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Review Article

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Effect of Thermo-Stress on Morpho-Phenological and Reproductive Behaviour of Groundnut (*Arachis hypogaea* L.)

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Abstract

Global warming is defined as the change in climate in terms of increased frequency of extreme weather events as well as increased air temperature and vapour pressure deficit of air, spatial and temporal change in rainfall. In spite of beneficial effect of increased atmospheric CO_2 concentration, climate change will adversely impact the production and productivity of groundnut grown in subtropical and tropical regions of the world. Increasing temperature in present day is the headache for the agricultural sectors. Most of the agricultural food crops are affected badly due to the temperature stress. Crop production is limiting due to the harsh effect of drought and thermo-stress. Groundnut (*Arachis hypogaea* L.), the king of oilseeds having a rich source of polyunsaturated fatty acids (oleic and linoleic acids) is in demand among people due to its good quality protein, oil, minerals and vitamins. It also shows a drastic change in their vegetative and reproductive stage when exposed to high temperature stress. In the present review we will discuss about different morpho-phenological and reproductive changes occur when temperature stress will coincide with the different growth period of groundnut.

Keywords: Climate change, groundnut, morpho-phenology, thermo stress

1. Introduction

Groundnut (*Arachis hypogaea* L.) is among the major leguminous crops grown in world and it is the third largest oilseed crop after soybean and seed cotton globally (Marfo et al., 1999). About two-thirds of world production is used for oil extraction and it is an essential source of vegetable protein and oil in sub-Saharan Africa (Marfo et al., 1999). Groundnut seed contains 44% to 56% oil and 22% to 30% protein on dry seed basis and is a rich source of minerals (phosphorus, calcium, magnesium, and potassium) and vitamins (Savage and Keenan, 1994). Groundnut root nodules can fix high amount of atmospheric nitrogen and enhances the sustainability of the farming and the haulm is used as fodder (Marfo et al., 1999). The young pods may be consumed as a vegetable whiles young leaves and tips are utilized as cooked green vegetable (Martin and Ruberte, 1975). In groundnuts, the basic reproductive units constitute the flowers. Flowering and flowers play an important role in all seed crops. The total number of flowers produced depends upon the genotype as well as between the sequential or alternate type (Cahanerand Ashri, 1974). Ramanatha Rao in 1988 reported that Groundnut plants start flowering about 30-40 DAS and maximum flower production occurs 6-10 weeks after planting. Plant depends on various physical properties of the nature like temperature, light, humidity etc. to grow and prosper. But it will cause stress when its availability touches the extremities and become a stress for plant. These in general called as abiotic stress. Among these abiotic stresses, temperature stress used to be a part of Heat stress and causes multidirectional changes in plants vegetative and reproductive level and ultimately results in reduction in yield.

Various mechanisms are adopted by plants include long-term evolutionary, morphological and phenological adaptations to escape or avoid the stress situation. Expose of plants to high temperatures brings change in orientation of leaf, change in leaf structure, transpiration cooling mechanism were adopted by plant (Wahid, 2007). In present scenario, the changing climate in terms of increased frequency of extreme weather events leads to increased air temperature. It is observed that decreased crop productivity is resulted from 1-2°C rises in air temperature at lower latitudes, especially in the seasonally dry tropical regions (IPCC, 2007). Bagnall and King (1991) reported that temperature affects the reproductive development under controlled conditions. Day temperature more than 34°C decreased fruit set and resulted in fewer numbers of pods (Prasad et al., 1999b and 2000a). Further because of high temperature reproductive stages of plant faces poor pollen viability, reduction in pollen production and poor growth of pollen tube which lead to poor fertilization of flowers and there by decreased fruit set (Prasad et al., 1999b, 2000a and 2001). The groundnut crops when undergo high temperature stress, may face several problems like reduction in germination, growth and development, Photosynthesis, oxidative stress in consequence of high temperature and finally decreased in quantity and quality of groundnut production (Singh et al., 2016) (Figure 1).

