metabolic profiling of grain carbon and nitrogen in wheat as influenced by high temperature. *Cereal Research Communications*, *41*(2), 230-242.

Asthir, B., & Bhatia, S. (2014). In vivo studies on artificial induction of thermotolerance to detached panicles of wheat (Triticum aestivum L) cultivars under heat stress. *Journal of food science and technology*, *51*(1), 118-123.

Asthir, B., Koundal, A., & Bains, N. S. (2012). Putrescine modulates antioxidant defense response in wheat under high temperature stress. *Biologia Plantarum*, *56*(4), 757-761.

Atkinson, N. J., & Urwin, P. E. (2012). The interaction of plant biotic and abiotic stresses: from genes to the field. *Journal of experimental botany*, *63*(10), 3523-3543.

Bahar, B., Yildirim, M., & Yucel, C. (2011). Heat and drought resistance criteria in spring bread wheat (Triticum aestivum L.): Morpho-physiological parameters for heat tolerance. *Scientific Research and Essays*, *6*(10), 2212-2220.

Akter, N., & Islam, M. R. (2017). Heat stress effects and management in wheat. A review. *Agronomy for sustainable development*, *37*(5), 1-17.

Balla, K., Karsai, I., Bencze, S., & Veisz, O. (2012). Germination ability and seedling vigour in the progeny of heat-stressed wheat plants. *Acta Agronomica Hungarica*, *60*(4), 299-308.

Bennani, S., Nsarellah, N., Birouk, A., Ouabbou, H., & Tadesse, W. (2016). Effective selection criteria for screening drought tolerant and high yielding bread wheat genotypes. *Universal Journal of Agricultural Research*, *4*(4), 134-142.

Bennett, D., Izanloo, A., Reynolds, M., Kuchel, H., Langridge, P., & Schnurbusch, T. (2012). Genetic dissection of grain yield and physical grain quality in bread wheat (Triticum aestivum L.) under water-limited environments. *Theoretical and Applied Genetics*, *125*(2), 255-271.

Braun, H. J., Atlin, G., & Payne, T. (2010). Multi-location testing as a tool to identify plant response to global climate change. *Climate change and crop production*, *1*, 115-138.

Castro, M., Peterson, C. J., Dalla Rizza, M., Dellavalle, P. D., Vázquez, D., Ibanez, V., & Ross, A. (2007). Influence of heat stress on wheat grain characteristics and protein molecular weight distribution. In *Wheat Production in Stressed Environments* (pp. 365-371). Springer, Dordrecht.

Caverzan, A., Casassola, A., & Brammer, S. P. (2016). Antioxidant responses of wheat plants under stress. *Genetics and molecular biology*, *39*, 1-6.

Chakraborty, D., Nagarajan, S., Aggarwal, P., Gupta, V. K., Tomar, R. K., Garg, R. N., & Kalra, N. (2008). Effect of mulching on soil and plant water

status, and the growth and yield of wheat (Triticum aestivum L.) in a semi-arid environment. *Agricultural water management*, *95*(12), 1323-1334.

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, *4*(4), 287-291.

Chapman, S. C., Chakraborty, S., Dreccer, M. F., & Howden, S. M. (2012). Plant adaptation to climate change—opportunities and priorities in breeding. *Crop and Pasture Science*, *63*(3), 251-268.

Chauhan, H., Khurana, N., Tyagi, A. K., Khurana, J. P., & Khurana, P. (2011). Identification and characterization of high temperature stress responsive genes in bread wheat (Triticum aestivum L.) and their regulation at various stages of development. *Plant molecular biology*, *75*(1), 35-51.

Chen, S. Y., Zhang, X. Y., Pei, D., Sun, H. Y., & Chen, S. L. (2007). Effects of straw mulching on soil temperature, evaporation and yield of winter wheat: field experiments on the North China Plain. *Annals of Applied Biology*, *150*(3), 261-268.

Ciucă, M., & Petcu, E. (2009). SSR markers associated with membrane stability in wheat (Triticum aestivum L.). *Romanian Agricultural Research*, *26*, 21-24.

Akter, N., & Islam, M. R. (2017). Heat stress effects and management in wheat. A review. *Agronomy for sustainable development*, *37*(5), 1-17.

Cochard, H., Venisse, J. S., Barigah, T. S., Brunel, N., Herbette, S., Guilliot, A., & Sakr, S. (2007). Putative role of aquaporins in variable hydraulic conductance of leaves in response to light. *Plant physiology*, *143*(1), 122-133.

