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Effect of Climatic Change on Fruits and Ornamental Crops

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The effect of climate change and sudden change in environment on fruits and ornamental crops is well known. There are four major environmental factors which savior affects observed on fruits and ornamental crops.

1. Effect of high of temperature on fruits and ornamental crops

The effect of global warming is now visible in many parts of the world. Abnormality in climate patterns, induced by accelerated warming, has started to affect a catchment-species chydrologic cycle. Higher temperatures lead to a high rate of evaporation and dry conditions in some areas of the world. The effect of high temperature on different growth stages (phenology) of fruit crops is summarized under following under sub-heads:

- Vegetative growth
- Flowering
- Fruit yield
- Fruit quality
- Disorders
- Metabolic processes

Vegetative growth

Under high temperature exposure (43^0C) in almond bud failure like symptoms appear in which there is complete separation of distorted and compressed cells from surrounding tissues takes place by a periderm like layer. Higher temperature in temperate fruits can negate the chilling effect. In apple, the trees, which were exposed to daily alternating temperatures, had lower levels of bud break (vegetative), when the high temperature in the diurnal cycle was greater than 14^0C. Practically no bud break was apparent on trees that were exposed to diurnal cycles with a high temperature of 20^0

C for 8 hours. In raspberry, the optimum temperature for node production is 22^0 C and it continues to support growth up to the range of 20^0 C. Above this range, it becomes supraspinal and node production is reduced. Mango cultivars exposed to higher temperature showed that vegetative growth increased with increasing temperatures. Likewise, mango, higher temperatures in citrus also enhances vegetative growth but after certain limit, it retards the shoot elongation. Troyer citrange and Valencia oranges showed that seedlings were with short internodes and leaves were markedly shorter as compared to normal ambient temperature ($28/22^0$ C). Beside the effects of high temperature on whole fruit trees, some examples are desiccation of leaves in Baramasi lime and young leaves of newly planted guava plants wilt and die during hot summers. Many a times pear on kainth rootstock newly-planted plants dry up during May-June due to desiccation.

Flowering

The various stages starting from flower bud differentiation, anthesis, rate of flowering and even development of various parts of flowers is influenced by the prevailing environmental temperature. Lack of chilling associated with mild winter conditions results in abnormal pattern of bud break and development in temperate fruit trees. After strict deprivation of cold temperature in peach all floral primordia died within 5 months. In red haven peaches grown at $20/15^0$ C from October to December, it was found that the bud necrosis could be attributed either to the weak establishment of vascular connections between stem and floral buds or the unavailability of the sugars. However, the sugars *viz.*, sorbitol and sucrose concentrations remained high in cushion and bud scales but low in floral meristem. Thus, it seems that under high temperature the bud scales and cushion beneath the meristem primordia served as strong sink as compared to meristem. The temperature rise at the end of January in apricot (during the period of rapid floral development) appears to increase the flower bud abscission. In most fruit crops, generally higher temperature decreased the days interval required for flowering and cooler temperature though required more days for flowering but the number of flowers produced increased proportionally at this temperature. The rate of flowering in raspberry cv. Autumn Bliss was dependent upon temperature. The flowering in primocane raspberry cultivars is initiated by the cessation of vegetative growth. Growth of plants at 24.5^0C slowed earliest after just less than 100 days but at temperature below or above this, the cessation of growth was delayed. In citrus (*Citrus unshiu*), the flower number at an air temperature of 15^0 C were greater than at 30^0 C. In sweet cherry, there is abnormality in pistil development, if the flower bud development period (mid July) exposed to higher temperature (35^0C). While evaluating the effect of temperature on flowering of peaches, it was found that the period of full bloom with treatments of 25/15 and $30/15^0$C were 5 and 8 days earlier, respectively than for the $20/15^0$C treatment. With the increase in temperature, rate of pollen development and tendency for the stamens to abort increased. Temperature not only influences the development of various parts of flowers but also determines the type of inflorescence. In litchi cultivars, when trees exposed to day/night temperatures of $30/25^0$ C and $25/20^0$ C did not flower and temperatures of 20/15 and $15/10^0$ C gave rise to variable proportions of vegetative, leafy panicles and leafless panicles depending on the cultivars. Similarly, in citrus, more leafless floral shoots are produced at cooler temperature (20/ 15^0C day/night) and higher soil and air temperature enhanced production of leafy floral shoots.

