International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 29-05-2022, Accepted: 14-06-2022, Published: 30-06-2022
Volume 7, Issue 6, 2022, Page No. 98-102

A review on impacts of high temperature stress on Indian mustard (*Brassica juncea*)

Pulipati Ramya Sree
Department of Genetics and Plant Breeding, Lovely Professional University, Jalandhar, Punjab, India

Abstract
Indian mustard (*Brassica juncea*), an amphidiploid with genetic constitution of 2n=36 (AABB) and a member of "*Cruciferae*" family grown as an cool season crop in many parts of the world. It is second most important vegetable oilseed crop in India and ranks 5th position in vegetable oil economy sharing 7.4% of world oilseed output. In agriculture, abiotic stress factors are the primary limiting factor for plant development and productivity. Being an c3 plant and thermosensitive nature this crop is adversely affected by high temperature stress due to climate changing scenarios. Abiotic stress mainly high temperature stress severely affects many physiological (chlorophyll content, osmotic water potential) morphological (Plant height, leaf area index, dry matter accumulation) and biochemical (antioxidant enzymes) mechanisms and disrupt normal plant growth and development, especially in the early phases of development, which is a major concern in many agricultural regions across the world. Climate change is an issue today, and researchers are working to understand its influence on crop development and production, as well as to discover appropriate management solutions to keep crops productive in the face of changing climates. In this review paper information on impacts of high temperature on morphological, biochemical, physiological, yield and yield attributing traits are discussed and the adaptive strategies, Breeding mechanisms for heat stress are discussed.

Keywords: Indian mustard, heat stress, yield and yield attributes

Introduction

Indian mustard (*Brassica juncea*) is an amphidiploid plant (2n=36) belongs to mustard family called *Brassicaceae*. Brassicas are second largest most important vegetable oil seed crop followed by soyabean in area and production. Indian mustard occupies 90% of area under brassica oil seeds in India. This crop grows in a variety of Agro-ecological conditions, including timely / late planted, rainfed / irrigated, mixed crop and sole crop with cereals (wheat, barley, etc.) and rabi (October-April) pulses (chickpea, lentil etc.). Intercropping with wheat, as well as late seeding after rice and cotton, subject this crop to considerable temperature stress during the reproductive period. Agricultural crop production has been severely affected by a variety of adverse environmental conditions across the world. Heat/high temperature and drought stresses are emerging as the most potent constraints to crop production owing to shrinking precipitation and drastically changing rainfall patterns (Fahad *et al* 2017). Global earth temperatures raised by 0.74 degrees Celsius over the twentieth century and are expected to rise by 1.1–6.4 degrees Celsius by 2100 (IPCC 2007) [1]. Heat stress disturbs plant's cellular homeostasis and affects protein denaturation/synthesis, membrane integrity, etc. often leading to cell injury and even death (Liu *et al* 2014) [4]. The adverse effects on plants of temperatures higher than the optimal temperature is considered as Heat Stress**.** Heat stress is a major threat to agricultural production across the world (Hall 2001) [3]. High temperatures during crop establishment are becoming a major hindrance to rapeseed- mustard production in India. Heat stress is an intricate function of duration, intensity, rate of temperature increase. Several studies show that temperature fluctuation impacts the grain and seed production of annual crops (Semenor and porter 1995). Flowering time has a significant impact on seed output, and a 3°C increase in maximum daily temperature (21-24°C) during flowering resulted in a 430 kg/ha decrease in canola seed yields (Nutall *et al* 1992). High temperature in Brassica caused flower abortion with appreciable loss in seed yield (Rao *et al* 1992) [5] and has been identified as one of the leading causes of yield and dry matter output reductions in many crops, including maize (Giaveno *et al*). Heat stress has been shown to reduce the concentration of chlorophyll a, chlorophyll b, and total chlorophyll content in crop plants. It has also been discovered that high temperatures have a negative impact on plant pigment content. Many plant species' morphological, biochemical, agronomical, and physiological processes are slowed by excessive heat stress, resulting in substantial yield loss. Climate change is an issue today, and researchers are working to understand its influence on crop development and production, as well as to discover appropriate management solutions to keep crops productive in the face of changing climates.