Cossani, C. M., & Reynolds, M. P. (2012). Heat stress adaptation in elite lines derived from synthetic hexaploid wheat. *Crop Science*, *55*(6), 2719-2735.

Deryng, D., Conway, D., Ramankutty, N., Price, J., & Warren, R. (2014). Global crop yield response to extreme heat stress under multiple climate change futures. *Environmental Research Letters*, *9*(3), 034011.

Dhanda, S. S., & Munjal, R. (2012). Heat tolerance in relation to acquired thermotolerance for membrane lipids in bread wheat. *Field Crops Research*, *135*, 30-37.

Dias, A. S., Bagulho, A. S., & Lidon, F. C. (2008). Ultrastructure and biochemical traits of bread and durum wheat grains under heat stress. *Brazilian Journal of Plant Physiology*, *20*, 323-333.

Dias, A. S., & Lidon, F. C. (2009a). Evaluation of grain filling rate and duration in bread and durum wheat, under heat stress after anthesis. *Journal of Agronomy and Crop Science*, *195*(2), 137-147.

Dias, A. S., & Lidon, F. C. (2009b). II. Heat stress in Triticum: kinetics of Cu and Zn accumulation. *Brazilian Journal of Plant Physiology*, *21*, 135-142.

Dias, A. S., & Lidon, F. C. (2010). Bread and durum wheat tolerance under heat stress: A synoptical overview. *Emirates Journal of Food and Agriculture*, 412-436.

Essemine, J., Ammar, S., & Bouzid, S. (2010). Impact of heat stress on germination and growth in higher plants: Physiological, biochemical and molecular repercussions and mechanisms of defence. *Journal of Biological Sciences*, *10*(6), 565-572.

Farooq, M., Bramley, H., Palta, J. A., & Siddique, K. H. (2011). Heat stress in wheat during reproductive and grain-filling phases. *Critical Reviews in Plant Sciences*, *30*(6), 491-507.

Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. *Sustainable agriculture*, 153-188.

Feng, B., Liu, P., Li, G., Dong, S. T., Wang, F. H., Kong, L. A., & Zhang, J. W. (2014). Effect of heat stress on the photosynthetic characteristics in flag leaves at the grain-filling stage of different heat-resistant winter wheat varieties. *Journal of Agronomy and Crop Science*, *200*(2), 143-155.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., & Zaks, D. P. (2011). Solutions for a cultivated planet. *Nature*, *478*(7369), 337-342.

Fontana, G., Toreti, A., Ceglar, A., & De Sanctis, G. (2015). Early heat waves over Italy and their impacts on durum wheat yields. *Natural Hazards and Earth System Sciences*, *15*(7), 1631-1637.

Fu, J., Momcilovic, I., Prasad, P. V. V., Josipovic, S., & Ludwig, E. (2012). Molecular bases and improvement of heat tolerance in crop plants. *Heat stress: Causes, prevention and treatments*, 185-214.

Głąb, T., & Kulig, B. (2008). Effect of mulch and tillage system on soil porosity under wheat (Triticum aestivum). *Soil and Tillage Research*, *99*(2), 169-178.

Gourdji, S. M., Mathews, K. L., Reynolds, M., Crossa, J., & Lobell, D. B. (2013). An assessment of wheat yield sensitivity and breeding gains in hot environments. *Proceedings of the Royal Society B: Biological Sciences*, *280*(1752), 20122190.

Grant, R. F., Kimball, B. A., Conley, M. M., White, J. W., Wall, G. W., & Ottman, M. J. (2011). Controlled warming effects on wheat growth and yield: field measurements and modeling. *Agronomy Journal*, *103*(6), 1742-1754.

Gupta, N. K., Agarwal, S., Agarwal, V. P., Nathawat, N. S., Gupta, S., & Singh, G. (2013). Effect of short-term heat stress on growth, physiology and antioxidative defence system in wheat seedlings. *Acta Physiologiae Plantarum*, *35*(6), 1837-1842.

Gupta, K., Dey, A., & Gupta, B. (2013). Plant polyamines in abiotic stress responses. *Acta physiologiae plantarum*, *35*(7), 2015-2036.

Hakim, M. A., Hossain, A., da Silva, J. A. T., Zvolinsky, V. P., & Khan, M. M. (2012). Protein and starch content of 20 wheat (Triticum aestivum L.) genotypes exposed to high temperature under late sowing conditions. *Journal of Scientific Research*, *4*(2), 477-477.

Hampton, J. G., Boelt, B., Rolston, M. P., & Chastain, T. G. (2013). Effects of elevated CO2 and temperature on seed quality. *The Journal of agricultural science*, *151*(2), 154-162.

