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EFFECT OF HEAT STRESS IN POTATO AND THEIR MANAGEMENT

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The potato (*Solanum tuberosum* L.) belongs to the genus Solanum and family *Solanaceae*. A significant vegetable crop, *Solanum tuberosum* L. is the world's most significant non-grain food crop. Potatoes are primarily regarded as cool-season crops; they came in first among root and tuber crops and rank fourth overall, after rice, wheat, and maize. Over a billion people consume it every day, and it is grown in 158 countries (Ivana Momcilovic). China and India are the two largest potato producers in the world, accounting for more than one-third of global potato production at the moment. Potatoes are a crop that the FAO strongly recommends for food security in the twenty-first century because they are primarily traded and consumed locally. It includes roughly 79% water, 18% starch, a rich source of energy, 2% protein, and 1% vitamins, including Vitamin C, minerals like calcium and magnesium, and several trace elements (Desta *et al.,* 2023). Potatoes prefer cool temperatures ranging from 16 to 25°C, which encourage leaf growth, photosynthesis, and tuberization. High temperatures in potato crops result in reduced assimilate production, delayed tuberization, and inefficient assimilate distribution to tubers. As a result, high temperatures in the tropics are regarded a limiting factor in potato production. In the following article, we will cover the many effects of excessive heat on potatoes and how to counteract these effects.

Effect of Heat Stress on Potato

Morphological and Physiological Effects

Elevated temperatures have a number of detrimental physiological effects on this crop, including decreased early sprouting, amorphous tubers, more small-sized tubers, cracking of tubers, the formation of bitter and toxic tubers, low-quality tubers with less dry matter, secondary tuber formation, pre-harvest sprouting, irregular skin, necrosis, chlorophyll loss, reduced stem thickness, increased plant height, more small-sized leaves, higher concentration of reducing sugars, and increased susceptibility to disease (. The interior brown patches and brown discolouration in the tuber are produced by heat stress from high soil temperatures. Heat stress enhances the amounts of glycoalkoid in tubers, making the tuber bitter in flavor.

Effect on Nutrition Quality of Tuber

The "sweetening" of the tubers, primarily in the basal ends (sugar ends), may result from heat stress shifting carbohydrate metabolism away from starch synthesis and toward starch mobilization and buildup of sucrose and reducing sugars. According to a recent study, when potato plants are exposed to 35 °C during tuberization, the amount of total starch, amylopectin, and amylose in the tubers decreases by 33.70%, 7.85%, and 35.88%, respectively (Ivana Momcilovic 2019). In potato tubers, even a brief exposure to high temperatures during tuberization may exacerbate stem end chip deformities and decreasing sugar concentration. This decrease was brought on by a decrease in the activity of ADP-glucose pyrophosphorylase, granule-bound and soluble starch synthases, starch branching enzyme, and other important enzymes involved in the production of starch in tuber cells. However, an increase in the breakdown of sucrose by vacuolar acid invertase is likely the cause of the accumulation of reducing sugars.

Yield

The majority of cultivated potato cultivars are grown in temperate locations because potatoes need short days and cool weather. Consequently, one of the most important uncontrollable factors influencing potato yields is excessive temperature. Global yields of potatoes are expected to decline by 18% to 32% in the 2050s due to the effects of global warming on potato cultivation (Singh *et al*., 2019).

Tuber Induction and Tuber Initiation

Higher temperatures have a greater impact on preventing, delaying, or suppressing tuberization. Higher soil temperatures hinder stolon from developing tubers. Different reactions have been documented, with higher temperatures (25°C) delaying tuberization by two weeks.

Photosynthesis

The range of 16–20°C is ideal for both photosynthesis and respiration. Heat stress has been shown to lower the rate of photosynthesis in important agricultural plants, as seen by decreased levels of chlorophyll, bisphosphate carboxylase activity, cyclic and non-cyclic electron transport chains, and pyrophosphate regeneration effects. Application of heat stress above ground decreased tuberization, however application of heat stress below ground influenced photosynthesis and SP6A. These data, taken together, imply that tuberization is regulated by bidirectional communication between source and sink organs during heat stress.