High Temperature Impact on Morphological Characters

Optimal temperature for crop growth and development of Indian mustard is 280C. slight increase in temperature results drastic changes in cool season crops. change in temperature from 3-4 degree Celsius from mean high temperature after 30-45 DAS reduces the growth of the Indian mustard. Heat stress effects on seed germination, loss of vigour resulting in poor establishment and reduced emergence. Morphological characters include plant height is significantly reduced by 22.8% at high temperatures conditions when sown in late sowing and it is due to decline in photosynthetic products limiting plant to reach its genetic potential because of decreased soil moisture (M. Singh *et al* 2014) [13, 24] and it is negatively influenced that might be due to less availability of water, light thus decreasing the photosynthetic activity. Crop growth rate, Leaf area index and Plant height are significantly reduced during terminal high temperature under controlled conditions and these parameters are also used for the identification of stress tolerant genotypes for further future breeding(j s Chauhan *et al*) warmer temperature reduced the leaf area index (LAI) which in turn lowered the Radiation use efficiency results finally decreased net photosynthesis and reduces dry matter accumulation in Indian mustard crop and it was observed under Info crop Model in mustard (Boomiraj *et al* 2010) [23]. Reduced plant height during heat stress seems to be relate with impaired meristematic cell division and elongation (Saini *et al* 1983). High temperatures reduced relative growth rate, net assimilation rate in main shoot dry mass in pearl millet, sugarcane, and maize (Ashraf *et al* 2004).Number of branches per plant has also been reduced under high temperature. Temperature of 35/15 degree Celsius of day and night temperatures reduced the dry matter accumulation up to 14% and moderate periods of high temperature also effects the dry matter in three species of mustard (Angadi *et al* 2003)

High Temperature Impact on Physiological Characters

Rise in air temperature result in rapid plant growth and shortens the duration of crop consequently reduces the cumulative light perception and absorption rate over the plant life cycle, and also disturbs the fundamental process such as whole plant metabolic activities includes respiration, carbon assimilation, resulted in malformed organs at vegetative stage(Driedonks *et al* 2016) [9] and increases transpiration rate and stomatal conductance while decreasing water usage efficiency and chlorophyll 'a' levels in Chinese cabbage (oh., *et al* 2014) [10] it has negative impact on several processes in plants, including photosynthesis, dry matter translocation, and stomatal exchanges, all of which impact their growth phases. Heat stress inhibited photosynthesis by altering the structure of thylakoids (Karim *et al* 1997) [11] resulting in formation of antennae depleted photosystem II resulting in diminished photosynthetic and respiratory activities (Zhang *et al* 2005). High temperature cause generation of free radicals (ROS) causing damage to oxidative system (knight., *et al*2001) as measured by electrolyte leakage and lipid peroxidation. ROS produced under heat stress react with unsaturated lipids in membranes, resulting in lipid peroxidation and MDA production. MDA causes cell membrane damage (da costa *et al*+) and it disrupts several biomolecules such as lipids, proteins, DNA, and so on causing catastrophic effects on plant metabolic activities. The inactivation of Rubisco enzyme central enzyme involved in photosynthesis due to breakdown of Rubisco activase caused the formation of xylulose-1,5- bisphosphate, which is thought to be an inhibitory molecule, when the temperature was raised slightly (sage *et al* 2008). Temperature stress affects various physiological parameters of plant like relative water content (RWC), membrane stability index (MSI) and chlorophyll content, chlorophyll stability index. these parameters are the selection indices in selection of Indian mustard genotypes for tolerant lines. MSI is declined under high temperature is seen in Pusa Agrani with 68.88% (Sudhir kumar 2013) which is also been reported in wheat (Almeselmani *et al* 2009) [21]