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. *Proceedings of the National Academy of Sciences*, *109*(37), E2415-E2423.

Haque, M. S., Kjaer, K. H., Rosenqvist, E., Sharma, D. K., & Ottosen, C. O. (2014). Heat stress and recovery of photosystem II efficiency in wheat (Triticum aestivum L.) cultivars acclimated to different growth temperatures. *Environmental and Experimental Botany*, *99*, 1-8.

Hasanuzzaman, M., Hossain, M. A., da Silva, J. A. T., & Fujita, M. (2012). Plant response and tolerance to abiotic oxidative stress: antioxidant defense is a key factor. In *Crop stress and its management: perspectives and strategies* (pp. 261-315). Springer, Dordrecht.

Hasanuzzaman, M., Nahar, K., Alam, M., Roychowdhury, R., & Fujita, M. (2013). Physiological, biochemical, and molecular mechanisms of heat

stress tolerance in plants. *International journal of molecular sciences*, *14*(5), 9643-9684.

Hays, D. B., Do, J. H., Mason, R. E., Morgan, G., & Finlayson, S. A. (2007). Heat stress induced ethylene production in developing wheat grains induces kernel abortion and increased maturation in a susceptible cultivar. *Plant Science*, *172*(6), 1113-1123.

Hedhly, A., Hormaza, J. I., & Herrero, M. (2009). Global warming and sexual plant reproduction. *Trends in plant science*, *14*(1), 30-36.

Heffner, E. L., Sorrells, M. E., & Jannink, J. L. (2009). Genomic selection for crop improvement.

Hemantaranjan, A., Nishant Bhanu, A., Singh, M. N., Yadav, D. K., Patel, P. K., Singh, R., & Katiyar, D. (2014). Heat Stress Responses and Thermotolerance. *Adv Plants Agric Res 1*(3), 00012.

Hossain, A., Sarker, M. A. Z., Saifuzzaman, M., Teixeira da Silva, J. A., Lozovskaya, M. V., & Akhter, M. M. (2013). Evaluation of growth, yield, relative performance and heat susceptibility of eight wheat (Triticum aestivum L.) genotypes grown under heat stress. *International Journal of Plant Production*, *7*(3), 615-636.

Hossain, A., & DA SILVA, J. A. T. (2012). Phenology, growth and yield of three wheat (Triticum aestivum L.) varieties as affected by high temperature stress. *Notulae Scientia Biologicae*, *4*(3), 97-109.

Huang, B., Rachmilevitch, S., & Xu, J. (2012). Root carbon and protein metabolism associated with heat tolerance. *Journal of experimental botany*, *63*(9), 3455-3465.

Hurkman, W. J., Vensel, W. H., Tanaka, C. K., Whitehand, L., & Altenbach, S. B. (2009). Effect of high temperature on albumin and globulin accumulation in the endosperm proteome of the developing wheat grain. *Journal of Cereal Science*, *49*(1), 12-23.

Hussain, S., Jamil, M., Napar, A. A., Rahman, R., Bano, A., Afzal, F., & Mujeeb-Kazi, A. (2016). Heat stress in wheat and interdisciplinary approaches for yield maximization. *Plant-Environment Interaction*, 161-183.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., & van Ypserle, J. P. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change* (p. 151). Ipcc.

Iqbal, M., Raja, N. I., Yasmeen, F., Hussain, M., Ejaz, M., & Shah, M. A. (2017). Impacts of heat stress on wheat: a critical review. *Adv Crop Sci Technol*, *5*(1), 01-09.

Iwai, M., Yokono, M., Inada, N., & Minagawa, J. (2010). Live-cell imaging of photosystem II antenna dissociation during state transitions. *Proceedings of the National Academy of Sciences*, *107*(5), 2337-2342.

Johkan, M., Oda, M., Maruo, T., & Shinohara, Y. (2011). Crop production and global warming. *Global warming impacts-case studies on the economy, human health, and on urban and natural environments*, 139-152.

Joshi, N. L., & Kar, A. (2009). Contingency crop planning for dryland areas in relation to climate change. *Indian Journal of Agronomy*, *54*(2), 237-243.

Kajla, M., Yadav, V. K., Chhokar, R. S., & Sharma, R. K. (2015). Management practices to mitigate the impact of high temperature on wheat. *Journal of Wheat Research*, *7*(1), 1-12.