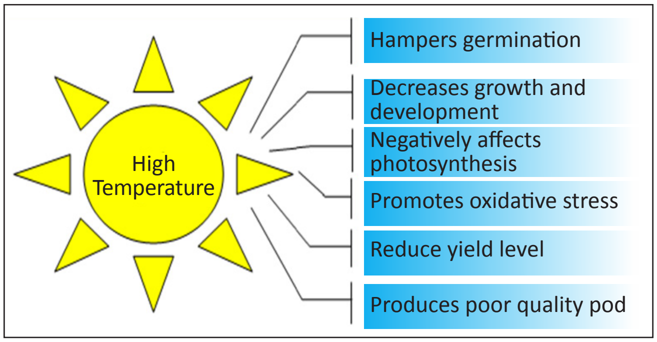

Figure 1: Major effects of high temperature in groundnut plants

Therefore to maintain the yield and quality of production, we need to be aware of the vegetative as well as reproductive changes and the mechanism that plant adopts during high temperature stress to mitigate the problem. In this review, we highlighted the morpho-phenological changes, the reproductive changes in groundnut due to heat stress and tried to establish the relation between them so that a better understanding about the heat stress and the groundnut cultivation will be established in the groundnut research programme and the subsequent breeding protocols will be enhanced for its improvement.

2. Groundnut and the Thermo Stress

Plants experience various stresses throughout their lifecycle. Some plants unable to survive, some trying to escape and some tolerate the stress. To deals with stress plants follow some mechanism like producing some stress responsive genes. This helps them to withstand the stress situations.

Expose of plant to high temperature stress also creates oxidative stress thereby results in disruption of cellular membranes and affects cellular homeostasis. In response to that some genes which are related to these stress condition are activated and gives signals for the activation of different signalling molecules, osmo-protectants and some antioxidant enzymes. These signalling molecules and antioxidant enzymes play a key role in regaining the cellular homeostasis and detoxification of ROS respectively and thereby enabling plants to tolerate the high temperature stress (Figure 2).

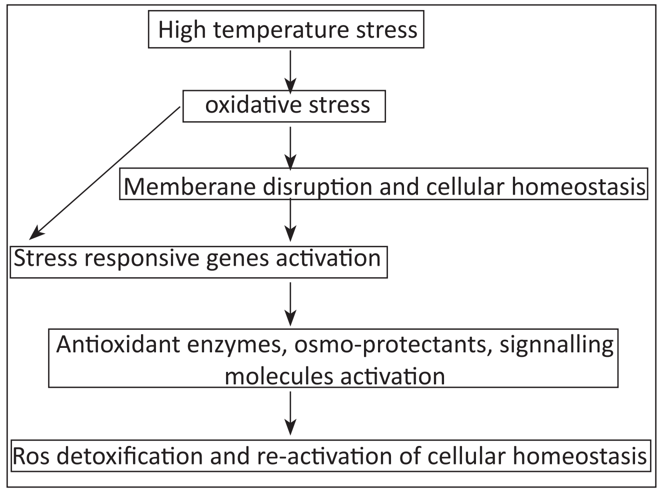

Figure 2: Mechanism behind heat stress tolerance in groundnut

3. Thermo-Stress Impose Morpho-Phenological Changes in Groundnut

Thermo stress alters plant growth, development, as well as plant yield by affecting the morphology and physiological processes in plant. Oxidative stress, created due to the production of excess reactive oxygen species (ROS) is one of the major consequence of thermo stress (Hasanuzzaman et al., 2013). According to Banterng et al. (2003) and Frimpong (2004), early planting due to longer vegetative and generative duration showed higher plant height while plant growth was negatively affected by late planting due to less biomass production as a result of decreased vegetative and reproductive duration (Asha, 2016). Leaf area, leaf water potential and pre-mature leaf senescence are negatively regulated by the high temperature stress which have also reduced total photosynthesis performance of plant (Hasanuzzaman et al., 2013). Asha (2016) worked on effect of temperature regimes on plant height and number of primary branches of different groundnut genotypes and observed significant among genotypes and concluded that variation in plant height and number of primary branches was due to genetical×environmental interactions. The study of periodic plant life cycle with respect to environment is known as phenology, which involves different parameters like days to flower initiation (DFI), days to 50 per cent flowering (DFF), days to pod initiation (DPI) and days to physiological maturity (DPM). Kotiet al., 1990 revealed that groundnut plant took 27-32 days for first flower to emerge in Spanish bunch and Time from sowing to first flowering was significantly affected by growing seasons and genotypes and those warmer seasons resulted in earlier flowering (Ishag, 2000).After focusing the effect of temperature regime at different growth stages, Bagnall and King (1991a) observed that under the lowest temperature regime (24/19°C) a delayed flower initiation was accompanying with reduced flower and peg production rate.

