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# Morpho-physiological and Biochemical Changes under Drought Stress in Strawberry: A Review

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## ABSTRACT

Drought stress is one of the most important environmental stress that affects plant growth and development. Strawberry plants are very sensitive to drought stress due to its herbaceous nature and shallow root system. Depending upon the nature, intensity, duration and cultivars, the effect of this stress augments losses in yield and quality of the fruits. This optimization of yield loss and quality is due to the response of the plant to the stress with the changes in morphological, physiological, biochemical and molecular attributes. Drought stress results in the change of leaf anatomy, leaf area, transpiration rate, photosynthesis, stomata closure, relative water content (RWC), shoot length, root length *etc*. ROS such as $H_2O_2$ production occurs as a result of drought causing oxidative damage to the plant cells. Strawberry plant on the other hand have a mechanism to detoxify these ROS with the production of both the enzymatic and non-enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT), peroxidase (POX), gluthathione, ascorbic acid, tocopherols, carotenoids *etc*.

**Key words:** Antioxidants, Drought, ROS, Stress.

Strawberry (*Fragaria* × *ananassa* Duch) is one of the important temperate fruit crop in the world which belongs to the family Rosaceae. They are man-made hybrid crop evolved by crossing *Fragaria chiloensis* and *Fragaria virginiana*. Even though strawberry is considered a temperate crop, some varieties are grown successfully in tropical and subtropical regions (Sachin *et al*., 2015). Strawberries are one of the most cultivated fruit crop over the world. In India, it is mostly grown in Satara district, Mahabaleshwar, Wai and Panchagani areas of Maharashtra and some parts of Himachal Pradesh and Jammu and Kashmir. The area under its cultivation is increasing due to its diverse ecological state and cultivars having tolerance to different environmental conditions.

Strawberry fruits are known for the rich source of vitamin C, fibre and antioxidants. It also contains potassium, vitamin K and magnesium which are important for healthy and strong bone (Sachin *et al*., 2015). The consumption of strawberry fruit also has benefit on cardiovascular, neurodegenerative and other human diseases such as aging, obesity and cancer (Maas *et al*. 1991, Zhang *et al*. 2008, da Silva Pinto *et al*., 2010). Strawberries are generally grown for fresh consumptions and are also used for making jam, jelly, cake, juice, ice-cream, soft drinks, confectionaries, chewing gums *etc.*

Strawberry plants are herbaceous perennials and a have shallow root system *i.e.*, about 50-90% of the roots are in 0-15 cm zone and are highly sensitive to water stress (Klamkowski and Treder, 2006). Therefore, ample water should be provided during the early growth and development in order to cope up with the loss of water through leaching, evapo-transpiration, inefficient application and inappropriate assessment of water on daily requirement by the crop. Limited water supply during early growth, flowering and fruiting reduce berry size and yield (Hoppula and Salo, 2007; Liu *et al*., 2007). Apart from being an important horticultural crop, strawberry (*Fragaria* spp.) is a good candidate for studying the principles of drought tolerance in the Rosaceae which contains economically important fruit, nut, ornamental and wood-bearing species from different subfamilies such as peach, cherry and almond (Amygyloideae), apple and pear (Maloideae), blackberry, raspberry and rose (Rosoideae), *etc* (Farzaneh Razavi, 2012).

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## Drought stress in strawberry

Strawberry plants are highly sensitive to certain environmental stresses. Drought stress is one of the major stresses limiting the plant growth (Moussa, 2011; Rohbakhsh, 2013). Limited water requirement induce morphological, physiological and biochemical response on plants (Chandler and Ferree, 1990; Johnson *et al*., 2009; Farzaneh Razavi, 2012; Nezhadahmadi *et al*., 2015; Gulen *et al*., 2018). Plants have their own adaptive mechanisms to survive under water deficit or avoidance mechanisms to get the specific growth habit even under water stress conditions (Levitt 1980) (Fig 1).

Depending upon the severity of the stress, drought stress results in changes of various morpho-physiological responses of the plants such as shoot and root length, leaf area, leaf number (Farzaneh Razavi, 2012),water use efficiency (WUE), chlorophyll inflorescence, total dry matter (Sairam *et al*., 1990; Gholamin and Khayatnezhad, 2010) and pigment content stability (Ehdaie *et al*., 1991; Datta *et al*., 2001; Keyvan, 2010) and finally death of the plant (Jaleel *et al*., 2008). Drought stress also changes the biochemical attributes of the plant by altering the activity of reactive oxygen species (ROS) and antioxidant responses (Sun *et al*., 2015). Proline level increases depending upon the severity of the stress and is considered to be an important indicator of drought stress and is correlated with the osmotic regulation (Ghaderi *et al*., 2015; Gulen *et al*., 2018).Under water deficit, *Fragaria* species responded well by adjusting osmotic potential and ROS scavenging mechanisms (Farzaneh Razavi, 2012). Drought stress also cause fruit yield reduction by decreasing flower numbers, fruit set, numbers of fruit per plant and fruit size. However, tolerance level to water stress in strawberry varies according to plant growth stage, stress duration, growing system, growing medium and cultivars (Adak *et al*., 2017). Furthermore, strawberries grown in greenhouse and soilless cultivation are more sensitive to water stress than those grown in open air (Adak, 2009; Nezhadahmadi *et al*., 2015). In strawberry, plants under deficit irrigation regulate fruit size and yield to cope up with stress effect (Liu *et al*., 2007), but despite this, the quality of fruit increases (Terry *et al*., 2007; Heiadari and Golpayegani, 2012).