Kaur, V., & Behl, R. K. (2010). Grain yield in wheat as affected by short periods of high temperature, drought and their interaction during pre-and post-anthesis stages. *Cereal Research Communications*, *38*(4), 514-520.

Kaushal, N., Bhandari, K., Siddique, K. H., & Nayyar, H. (2016). Food crops face rising temperatures: an overview of responses, adaptive mechanisms, and approaches to improve heat tolerance. *Cogent food & agriculture*, *2*(1), 1134380.

Khalil, S. I., El-Bassiouny, H. M. S., Hassanein, R. A., Mostafa, H. A., El-Khawas, S. A., & El-Monem, A. A. A. (2009). Antioxidant defense system in heat shocked wheat plants previously treated with arginine or putrescine. *Australian Journal of Basic and Applied Sciences*, *3*(3), 1517-1526.

Khan, A. A., & Kabir, M. R. (2014). Evaluation of spring wheat genotypes (Triticum aestivum L.) for heat stress tolerance using different stress tolerance indices. *Cercet Agron Mold*, *160*, 49-63.

Khanna-Chopra, R. (2012). Leaf senescence and abiotic stresses share reactive oxygen species-mediated chloroplast degradation. *Protoplasma*, *249*(3), 469-481.

Khichar, M. L., & Niwas, R. (2007). Thermal effect on growth and yield of wheat under different sowing environments and planting systems. *Indian Journal of Agricultural Research*, *41*(2), 92-96.

Kosová, K., Vítámvás, P., Prášil, I. T., & Renaut, J. (2011). Plant proteome changes under abiotic stress—contribution of proteomics studies to understanding plant stress response. *Journal of proteomics*, *74*(8), 1301-1322.

Krasensky, J., & Jonak, C. (2012). Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. *Journal of experimental botany*, *63*(4), 1593-1608.

Kumar, S., Singh, R., & Nayyar, H. (2013). α-Tocopherol application modulates the response of wheat (Triticum aestivum L.) seedlings to elevated temperatures by mitigation of stress injury and enhancement of antioxidants. *Journal of plant growth regulation*, *32*(2), 307-314.

Kumar, R. R., Sharma, S. K., Goswami, S., Singh, G. P., Singh, R., Singh, K., & Rai, R. D. (2013). Characterization of differentially expressed stress-associated proteins in starch granule development under heat stress in wheat (Triticum aestivum L.).

Kumar, S., Singh, R. G. M. S., Grover, M., & Singh, A. K. (2012). Terminal heat—an emerging problem for wheat production. *Biotechnol today*, *2*(2), 7-9.

Kumar, U., Joshi, A. K., Kumari, M., Paliwal, R., Kumar, S., & Röder, M. S. (2010). Identification of QTLs for stay green trait in wheat (Triticum aestivum L.) in the 'Chirya 3'×'Sonalika'population. *Euphytica*, *1 74*(3), 437-445.

Kumari, M., Pudake, R. N., Singh, V. P., & Joshi, A. K. (2013). Association of staygreen trait with canopy temperature depression and yield traits under terminal heat stress in wheat (Triticum aestivum L.). *Euphytica*, *190*(1), 87-97.

Li, Y. F., Wu, Y., Hernandez-Espinosa, N., & Peña, R. J. (2013). Heat and drought stress on durum wheat: Responses of genotypes, yield, and quality parameters. *Journal of Cereal Science*, *57*(3), 398-404.

Lipiec, J., Doussan, C., Nosalewicz, A., & Kondracka, K. (2013). Effect of drought and heat stresses on plant growth and yield: a review. *International Agrophysics*, *27*(4), 463-477.

Liu, P., Guo, W., Jiang, Z., Pu, H., Feng, C., Zhu, X., & Little, C. R. (2011). Effects of high temperature after anthesis on starch granules in grains of wheat (Triticum aestivum L.). *The Journal of agricultural science*, *149*(2), 159-169.

Lizana, X. C., & Calderini, D. F. (2013). Yield and grain quality of wheat in response to increased temperatures at key periods for grain number and grain weight determination: considerations for the climatic change scenarios of Chile. *The Journal of Agricultural Science*, *151*(2), 209-221.

Lobell, D. B., Bonfils, C. J., Kueppers, L. M., & Snyder, M. A. (2008). Irrigation cooling effect on temperature and heat index extremes. *Geophysical Research Letters*, *35*(9).

Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant physiology*, *160*(4), 1686-1697.

Lopes, M. S., & Reynolds, M. P. (2012). Stay-green in spring wheat can be determined by spectral reflectance measurements (normalized difference vegetation index) independently from phenology. *Journal of experimental botany*, *63*(10), 3789-3798.