However, a significantly enhanced flower production was found in plants exposed to short-day photoperiods (Bagnall and King, 1991b). Earlier studies (Fortanier, 1957, Bolhuisand de Groot, 1959) observed an optimum temperature range of 28–30°C for vegetative growth and flowering for different groundnut varieties. On the other hand heat stress influence the plant root system negatively, which is very important to give support, helps in nutrient and water uptake as well as its transport to other plant organs (Valdes-Lopez et al., 2016), resulting in disrupted pollination, flowering, root development, and root growth stages (Sehgal et al., 2017; Cho, 2018). Muldoon (2002) suggested that During late planting as crop duration shortened severely, plant get a shorter period for the pod production thereby resulted in slightly lower rate of pod production due to reduced growth and exposure to a warmer and longer photoperiod (long day). Pilumwong et al. (2007) noticed that the duration from planting to first flower was 22 and 34 days at 35/25°C and 25/15°C, respectively for both ambient and elevated CO_2. Prasad et al. (2003) also observed high temperature (40/30°C and higher) delayed flowering, pegging and podding in groundnut. Asha (2016) worked on effect of temperature regimes on different phenological parameters in groundnut genotypes and concluded that days to flower initiation (0.825^{**}), days to 50% flowering (0.920^{**}) and days to physiological maturity (0.846^{**}) showed strong correlation with pod yield.

4. Reproductive Changes in Relation to Thermo-Stress

Reproductive parameters like flower count, pollen sterility, influenced significantly with respect to temperature regimes, genotypes and their interactions at different growth stages.

4.1. Flower count

In groundnut, the flowering is mostly dependant on temperature and photoperiod. So, number of flowers produced per plant depends on the temperature regimes and crop growth period. Bagnall and King (1991a) demonstrated the reproductive development of groundnut in the temperature range of 24/19°C to 33/28°C and concluded that total flower and total peg numbers were strongly correlated with vegetative growth. From the two groundnut cultivars (Robut 33-1 and Early Bunch) in long (16 h) and short day (12 h) treatments and they concluded the short days promoted greater flowering numbers in both groundnut cultivars as compared to long day treatment as long day exposure make the plants to face high temperature for a longer period of time (Bagnall and King, 1991b). Talwar et al. (1999) reported that high temperature (35/30°C) enhances the flower number plant^{-1} as compared to 25/25°C. In contrast, Laurie and Stewart (1993), Kiran (2014) and Rathod (2015) noticed reduction in number of flowers and duration of flowering in chickpea at high temperature. This is also supported by Dash and Chimmad (2017) in Groundnut crop. According to Kaba et al. (2014), higher number of mature pods can be pre-indicated by the maximal flower production in both the 'Chinese' and 'Kpedevi' variety. Kakani (2015) reported that differences in pattern of flowering and its number between different genotype scan take as a sign to recognise high temperature tolerance genetic adaptation. The increase in temperature, short days, light intensity and high humidity promote flower numbers in groundnut (Lee et al., 1972; Bagnall and King, 1991a & b; Talwar et al., 1999 and Prasad et al., 1999b).

4.2. Pollen sterility

Groundnut plants are particularly sensitive to hot days during flower production and anthesis period. Flower buds of groundnut at 3–5 days prior to anthesis are sensitive to temperature stress because of its simultaneous occurrence with the microspore formation (Martin et al., 1974 and Talwar et al., 1997). Ahmed et al. (1992) and Suzuki et al. (2001) reported that the male sterility in high temperature stress is a result of low pollen viability, poor anther dehiscence is also associated with early tapetal layer degeneration and carbohydrates reduction in developing pollen (Pressman et al., 2002). Hall (1992) noticed that the impact of high temperature is severe on reproductive processes when compared to the vegetative development in many crops. Prasad et al. (1999b) after working on short episodes of heat stress revealed that pollen production as well as viability inversely related with increasing day temperature from of 28 to 48°C.