Impact on Yield and Yield Attributing Characters

Yield is a complex trait with a polygenic inheritance pattern that makes it more susceptible to environmental changes and it is result of genotype and environment interaction. Changes in sowing time subject the crop cycle to a range of environmental conditions, affecting the length of phenological phases. Mustard crop when grown after harvesting of kharif season crops i.e., rice, soyabean, sesamum faces high temperature effect at terminal stages. In agriculture, abiotic stress factors are the primary limiting factor for plant development and productivity. High temperature stress accelerates plant development, reducing both growth and crop production. Changes in sowing time subject the crop cycle to a range of environmental conditions, affecting the length of phenological phases. Phenological shifts are mostly caused by changes in photoperiod and temperature, which affect numerous plant structures (e.g., number of leaf primordia and rate of leaf emergence), crucial for crop phenology. Delay in planting, face adverse weather during the floral phase, pollination, and pod formation can all contribute to a reduction in the span of the maturity period, the number of pods per plant, weight of seeds, and, ultimately, a reduction in grain yields. At maturity, high temperatures prevent starch accumulation into grain, lowering crop output. Because mustard is very susceptible to environmental factors, climate change might have a big impact on its productivity. Temperature stress causes the highest agricultural production loss during flowering and grain filling, most likely due to sensitivity during pollen and grain development, anthesis, and fertilization. The loss in seed weight caused by temperature stress has been related to the reduction in seed size and poor growth. Heat exposure during the seed filling stage has a direct influence on yield because rapid senescence impairs seed setting, eventually resulting to weight reduction (Siddique *et al*). short period of high temperature resulted in significant increase in abortion frequency of young reproductive organs. High temperature at both night and day time interrupted the development and rapid absiscion of reproductive organs (guilioni *et al* 1997).grain yield is decreased by 2.01q/ha per degree rise in seasonal temperature. Rise in temperature from 21-14 degree Celsius resulted in decreasing seed yied in canola. floral sterility and yield loss has been observed when temperature greater than 27 degree Celsius in Brassica juncea.(Morrison and stewart

2002).30 to 40% reduction in yield has been reported when temperature is raised 3.5 to 4.8 degree Celsius from normal temperature during seedling stage and terminal stage in Indian mustard (vikranth singh *et al* 2016)

Biochemical Parameters Effected By High Temperatures

The growth and development of plant involves several number of biochemical reactions all of which are sensitive to some degree of temperature. Biochemical parameters includes both enzymatic and non-enzymatic contents. Non enzymatic parameters includes Proline, Ascorbic acid, Carotenoids. Proline which is an secondary amino acid accumulated under adverse environment conditions like high temperature helps the plant to maintain relative water content and osmotic potential and their corelation was observed in Indian mustard (Tyagi *et al* 1999) it is accumulated more in thermotolerant genotypes than thermosensitive genotypes with the significant difference of 36.8% to 28.1% in RGN 368 and RH-0749 (Narender mohan 2017). oxidative damage has been reduced by carotenoid synthesis which is a class of isoprenoids in plants and ascorbic acid which acts as a reducing agent concentrations has been increased during terminal heat stress in temperature tolerant genotypes than in stress tolerant genotypes. Enzymatic activators are stress indicators includes Hydrogen peroxide(H2o2) Higher accumulation of this stress indicator has been observed in heat stress conditions in Indian mustard (Sudhir 2010) and concentration will be higher in stress sensitive genotypes reported by(Rani *et al* 2016., Narender mohan 2017) in wheat it was reported by (Li *et al* 2004). Malonialdehyde (MDA) which is accumulated due to lipid peroxidation caused by reactive oxygen species (ROS) increased under high temperature results in higher oxidative damage, less accumulation of this will result in selection of stress tolerant genotypes in mustard (Wilson *et al* 2012).In order to counter effect to ROS damage plant have synthesised Antioxidant enzymes includes super oxide dismutase (SOD), catalase (CAT), Peroxidase (POD) glutathione peroxidase (GPX) and Ascorbate peroxidase(APX) (Lee and lee., 2000, Zhang *et al* 2004) all of these were increased under heat stress conditions in Indian mustard and the genotypes which are able to withstand terminal heat stress showed this increment significantly higher than sensitive genotypes. Increased SOD activity in Indian mustard was reported by (Sairam *et al* 2000, rani *et al* 2006, Sudhir 2010, Narender), Increased Peroxidase activity up to 52.26% to 22.11% in tolerant sensitive cultivars has been observed by (Wilson *et al* 2012) in Indian mustard.

Impact of Heat Stress on Oil Content

Heat stress resulted in increased sugar content and decreased seed oil accumulation indicating that incorporation of carbohydrates, Triglycerides were also impaired (huang *et al*) Seed oil percentage has been decreased due to high temperature and seed oil can be achieved maximum when suitable conditions of temperature and relative humidity are there. The oil productivity depends upon the grain yield and percentage of oil in grain. oil content has been varied from under stress and nonstress conditions with significant difference of 40.01 % to 38.1% in Brassica juncea andit was affected by terminal heat stress (Narender mohan)

Adaptive Strategies to Cope With Heat Stress

In response to external environments plant adapt themselves to resist the conditions by adapting different mechanisms.