Lukac, M., Gooding, M. J., Griffiths, S., & Jones, H. E. (2012). Asynchronous flowering and within-plant flowering diversity in wheat and the implications for crop resilience to heat. *Annals of botany*, *109*(4), 843-850.

Martínez-Ballesta, M. C., López-Pérez, L., Muries, B., Muñoz-Azcarate, O., & Carvajal, M. (2009). Climate change and plant water balance: the role of aquaporins–a review. In *Climate change, intercropping, pest control and beneficial microorganisms* (pp. 71-89). Springer, Dordrecht.

Marutani, Y., Yamauchi, Y., Kimura, Y., Mizutani, M., & Sugimoto, Y. (2012). Damage to photosystem II due to heat stress without light-driven electron flow: involvement of enhanced introduction of reducing power into thylakoid membranes. *Planta*, *236*(2), 753-761.

Mason, R. E., Mondal, S., Beecher, F. W., Pacheco, A., Jampala, B., Ibrahim, A. M., & Hays, D. B. (2010). QTL associated with heat susceptibility index in wheat (Triticum aestivum L.) under short-term reproductive stage heat stress. *Euphytica*, *174*(3), 423-436.

Mathur, S., Agrawal, D., & Jajoo, A. (2014). Photosynthesis: response to high temperature stress. *Journal of Photochemistry and Photobiology B: Biology*, *137*, 116-126.

Mathur, S., Jajoo, A., Mehta, P., & Bharti, S. (2011). Analysis of elevated temperature-induced inhibition of photosystem II using chlorophyll a fluorescence induction kinetics in wheat leaves (Triticum aestivum). *Plant Biology*, *13*(1), 1-6.

McClung, C. R., & Davis, S. J. (2010). Ambient thermometers in plants: from physiological outputs towards mechanisms of thermal sensing. *Current Biology*, *20*(24), R1086-R1092.

Mengutay, M., Ceylan, Y., Kutman, U. B., & Cakmak, I. (2013). Adequate magnesium nutrition mitigates adverse effects of heat stress on maize and wheat. *Plant and soil*, *368*(1), 57-72.

Miller, G., Schlauch, K., Tam, R., Cortes, D., Torres, M. A., Shulaev, V., & Mittler, R. (2009). The plant NADPH oxidase RBOHD mediates rapid systemic signaling in response to diverse stimuli. *Science signaling*, *2*(84), ra45-ra45.

Mittler, R., Vanderauwera, S., Suzuki, N., Miller, G. A. D., Tognetti, V. B., Vandepoele, K., & Van Breusegem, F. (2011). ROS signaling: the new wave?. *Trends in plant science*, *16*(6), 300-309.

Mohammadi, M. O. H. T. A. S. H. A. M., Karimizadeh, R. A., & Naghavi, M. R. (2009). Selection of bread wheat genotypes against heat and drought tolerance based on chlorophyll content and stem reserves. *J. Agric. Soc. Sci*, *5*(5), 119-122.

Mondal, S., Singh, R. P., Crossa, J., Huerta-Espino, J., Sharma, I., Chatrath, R., & Joshi, A. K. (2013). Earliness in wheat: a key to adaptation under terminal and continual high temperature stress in South Asia. *Field crops research*, *151*, 19-26.

Mueller, B., Hauser, M., Iles, C., Rimi, R. H., Zwiers, F. W., & Wan, H. (2015). Lengthening of the growing season in wheat and maize producing regions. *Weather and Climate Extremes*, *9*, 47-56.

Murata, N., Takahashi, S., Nishiyama, Y., & Allakhverdiev, S. I. (2007). Photoinhibition of photosystem II under environmental stress. *Biochimica et Biophysica Acta (BBA)-Bioenergetics*, *1767*(6), 414-421.

Nagar, S., Singh, V. P., Arora, A., Dhakar, R., & Ramakrishnan, S. (2015). Assessment of terminal heat tolerance ability of wheat genotypes based on physiological traits using multivariate analysis. *Acta physiologiae plantarum*, *37*(12), 1-9.

Nahar, K., Ahamed, K. U., & Fujita, M. (2010). Phenological variation and its relation with yield in several wheat (Triticum aestivum L.) cultivars under normal and late sowing mediated heat stress condition. *Notulae Scientia Biologicae*, *2*(3), 51-56.

Nain, L., Rana, A., Joshi, M., Jadhav, S. D., Kumar, D., Shivay, Y. S., & Prasanna, R. (2010). Evaluation of synergistic effects of bacterial and cyanobacterial strains as biofertilizers for wheat. *Plant and soil*, *331*(1), 217-230.