Dry Matter Partitioning

Heat stress considerably lowers tuber yield, dry matter, and net assimilation rate. Temperatures ranging from 14°C to 22°C improve dry matter partitioning to tubers, promote tuberization, and minimize haulm development. However, high temperatures encourage the haulm's dry matter partitioning, shoot and root growth, and lower tuber yield by reducing both the size and quantity of tubers. According to reports, a rise in temperature causes a drop in tuber dry matter percentage and an increase in leaf dry matter %.

Tuber Quality

Physiological tuber disorders

Potato tubers experience physiological disorders due to heat exposure and hot, dry conditions. Internal rust or chocolate spots are a sign of necrotic brown patches in the tuber parenchyma and are caused by exposure to high temperatures. Likewise, elevated soil temperatures resulted in brown discolouration and heat necrosis within the vascular ring. The degree of stress, cultivar, developmental stage of the tuber, and environmental factors all affect these necrotic signs. Higher temperatures can cause several indications of tuber disease, such as sprouting tubers, uneven tuber shape, chain tuberization, or secondary tuber production (which is frequently linked to excessive stolon elongation and branching). Common issues, such as tuber malformation and sprouting, are linked to excessive temperature and drought stress on field conditions. On the other hand, even short-term exposure to high temperatures promotes tuber cracking, which is connected with the production of a high internal turgor pressure on potatoes. High temperatures during growth have also been shown to raise the content of steroidal glycoalkaloids in tubers, which may result in a bitter taste.

Methods To Cope with Heat Stress

Agronomic practices for better growth: Early sowing: Farmers should adjust the planting dates in response to climate change in order to increase potato output. Early planting and increased usage of inorganic nitrogen may help in lower yield loss in potatoes. In hotter locations, planting potatoes early in the growing season helps them establish before intense heatwaves, which improves their stress tolerance. On the other hand, in colder climates, planting later in the spring will guarantee maturity in the warmer months and help avoid frost damage. Potato growth and resistance to heat stress are optimized when sowing times are coordinated with local climate conditions.

Mulching: Mulching is essential for controlling heat stress in potato farming because it improves the growth conditions for potatoes by preserving soil moisture, regulating soil temperature, and lowering evaporation. Additionally, it lessens the burden on the plants by preventing the growth of weeds, which provide a competition for nutrients and water with potatoes.

Irrigation management: The potato is a crop that is sensitive to drought because of its shallow root design. Therefore, under stressful situations, improved irrigation technologies, such drip irrigation, can enhance potato yield along with qualitative attributes. Water scarcity is typically linked to heat stress. Water management is therefore essential to enhancing crop productivity during heat stress. As long as they can transpire readily, plants have been shown to be able to withstand heat stress with ease. The reason for the reduced production at high temperatures is because plants under stress from water scarcity attempt to conserve water by closing their stomata. This significantly reduces evaporative cooling, and leaves can get as hot as 50^{o} C in the absence of cooling. Thus, it can be inferred that the best practices for water management involve timing irrigation and applying water using the proper irrigation techniques.

Disbudding

The main location of gibberellin synthesis is the shoot portion. The reaction of potatoes to exogenous gibberellins may validate findings suggesting this hormone regulates tuberization. The reported impact of disbudding is determined by the amount of gibberellin that reaches stolons from the buds. High temperature may increase the quantity of endogenous gibberellins while preventing tuberization. Endogenous gibberellins are preventing tuberization. The scientists also suggested that the unfavourable effects of high temperatures on tuberization could be mitigated through physical or chemical disbudding. The removal of buds and early leaves greatly boosted tuber output, number, dry matter content, and specific gravity. This suggests that bud and younger leaf growth may have a negative influence on tuber development, possibly because to competition for assimilate (Desta *et al*., 2023).

Paclobutrazol

PBZ stimulates chlorophyll synthesis, resulting in dark green leaves on treated plants. Plants treated with PBZ had increased chlorophyll content and faster tuberization, which promoted better net leaf photosynthesis (Desta *et al.*, 2023). The effect of PBZ on the partitioning of dry matter is also extensively documented. This could be related to the role of PBZ in the production of reduced GA levels in tuber tissues, which may promote tuber sink function. The PBZ treatment of potatoes approximately increased the number of tubers per plant, but had no effect on the overall fresh weight of the tubers. PBZ increases tuber crude protein content. There is a positive link between crude protein content and dry matter content, with higher dry matter content increasing crude protein content. Plants treated with PBZ had considerably longer tuber dormancy periods. This could be attributed to the impact of PBZ in inhibiting GA production and preventing ABA catabolism (Desta *et al*., 2023).