Heat Tolerance: The ability of the genotypes to survive under same high temperature conditions when compared to others referred as heat tolerance. Long-term evolutionary phenological processes of heat tolerance include membrane stability, stem reserve mobilization, osmoregulation, decreased heat sensitivity of photosystem II, photosynthate translocation, and numerous proteins in late embryogenesis have been developed inside. Heat treatment raised relative levels of linolenic acid (among galactolipids) and trans3- hexaldecanoic acid (among phospholipids) in a mutant wheat line with improved heat tolerance in comparison to the wild kind.

Heat Avoidance: It refers to a genotype's capacity to disperse radiation energy and so prevent an increase in plant temperature to a stress threshold. In response to acute heat stress, plants developed short-term responsive mechanisms such as leaf rolling, transpiration cooling, and changes in membranous composition. Membrane lipid saturation is thought to be a key factor in high temperature tolerance. Various cis-acting elements and transcription factors are involved in the signal transduction pathway for adaptation under stress conditions (Shinozaki *et al*) Plants may be subjected to many forms of stress at various phases of growth, and their stress-response systems may differ in different tissues.(Quietsch *et al*).Exogenous application of salicylic acid(SA) to Indian mustard plants encounters both direct and indirect injuries caused by high temperature by elevating antioxidative enzymes like superoxide dismutase, catalase and peroxidase ativities and proline accumulation is also elevated. production of heat shock proteins (hsp 70) helps in preventing improper folding of proteins and acts as chaperonin involved in heat tolerance and to other stresses.

Breeding Mechanisms for High Temperature Stress

Among diverse crops, the conventional breeding technique to developing heat tolerance cultivars requires the least amount of work. Using some of the incredibly important traits/genes from wild accessions in ongoing breeding efforts may be difficult, but a methodical approach can assist overcome this limitation and benefit from the amount of variety held in wild species and accessions. Exotic libraries, which are made up of marker-defined genomic sections extracted from wild species and introgressed onto the background of top crop lines, provide plant breeders a valuable chance to improve the agricultural performance of current crop types. Molecular genetic markers are a powerful tool for studying plant genomes and how heritable features relate to underlying genetic diversity. anonymous molecular marker methods such as amplified fragment length polymorphism (AFLP) are frequently used. Genetic enhancement using molecular marker technology has revolutionized plant breeding. The combination of traditional QTL mapping, QTL-seq analysis, and RNA-sequence can quickly discover heat- tolerance QTLs and high-temperature stress-responsive genes. Latest development in ‘omics’ after post genomic era such as next generation sequencing, modelling of different physiological and molecular understanding, genome scale molecular analysis, and correlation of these molecular analysis with physiology of the plant provides an execute move to adaptability and productivity under heat stress. Comprehensive proteome profiling activities are beneficial strategies for better understanding heat stress reactions and enhancing the breeding of heat- tolerant crops in response to global temperature rise

Conclusion

Increasing populations rapidly demands more production of vegetable oilseeds which will be diminished under these critical climate situations. In order to meet this demand and for global food security there is a need to study the effects of increasing temperature on plant developmental stages which helps in determining the parameters results in better yields and selection of thermoresistant genotypes under high temperature stress for further future breeding. The use of phenotyping methodologies to categorise heat stress responses into the proper tolerance, escape, or avoidance categories is an important first step in developing stress- resistant crops for the future hotter environment