High temperature stress affecting the pollen viability by altering the carbohydrates, prolines, lipids, polyamine and hormone concentration in the plants because they contribute towards pollen nutrition, Amino acid metabolism, pollen germination, scavenging of ROS and growth signalling respectively. Reduction of pollen viability is an indication of more sterile pollen which means reduction in final grain production/yield. Therefore the mechanism behind the sterile pollen production should be more focused now a day to take the groundnut production to a next level during high temperature stress (Figure 3).

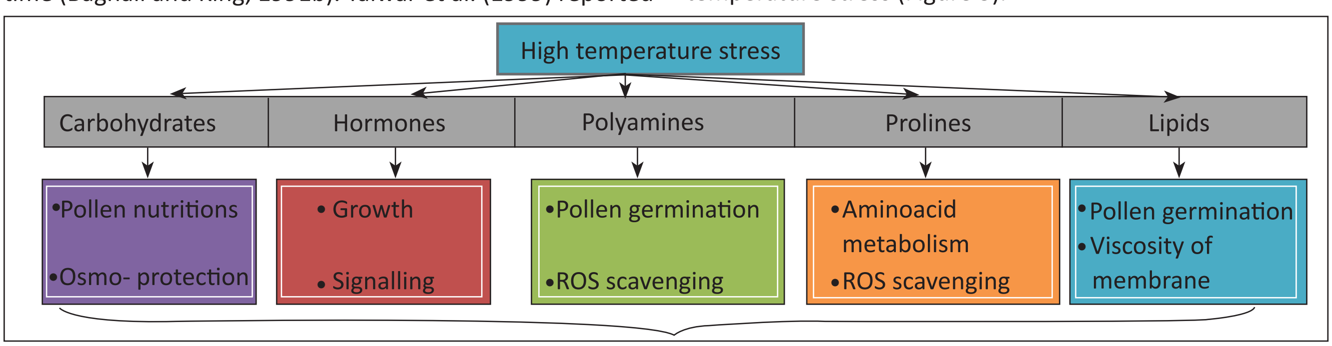

Figure 3: High Temperature stress effect on pollen viability by affecting metabolites

Talwar and Yanagihara (1999) showed that reduced pollen tube growth and increased hypanthium length is a consequence of high temperature stress (35/25°C) in heat susceptible genotypes of groundnut. According to Prasad et al. (2000a), during day air temperature of range 28-43°C the number of flower and flower bud temperature are quantitatively related with each other. The high temperature during heat stress severely affects microsporogenesis, hypanthium elongation (Pattee and Mohapatra, 1986), pollen development, anther dehiscence and pollination (Kakani et al., 2002). As per Kelly (2010), the most critical stage in temperature stress is pollen development and fertilization. Process of fertilization may contrive due to the impede function of style and ovule at anthesis. (Gross and Kigel, 1994). Embryo abortion may cause reduction in Post-fertilization fruit-set (Gross and Kigel, 1994). Pod set rate is linearly related with reduction in pollen production and viability under high temperature stress. The heat tolerant genotypes showed a viable pollen in 35/20°C (41% fertile) and at 40/25°C (13% fertile), whereas heat sensitive ones showed complete sterile pollen at 35/20°C with no *in vitro* germination. (Devasirvatham et al., 2012). Pollen maturation requires starch as an energy reserve and thus starch accumulated in the stem tissue is exploited as transitory sink during reproductive phase of plants. Starch metabolism is interrupts within the anther because of high temperature and leads to unsuccessful pollen development, thereby causes pollen mortality (Dwivedi et al., 2017). Grain yield in crops is critically dependent on successful reproductive development and evaluating pollen viability may be considered as an important criterion in selecting the heat tolerant genotype (Zhang et al., 2012).

5. Conclusion

Heat stress due to high ambient temperatures is a serious threat to crop production worldwide particularly groundnut. Along with the morphological and physiological improvement of the cultivars, the researcher should concentrate and give emphasis on the molecular knowledge of temperature stress response and tolerance mechanisms to develop temperature stress tolerant groundnut crop plants. Characterization of stress induced genes in groundnut is also important to know so that the practical evaluation of heat tolerant groundnut genotypes can be made easy.

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