Nawaz, A., Farooq, M., Cheema, S. A., & Wahid, A. (2013). Differential response of wheat cultivars to terminal heat stress. *International Journal of Agriculture and Biology*, *15*(6).

Ortiz, R., Sayre, K. D., Govaerts, B., Gupta, R., Subbarao, G. V., Ban, T., & Reynolds, M. (2008). Climate change: can wheat beat the heat? *Agriculture, Ecosystems & Environment*, *126*(1-2), 46-58.

Oshino, T., Miura, S., Kikuchi, S., Hamada, K., Yano, K., Watanabe, M., & Higashitani, A. (2011). Auxin depletion in barley plants under high-temperature conditions represses DNA proliferation in organelles and nuclei via transcriptional alterations. *Plant, cell & environment*, *34*(2), 284-290.

Paliwal, R., Röder, M. S., Kumar, U., Srivastava, J. P., & Joshi, A. K. (2012). QTL mapping of terminal heat tolerance in hexaploid wheat (T. aestivum L.). *Theoretical and Applied Genetics*, *125*(3), 561-575.

Parry, M. A., Reynolds, M., Salvucci, M. E., Raines, C., Andralojc, P. J., Zhu, X. G., & Furbank, R. T. (2011). Raising yield potential of wheat. II. Increasing photosynthetic capacity and efficiency. *Journal of experimental botany*, *62*(2), 453-467.

Peck, A. W., & McDonald, G. K. (2010). Adequate zinc nutrition alleviates the adverse effects of heat stress in bread wheat. *Plant and soil*, *337*(1), 355-374.

Pinto, R. S., Reynolds, M. P., Mathews, K. L., McIntyre, C. L., Olivares-Villegas, J. J., & Chapman, S. C. (2010). Heat and drought adaptive QTL in a wheat population designed to minimize confounding agronomic effects. *Theoretical and applied genetics*, *121*(6), 1001-1021.

Pradhan, G. P., & Prasad, P. V. (2015). Evaluation of wheat chromosome translocation lines for high temperature stress tolerance at grain filling stage. *PLoS One*, *10*(2), e0116620.

Prasad, P. V., & Djanaguiraman, M. (2014). Response of floret fertility and individual grain weight of wheat to high temperature stress: sensitive stages and thresholds for temperature and duration. *Functional Plant Biology*, *41*(12), 1261-1269.

Prasad, P. V., Pisipati, S. R., Ristic, Z., Bukovnik, U. R. S. K. A., & Fritz, A. K. (2008). Impact of nighttime temperature on physiology and growth of spring wheat. *Crop science*, *48*(6), 2372-2380.

Prasad, P. V. V., Staggenborg, S. A., & Ristic, Z. (2008). Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. *Response of crops to limited water: Understanding and modeling water stress effects on plant growth processes*, *1*, 301-355.

Akter, N., & Islam, M. R. (2017). Heat stress effects and management in wheat. A review. *Agronomy for sustainable development*, *37*(5), 1-17.

Rahman, M. A., Chikushi, J., Yoshida, S., & Karim, A. J. M. S. (2009). Growth and yield components of wheat genotypes exposed to high temperature stress under control environment. *Bangladesh Journal of Agricultural Research*, *34*(3), 360-372.

Raines, C. A. (2011). Increasing photosynthetic carbon assimilation in C3 plants to improve crop yield: current and future strategies. *Plant physiology*, *155*(1), 36-42.

Rangan, P., Subramani, R., Kumar, R., Singh, A. K., & Singh, R. (2014). Recent advances in polyamine metabolism and abiotic stress tolerance. *BioMed Research International*, *2014*.

Pasala, R. K., Khan, M. I. R., Minhas, P. S., Sultana, R., Per, T. S., Deokate, P. P., & Rane, J. (2016). Can plant bioregulators minimize the crop productivity losses caused by drought, heat stress and salinity? An integrated review.

Reidsma, P., Ewert, F., Lansink, A. O., & Leemans, R. (2010). Adaptation to climate change and climate variability in European agriculture: the importance of farm level responses. *European journal of agronomy*, *32*(1), 91-102.

Reynolds, M., & Langridge, P. (2016). Physiological breeding. *Current Opinion in Plant Biology*, *31*, 162-171.

Ristic, Z., Bukovnik, U., Momčilović, I., Fu, J., & Prasad, P. V. (2008). Heat-induced accumulation of chloroplast protein synthesis elongation factor, EF-Tu, in winter wheat. *Journal of plant physiology*, *165*(2), 192-202.