References

1. IPCC: Boko M, Niang I, Nyong A, Vogel C, Githeko A, Osman-Elasha B *et al*. Africa in ML Parry, OF Canziani, JP Palutikof, PJ Van der Linden, and CE Hanson, editors. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, 2007.
2. Semenov MA, Porter JR. Climatic variability and the modelling of crop yields. Agricultural and forest meteorology,1995:73(3-4):265-283.
3. Hall AE. Heat Stress and its impact. Plant Stress. Ed A Blum, 2001. http://www. plantstress. com/Articles/heat_i/heat_i. htm.
4. Liu F, Wang W, Sun X, Liang Z, Wang F. RNA-Seq revealed complex response to heat stress on transcriptomic level in Saccharina japonica (Laminariales, Phaeophyta). Journal of Applied Phycology,2014:26(3):1585-1596.
5. Rao GU, Jain A, Shivanna KR. Effects of high temperature stress on Brassica pollen: viability, germination and ability to set fruits and seeds. Annals of botany,1992:69(3):193-198.
6. Giaveno C, Ferrero J. Introduction of tropical maize genotypes to increase silage production in the central area of Santa Fe, Argentina. Crop Breeding and Applied Biotechnology,2003:3(2).
7. Chauhan JS, Meena ML, Saini MK, Meena DR, Singh M, Meena SS *et al*. Heat stress effects on morpho-physiological characters of Indian mustard (Brassica juncea L.). 16th Australian Research Assembly on Brassicas, Ballarat Victoria, 2009, 91- 97.
8. Ashraf M, Hafeez M. Thermotolerance of pearl millet and maize at early growth stages: growth and nutrient relations. Biol. Plant,2004:48:81-86.
9. Driedonks N, Rieu I, Vriezen WH. Breeding for plant heat tolerance at vegetative and reproductive stages. Plant reproduction,2016:29(1):67-79.
10. Oh S, Moon KH, Son IC, Song EY, Moon YE, Koh SC. Growth, photosynthesis and chlorophyll fluorescence of Chinese cabbage in response to high temperature. Korean Journal of Horticultural Science & Technology,2014:32(3):318-329.
11. Karim MA, Fracheboud Y, Stamp P. Heat tolerance of maize with reference of some physiological characteristics. Ann. Bangladesh Agri,1997:7:27-33.
12. Griffin JJ, Ranney TG, Pharr DM. Heat and drought influence photosynthesis, water relations, and soluble carbohydrates of two ecotypes of redbud (Cercis canadensis). J. Am. Soc. Hortic. Sci,2004:129:497-502.
13. Singh M, Rathore SS, Raja P. Physiological and stress studies of different rapeseed- mustard genotypes under terminal heat stress. International Journal of Genetic Engineering and Biotechnology,2014:5(2):133-142.
14. Siddique KHM, Loss SP, Regan KL, Jettner RL. Adaptation and seed yield of cool season grain legumes in Mediterranean environments of south-western Australia. Aust J Agric Res,1999:50:375-388. https://doi.org/10.1071/a98096
15. GUILIONI L, WERY J, Tardieu F. Heat stress-induced abortion of buds and flowers in pea: is sensitivity linked to organ age or to relations between reproductive organs?. Annals of Botany,1997:80(2):159-168.
16. Morrison MJ, Stewart DW. Heat stress during flowering in summer Brassica. Crop science,2002:42(3):797-803.

17. Huang R, Liu Z, Xing M, Yang Y, Wu X, Liu H *et al*. Heat stress suppresses Brassica napus seed oil accumulation by inhibition of photosynthesis and BnWRI1 pathway. Plant and Cell Physiology,2019:60(7):1457-1470.
18. Queitsch C, Hong SW, Vierling E, Lindquist S. Heat shock protein 101 plays a crucial role in thermotolerance in Arabidopsis. The Plant Cell,2000:12(4):479-492.
19. Shinozaki KY, Shinozaki K. Transcriptional regulatory networks in cellular responses and tolerance to dehydration and cold stresses. Annu Rev Plant Biol,2006:57:781-803.
20. Kumar S, Sairam RK, Prabhu KV. Physiological traits for high temperature stress tolerance in Brassica juncea. Indian Journal of Plant Physiology,2013:18(1):89-93.
21. Almeselmani M, Deshmukh P, Sairam R. High temperature stress tolerance in wheat genotypes: role of antioxidant defence enzymes. Acta Agronomica Hungarica,2009:57(1):1-14.
22. Singh V, Bhajan C. Evaluation of Indian mustard genotypes to heat stress in irrigated environment-seed yield stability and physiological model. Journal of crop science and biotechnology,2016:19(5):333-339.
23. Boomiraj K, Chakrabarti B, Aggarwal PK, Choudhary R, Chander S. Assessing the vulnerability of Indian mustard to climate change. Agriculture, ecosystems & environment,2010:138(3-4):265-273.
24. Singh M, Rathore SS, Raja P. Physiological and stress studies of different rapeseed-mustard genotypes under terminal heat stress, 2014.
25. Mohan N. Biochemical and Morpho-physiological Changes in Indian Mustard [Brassica Juncea (L.) Czern & Coss.] Under Terminal Heat Stress [With CD Copy] (Doctoral dissertation, Biochemistry, CCSHAU, Hisar), 2017.