Application of Nutrients

The growth regulators DTA-6, S-ABA, S3307, and SA significantly enhanced the agronomic characteristics of late-sown spring potatoes under high-temperature stress. They improved photosynthetic capacity, reduced stress substance accumulation, and ultimately increased yield and quality. For the late-sown tolerant variety Zhongshu Zao45 and the not-tolerant variety Yunshu 902, S-ABA and S3307 were the most effective treatments, respectively. The mechanism of these growth regulators involves balancing plantendogenous hormones, increasing antioxidant enzyme activity, and regulating plant growth and development in response to damage caused by late-sown high-temperature stress. Choosing suitable growth regulators for different varieties can achieve stable yield and improved tuber quality in late-sown spring potatoes (Huang *et al*.,2024).

Breeding Potatoes for Heat Stress

One of the primary goals of modern potato breeding programs is to produce potatoes that can withstand hot and dry regions. Wild potato germplasms, such as *Solanum chacoense*, are frequently utilized to introduce heat-tolerant genes into cultivars. Direct introduction of such germplasm into *S. tuberosum* would necessitate somatic hybridization, artificial chromosomal doubling, or sexual polyploidization through breeding diploids with *dihaploid*s of S. tuberosum, followed by tetraploidization. In breeding programs, a number of naturally occurring heat-tolerant potato species, including *S. kurtzianum* and *S. sogarandinum*, *S. chacoense*, *S. stoloniferum*, *S. demissum*, and *S. berthaultii*, can be employed to create heat-tolerant lines. The most popular method used in the past century to create abiotic stress-tolerant cultivars has been the introduction of genes from other sexually compatible wild species.

Use of resistant Verities

- Kufri Lauvkar: This variety released in 1972 by potato research institute kufri, it is a early sowing variety with yield 20-25 t/ha. It is mainly use for table purpose and heat tolerant.
- Kufri Surya: it is released in 2006 and give yield about 25-30 q/ha. The kufri surya is early maturing variety and mainly grow for processing purpose. It is heat tolerant variety.
- Kufri Lima: this variety released in 2018 and give yield around 30-35t/ha. it is medium to late maturing varieties and tolerant to early heat.
- Kufri Kiran: is a heat tolerant table potato variety suitable for early planting in north Indian plains.

Conclusion

Heat stress significantly impacts potato cultivation, affecting growth stages, physiological processes, yield, and tuber quality. High temperatures delay tuberization, reduce photosynthesis, and cause physiological disorders, compromising the nutritional quality of tubers. Mitigation strategies include early sowing, mulching, efficient irrigation, and the use of growth regulators like paclobutrazol to enhance photosynthesis and tuberization. Specific nutrient applications can also improve stress tolerance. Additionally, breeding heat-tolerant varieties and utilizing wild germplasms are crucial for developing resilient cultivars. A multifaceted approach combining improved agronomic practices, targeted use of growth regulators, and the development of heat-resistant varieties is necessary to sustain potato production and ensure food security in the face of climate change.

Reference

Desta, B., Tena, N., & Amare, G. Response of potato to heat stress and strategic methods to cope with it. *Innovare Journal of Agricultural Science*, 11(1), 1-9.

Momcilovic, I. (2019). Effects of heat stress on potato productivity and nutritive quality. *Hrana i ishrana*, *60*(2), 43-48.

Singh, B., Kukreja, S., & Goutam, U. (2020). Impact of heat stress on potato (Solanum tuberosum L.): Present scenario and future opportunities. *The Journal of Horticultural Science and Biotechnology*, *95*(4), 407-424.

Wu, C., Huang, W., Fang, X., Ma, H., Song, W., Zhang, K., ... & Zheng, S. (2024). Foliar spraying of plant growth regulators can alleviate high-temperature stress in late-sown spring potatoes to improve yield and quality. *Research Square* DOI: https://doi.org/10.21203/rs.3.rs-4051088/v1