Fruit set and Yield

Fruit set and yield in fruit crops are directly related with the environmental temperature. Likewise in apple and pear low temperatures appeared to promote fruit set on potted trees to different temperature regimes from February to harvest. In apricot, at higher temperature, the pistil size is reduced which leads to abnormal flower and ultimately reduced fruit set. In Cherimoya (tropical fruit), the effect of warm ($30/25^0$C) and cool ($20/15^0$ C) day/night temperatures on fruit set and fruit growth the low fruit set at warm temperature regime was ascribed to both pollen and stigma damage from heat stress. Beside pre-blossom and blossom temperature, the higher temperature during fruit set stage also affect the fruit retention. The fruit set in soft pear and peaches is reduced due to sudden rise in temperature.

Fruit quality

Quality is a measure of degree of excellence or degree of acceptability by the consumer. It includes external parameters (color size, shape and defects) and internal parameters (texture, flavor and nutritional qualities).

External parameters

Natural colour development in fruits is one of the external quality parameters visibly sought after by the consumer. High temperature generally reduces the anthocyanin accumulation in fruit crops. In grapes, version is a critical period for the berry tissues to perceive environmental stimulation and trigger anthocyanin biosynthesis. At this stage, night temperature is more critical than the day temperature. Anthocyanin synthesis in the skin of berries grown at high night temperatures (30^0 C continuous day and night) is reduced as compared to that of berries grown at low night temperatures ($30/15^0$ C; day/night). Fruits of Cavendish banana subgroup failed to degree, when ripened at the high temperatures of the tropics ($>24^0$ C). The fruits remained green because of the retention of chlorophyll and associated thylakoid lamellae in citrus, if mature fruits are left on the trees during summer months, chlorophyll returns to rind and carotenoid content decreases. This condition is referred to as regreening, degree of which is influenced by high temperatures.

Internal parameters

Kiwi fruit grown under high temperature ($3\text{-}4^0$ C more than the ambient temperature) during mid march to mid may had lower soluble solids, more firmness and had higher starch concentrations in both core and cortex tissue. However, in the grapes also a vine crop, the soluble solids content increased with the increase in temperature from 15 to 30^0 C.

Disorders

Early water core of apple cultivars in which there is sorbitol accumulation takes place is increased by high temperature above 30^0 C during the summer. The resistant cultivar ‘Fuji’ showed a difference in sugar compartmentation and higher fructose and glucose in the vacuoles. Conversely, the susceptible ‘Orin’ apples had higher sorbitol level in cytoplasm and tonoplast. These results implied that higher fruit temperature may increase tonoplast permeability especially to sorbitol in the early water core susceptible ‘Orin’ cultivar but not in resistant ‘Fuji’. Similarly, higher temperature grown fruits, when stored at 3^o c, here is breakdown incidence. In pear also, the higher temperature accelerates the development of water core in pineapple, translucency of fruits is most commonly encountered disorder in which the flesh gives water-soaked appearance. It is a hindrance in the fresh marketing of fruits. The incidence of the disorder is correlated with both higher (28/18^0 C, max/min temperature) and lower (23/15^0 C) 3 months preceding the harvest. Albinism of strawberry is a serious disorder, which has attained alarming situation in USA, Belgium and Netherlands. Fruit suffering from this malady appear blotted and develop pink or white areas on their surface, the pulp remains pale. It occurs frequently in the fields during peak fruit production in localities experiencing warm weather. This disorder is also favored by black polythene as it raises the soil temperature.