Ristic, Z., Bukovnik, U., & Prasad, P. V. (2007). Correlation between heat stability of thylakoid membranes and loss of chlorophyll in winter wheat under heat stress. *Crop Science*, *47*(5), 2067-2073.

Ruelland, E., & Zachowski, A. (2010). How plants sense temperature. *Environmental and experimental botany*, *69*(3), 225-232.

Sareen, S., Tyagi, B. S., Tiwari, V., & Sharma, I. (2012). Response estimation of wheat synthetic lines to terminal heat stress using stress indices. *Journal of Agricultural Science (Toronto)*, *4*(10), 97-104.

Savicka, M., & Škute, N. (2010). Effects of high temperature on malondialdehyde content, superoxide production and growth changes in wheat seedlings (Triticum aestivum L.). *Ekologija*, *56*(1), 26-33.

Semenov, M. A. (2009). Impacts of climate change on wheat in England and Wales. *Journal of the Royal Society Interface*, *6*(33), 343-350.

Sharma, A., RAWAT, R., VERMA, J., & JAISWAL, J. (2013). Correlation and heat susceptibility index analysis for terminal heat tolerance in bread wheat. *Journal of Central European Agriculture*.

Sharma, I., Tyagi, B. S., Singh, G., Venkatesh, K., & Gupta, O. P. (2015). Enhancing wheat production-A global perspective. *Indian Journal of Agricultural Sciences*, *85*(1), 3-13.

Sharma, P., Jha, A. B., Dubey, R. S., & Pessarakli, M. (2012). Reactive oxygen species, oxidative damage, and

antioxidative defense mechanism in plants under stressful conditions. *Journal of botany*, *2012*.

Sharma, R. C., Tiwary, A. K., & Ortiz-Ferrara, G. (2008). Reduction in kernel weight as a potential indirect selection criterion for wheat grain yield under terminal heat stress. *Plant breeding*, *127*(3), 241-248.

Sharma-Natu, P., Sumesh, K. V., & Ghildiyal, M. C. (2010). Heat shock protein in developing grains in relation to thermotolerance for grain growth in wheat. *Journal of Agronomy and Crop Science*, *196*(1), 76-80.

Shewry, P. R. (2009). Wheat. *Journal of experimental botany*, *60*(6), 1537-1553.

Sikder, S., & Paul, N. K. (2010). Effects of post-anthesis heat stress on stem reserves mobilization, canopy temperature depression and floret sterility of wheat cultivars. *Bangladesh Journal of Botany*, *39*(1), 51-55.

Singh, A., Singh, D., & Gill, B. S. (2011, February). Planting time, methods, and practices to reduce the deleterious effects of high temperature on wheat. In *International conference on preparing agriculture for climate change, Punjab Agric. Univ. Ludhiana* (pp. 338-339).

Singh, A., Singh, D., Kang, J. S., & Aggarwal, N. (2011). Management practices to mitigate the impact of high temperature on wheat: a review. *IIOABJ*, *2*(7), 11-22.

Song, W. F., Zhao, L. J., Zhang, X. M., Zhang, Y. M., Li, J. L., Zhang, L. L., & Xiao, Z. M. (2015). Effect of timing of heat stress during grain filling in two wheat varieties under moderate and very high temperature. *Indian Journal of Genetics*, *75*, 121-124.

Šramková, Z., Gregová, E., & Šturdík, E. (2009). Chemical composition and nutritional quality of wheat grain. *Acta Chimica Slovaca*, *2*(1), 115-138.

Sumesh, K. V., Sharma-Natu, P., & Ghildiyal, M. C. (2008). Starch synthase activity and heat shock protein in relation to thermal tolerance of developing wheat grains. *Biologia plantarum*, *52*(4), 749-753.

Suzuki, N., Koussevitzky, S. H. A. I., Mittler, R. O. N., & Miller, G. A. D. (2012). ROS and redox signalling in the response of plants to abiotic stress. *Plant, cell & environment*, *35*(2), 259-270.

Suzuki, N., Miller, G., Morales, J., Shulaev, V., Torres, M. A., & Mittler, R. (2011). Respiratory burst oxidases: the engines of ROS signaling. *Current opinion in plant biology*, *14*(6), 691-699.

Talukder, A. S. M. H. M., McDonald, G. K., & Gill, G. S. (2014). Effect of short-term heat stress prior to flowering and early grain set on the grain yield of wheat. *Field Crops Research*, *160*, 54-63.