Metabolic processes

High temperature also has a direct effect on the processes like respiration and photosynthesis. In mango, with the increase in temperature from 15 to 35^0 C, the photosynthesis rates increased. However, the photosynthesis rates decreased, when the temperature was increased further at the same vapour pressure deficit.

- **Observed impacts of low temperature on fruit and ornamentals production in India:**

The low temperature coupled with dry air during winter may develop a situation where evergreen plants fail to tolerate the high rate of transpiration, leading to winter injury.

Chilling Injury:

Tropical and sub-tropical fruit plants get injured by low temperature above freezing point. The intensity of injury depends upon the duration of the exposure to the low temperature. Plant height depends upon the extent of low temperature. Kinnow leaves inside the plants are injured due to low temperature. The prolonged hours of low temperature can cause temporary to permanent wilting of the plant parts or whole of the tree. Papaya and guava leaves and trees got damaged due to prolonged low temperature for a month during.

- **Freezing Injury:**

In temperate and sub-tropical climate many a times temperature falls below 0°C for long duration, resulting into formation of ice from water in the cells and tissues of the fruits plants. The tissues get killed due to enlarged size of ice crystals. The severity of injury depends upon the tolerance of the plant to freezing atmosphere. Fully grown trees of mango and guava got killed due to freeze injury during. Tree trunks of many mango and citrus plantation were damaged due to bark shredding/injury.

4. Physiological Disorders:

Both higher and lower temperature than normal induces higher rate of transpiration in comparison to rate of photosynthesis leading to imbalance in the hormonal activity and metabolite synthesis and their translocation. This imbalance adversely affect various growth processes particularly apical dominance and flowering.

Winter temperatures and precipitation especially in the form of snow are very crucial for induction of dormancy, bud break and ensuring flowering in apples. Apple requires 1200-1500 hours of chill depending upon the variety. The chilling bellow 1000 results in the poor fruit set which consequently lead to poor yield of the crop.

3. Observed impacts of heavy rainfall on fruit and ornamentals production in India:

Flooding or excess water damage can be caused by short to medium term, intense introductions of water, as a result of poor soil drainage causing soil saturation and pooling, from over application of water through irrigation or through heavy rains or runoff from water bodies.

General Plant Damage / Impact

Plants that have been flooded or that grow in saturated soil situations will often exhibit reduced growth and/or stunting. Foliage (leaves and stems) may look yellowed and chlorotic and, if conditions persist, may become necrotic (dead). Seeds may rot and root death may occur. Plants may wilt and decline (depending on the duration of the saturated soil conditions). There will be an increase in the incidence of diseases (bacterial, fungal) due to weakening to the plants and due to improved conditions for disease development (increased humidity, prolonged leaf wetness periods, etc.). Plants that are exposed to excess water will have altered plant hormone levels, which will result in abnormal growth, including twisting, epinasty, distortion, enlarged lenticels, and aerial or adventitious root formation. The main impact that comes from excess water is due to a reduction in the amount of oxygen that is in the roots, which affects respiration and metabolic transport systems. Reduced oxygen also damages roots, which reduces uptake of nutrients (such as calcium) and can result in increased uptake of toxins and attack from pathogens. Different crops respond to flooding in different ways, depending on the previously outlined factors. The rain is rarely considered to be negative weather, however if it arrives in excessive amounts in a short time, resulting in localized flooding of soil and associated excess moisture damage. Sudden, heavy rains can also produce damage that is very similar to hail damage, causing varying degrees of defoliation, bruising of plants (particularly soft fruit), specifically in the shoulder regions. Some cracking of the shoulder regions can also occur. Disease development may increase due to soil splash, damaged tissues and increased humidity.

Dealing with heavy rain is similar to dealing with excess water / flooding or hail, depending on the situation. Producers should ensure that there is good drainage (or actively work to drain soils) and may apply protective fungicides may help protect damaged tissues from infection. Replacement of lost nutrients may also be necessary.

In mango untimely rain caused the vegetative growth of trees with new leaves hampering their productive growth. Then the untimely budding of mango trees due to fluctuation of temperature as well as knocking down by seasonal storms of green mangoes have been responsible for poor yield.

4. Observed impacts of drought on fruit and ornamentals production in India:

In banana, one of the major constraints for productivity is drought. Water deficit severely affects the plant growth and yield, because it deeply reduces the photosynthetic capacity of the banana plants as the crop sensitivity is reflected by reduced greenness of foliage. Water deficit during the period of finger development inhibits the translocation of assimilates to bunches. The present review made for the better understanding of the effects of water deficit to physiological and biochemical changes in banana.

The potential for a drought during the growing season is a very real probability. The length and severity of droughts vary greatly and cannot be predicted, so planning is critical in order to minimize the effects of a drought. However, the potential for a drought is such that current recommendations for fruit orchards include irrigation as an integral part of fruit production and not as an option. With perennial tree fruit crops it is best to take a proactive position rather than waiting for a drought before taking action. Many orchards are poorly located where water is not readily available. Also, in mature orchards, where fruit trees are relatively deep rooted, installation of an irrigation system during a drought period is impractical and usually not as effective. The effect of a drought on tree fruit production can result in reduced yields for several years, assuming that the trees survive the drought. With fruit trees, the flower buds for the following season are initiated during the previous summer, and prolonged drought can inhibit the initiation of flowers for the next season. A drought can also reduce the quantity and quality of the current season's fruit crop as well. To better understand the effect of drought on fruit production it is necessary to understand the fruit's seasonal moisture requirements and to understand how drought affects fruit growth and development. Fruit trees have different patterns of shoot and fruit growth, so drought during different times of the season will result in varying responses. Growth of all plant organs is dependent on an adequate supply of carbohydrates. Carbohydrates, the main food source in trees, are produced in the leaves during photosynthesis. Photosynthesis requires sunlight, carbon dioxide, and water. Stomata's, small openings in the underside of leaves, allow carbon dioxide to enter the leaf and water vapor to exit. Maximum photosynthetic rates and, therefore, maximum carbohydrate production occur when the stomata's are open. When plants experience drought stress the stomata's close to conserve water and photosynthesis and carbohydrate production is seriously reduced.

Under drought conditions, afternoon apple leaf photosynthetic rates may drop to 20% of normal. Therefore, avoiding drought stress with irrigation will result in greater production of carbohydrates for increased tree and fruit growth. Apple fruit growth is fairly uniform during the entire season. Fruit enlargement for the first 50 days after bloom is largely due to cell division, thereafter fruit growth is due to cell enlargement. Prolonged drought stress any time during the season may adversely affect fruit growth, but early season drought is most detrimental because ultimate fruit size is related to cell numbers.

Color: In addition to fruit size, fruit quality can also be related to water availability. Because sugar is the building block for the red pigment in the apple skin, anything that reduces photosynthesis may delay or reduce red color development.

Storage Potential: Starch accumulates in apple fruits from about

50 days after bloom until fruit maturity and is converted to sugar in the maturing fruit. Stored starch is the energy source used by fruit tissues in storage. Harvested fruits having little starch will not store well and will soften earlier than expected.

Nutrient Disorders: Calcium uptake by roots requires adequate soil moisture. During dry seasons, fruit calcium levels are often low, and cork spot, bitter pit, and internal breakdown in storage may be severe. There is also some evidence that fruit rots before and after harvest may be most severe in fruits with low calcium concentrations.

Pre Harvest Fruit Drop: Pre harvest apple drop is influenced by environmental conditions, but field observations do indicate a consistent relationship between drought and fruit drop. A high percentage of fruit dropped in some orchards before harvest. In this case, severe drop may have been related primarily to the drought-induced late harvest.

Water Conservation Practices

Due to the potential reduction in fruit yield and tree growth and survival, it is important that growers know what actions can be taken to minimize the effect of a drought on tree fruit production. However, during a serious drought nothing can take the place of a well-designed and properly installed irrigation system. One of the best ways to help minimize drought stress in an orchard is to provide a vegetation-free strip down the tree row before growth begins in the spring. This strip is usually implemented and maintained with an herbicide program. For optimal results, the vegetation-free strip should extend from the trunk of the tree out to at least the drip line of the tree on both sides of the tree row.