Talukder, S. K., Babar, M. A., Vijayalakshmi, K., Poland, J., Prasad, P. V. V., Bowden, R., & Fritz, A. (2014). Mapping QTL for the traits associated with heat tolerance in wheat (Triticum aestivum L.). *BMC genetics*, *15*(1), 1-13.

Tang, Y., Wu, X., Li, C., Wu, C., Ma, X., & Huang, G. (2013). Long-term effect of year-round tillage patterns on yield and grain quality of wheat. *Plant Production Science*, *16*(4), 365-373.

Teixeira, E. I., Fischer, G., Van Velthuizen, H., Walter, C., & Ewert, F. (2013). Global hot-spots of heat stress on agricultural crops due to climate change. *Agricultural and Forest Meteorology*, *170*, 206-215.

Trethowan, R. M., & Mujeeb-Kazi, A. (2008). Novel germplasm resources for improving environmental stress tolerance of hexaploid wheat. *Crop science*, *48*(4), 1255-1265.

Tripathi, A., Tripathi, D. K., Chauhan, D. K., Kumar, N., & Singh, G. S. (2016).

Paradigms of climate change impacts on some major food sources of the world: a review on current knowledge and future prospects. *Agriculture, ecosystems & environment*, *216*, 356-373.

Ugarte, C., Calderini, D. F., & Slafer, G. A. (2007). Grain weight and grain number responsiveness to pre-anthesis temperature in wheat, barley and triticale. *Field Crops Research*, *100*(2-3), 240-248.

Upreti, K. K., & Sharma, M. (2016). Role of plant growth regulators in abiotic stress tolerance. In *Abiotic stress physiology of horticultural crops* (pp. 19-46). Springer, New Delhi.

Vijayalakshmi, K., Fritz, A. K., Paulsen, G. M., Bai, G., Pandravada, S., & Gill, B. S. (2010). Modeling and mapping QTL for senescence-related traits in winter wheat under high temperature. *Molecular Breeding*, *26*(2), 163-175.

Wang, H., Wang, H., Shao, H., & Tang, X. (2016). Recent advances in utilizing transcription factors to improve plant abiotic stress tolerance by transgenic technology. *Frontiers in plant science*, *7*, 67.

Wang, X., Cai, J., Jiang, D., Liu, F., Dai, T., & Cao, W. (2011). Pre-anthesis high-temperature acclimation alleviates damage to the flag leaf caused by post-anthesis heat stress in wheat. *Journal of plant physiology*, *168*(6), 585-593.

Wang, X., Cai, J., Liu, F., Dai, T., Cao, W., Wollenweber, B., & Jiang, D. (2014). Multiple heat priming enhances thermo-tolerance to a later high temperature stress via improving subcellular antioxidant activities in wheat seedlings. *Plant Physiology and Biochemistry*, *74*, 185-192.

Waraich, E. A., Ahmad, R., Ashraf, M. Y., Saifullah, & Ahmad, M. (2011). Improving agricultural water use efficiency by nutrient management in crop plants. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, *61*(4), 291-304.

Waraich, E. A., Ahmad, R., Halim, A., & Aziz, T. (2012). Alleviation of temperature stress by nutrient management in crop plants: a review. *Journal of soil science and plant nutrition*, *12*(2), 221-244.

Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.

Yamamoto, Y., Aminaka, R., Yoshioka, M., Khatoon, M., Komayama, K., Takenaka, D., & Yamamoto, Y. (2008). Quality control of photosystem II: impact of light and heat stresses. *Photosynthesis Research*, *98*(1), 589-608.

Yang, J., Kloepper, J. W., & Ryu, C. M. (2009). Rhizosphere bacteria help plants tolerate abiotic stress. *Trends in plant science*, *14*(1), 1-4.

Yin, X., Guo, W., & Spiertz, J. H. (2009). A quantitative approach to characterize sink–source relationships during grain filling in contrasting wheat genotypes. *Field Crops Research*, *114*(1), 119-126.

Zhao, H., Dai, T., Jing, Q., Jiang, D., & Cao, W. (2007). Leaf senescence and grain filling affected by post-anthesis high temperatures in two different wheat cultivars. *Plant Growth Regulation*, *51*(2), 149-158.

Zheng, B., Chenu, K., Fernanda Dreccer, M., & Chapman, S. C. (2012). Breeding for the future: what are the potential impacts of future frost and heat events on sowing and flowering time requirements for A ustralian bread wheat (T riticum aestivium) varieties?. *Global Change Biology*, *18*(9), 2899-2914.