Frequent mowing of the vegetation in the orchard should also be avoided. When grass is mowed before seed stalks form, the grass vigorously grows back after being mowed, further reducing soil moisture in the orchard. Options to mowing the vegetative row middles include using sub lethal rates of herbicide applied during the spring and early summer. This practice is commonly referred to as chemical mowing and is used to suppress vegetative growth of the orchard floor for 6 to 8 weeks.

A well-managed orchard should not look like a lush green park or golf course. When new orchards are planted, a good technique is to prepare the soil a year in advance and plant a vegetative cover.

Then 3 to 4 weeks before planting, apply a contact herbicide to provide killed sod-row strips into which the new trees will be planted. By planting into a killed vegetative cover moisture infiltration is greatly improved, and moisture loss by evaporation is reduced, maximizing the use of brief rain showers that may occur during periods of drought stress.

Another practice that may help to minimize the effect of a drought is to thin the fruit crop properly early in the season. By removing the excess fruit early in the season the tree does not expend carbohydrates and moisture in fruit that are later removed. Early thinning minimizes the amount of wasted energy and promotes growth of the desired fruit. Thinning at bloom time is preferred; however, in the Southeast the potential for spring frost-freeze problems limits the use of bloom thinning in order to guarantee a crop.

Growers may help minimize the effect of a drought on fruit production by controlling insects and disease pests that defoliate the trees, which reduces photosynthesis and carbohydrate production.

Irrigation Systems

As mentioned earlier, the best option is to have a properly installed irrigation system in place to avoid any drought-stress problems. There are several different types of irrigation systems that should be considered for fruit trees. There are advantages and disadvantages to each type and for each specific orchard and local circumstances, and these must be considered before installation. It is best to consult an irrigation specialist and your county Extension Service agent to aid in designing a reliable system to meet individual needs. The three basic types of systems primarily used in commercial orchards in the Southeast are: (1) low-volume drip or trickle, (2) high-volume overhead, and (3) micro sprinkler.

Observed impacts of climate change on fruit production in India: However, there are certain beneficial effects of climate change such as projected improvement in coconut yield in west coast of India (Naresh Kumar et al., 2008; Naresh Kumar and Aggarwal, 2009). More number of such potential benefits need to be analyzed for maximizing the positive impacts.

Strategies for Adoption in the change Climate:

- Improvement of heat, drought, and pest resistant varieties
- Improvement of resources for irrigation efficiencies: drip and sprinkler irrigation

- Research in water and nutrient management in various agro-ecologies to meet the climate change
- Research in green manuring crops, cover crop, to preserve soil moisture, soil organic matter and micronutrients
- Research on climate prediction related models and their application
- Research work on new technologies towards low carbon economy
- Research on land use planning, watershed management, vulnerability assessment and resource management
- Resource on yield gap analysis to analyze the factors responsible to climate change

Strategies for improving the fruit production

- Promote seminar, workshop, training and general education to rural population dependent on agriculture
- Identification of present issues of climate change related to fruit crops
- Strengthen Horticultural Research Station and community program to run effective research related to climate change
- Interactive communication for transfer of technologies to farmer about climate change and its impact on fruit production
- Preservation of genetic materials to reduce extinction of biodiversity
- Crop insurances for social security and food securities
- Change in national policies towards farmers incentives such as subsidy in agricultural inputs and agricultural investment.

Conclusion

In order to provide environmentally-resilient cultivar for sustainability of future fruit production, breeder require accurate and high-throughput phenotyping protocols for identification of the varying levels of chill requirement in the available germplasm. We illustrate here preliminary results of one such careening method. So mitigating the adverse effect of climate and the damage by emerging pest's adaption of some techniques that can restore the health and productivity of the trees enabling us to produce commercial quantities is desirable.