Drought tolerance has been studied for various crop species (Bota *et al*., 2001,Herralde *et al*., 2001), but there is still a lack of information about morpho-physiological behaviour of different strawberry cultivars under limited water availability (Klamkowski and Treder, 2008).

## Morpho-physiological changes under drought stress

Drought stress are linked to different plant morphological and physiological traits like reduced plant size, early maturity and also reduced leaf area (Rizza *et al.,* 2014). Due to adverse effect of drought, there is decreased in plant height in strawberry (Nezhadahmadi *et al*., 2015). Decreased in plant height can be considered as an important mechanism for preservation of the carbohydrates by plants for constant metabolism and accumulation of solute for osmotic adjustment (Sunkar and Bartels, 2005). Drought stress in strawberry results in reduced leaf area and shoot length but stimulates root length, leaf abscission, leaf wax deposition, the number of leaves per plant, leaf size and leaf longevity (Shao *et al*., 2008; Jamali *et al*., 2011; Hussein *et al*., 2017). Reduced leaf area decreases the transpirational surface thereby diminishing the water loss and on the other hand the higher root to shoot ratio results in greater water uptake

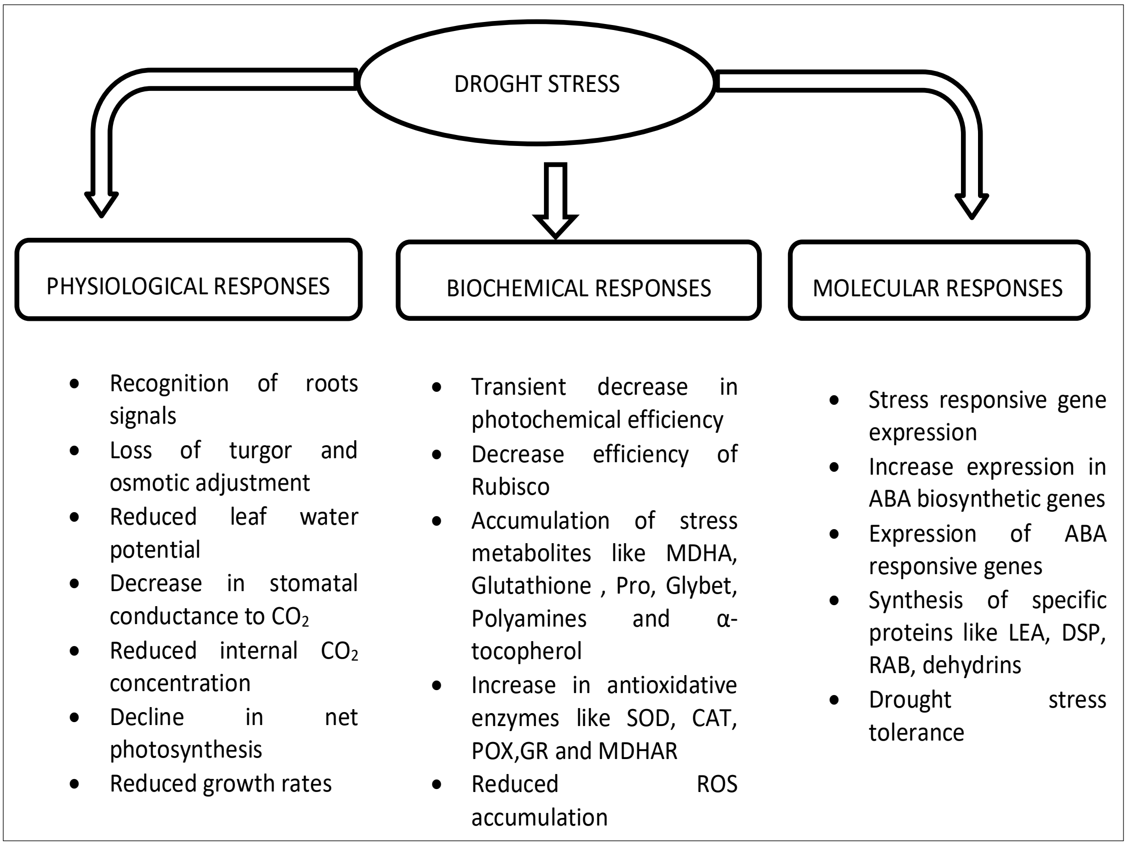


**Fig 1:** Physiological, biochemical and molecular responses of drought stress in higher plants (Reddy *et al*., 2014).

due to higher root depth. This is important factor for the plants survival under drought stress (Klamskowki and Treder, 2006; Nezhadahmadi *et al*., 2015).The small leaf area of strawberry cultivars can also be of advantage for variety selection as a drought tolerant characteristic (Grant *et al*., 2010). Relative water content (RWC) of leaf is also an important criterion for water status of the plant. It decreases as a result of drought stress which in turn limited plant growth and development (Parvin *et al*., 2015; Bolat *et al*, 2014; Li *et al*., 2011; Jungklang and Saengil, 2012).

Drought stress dominantly alters stomatal activities in strawberry and restricts gas exchange between the leaves and atmosphere under severe condition (Klamkowski and Treder, 2008).The closing of stomata by leaf under drought stress is due to the modulation by drought-induced root-to-leaf signalling of abscisic acid (ABA) promoted by soil drying through the transpiration stream (Reddy *et al*., 2014).The stimulation of stomata closure under drought decreases the photosynthesis by limiting $CO_2$ uptakes in the leaves (Chaves *et al*., 2003).This results in the influence of electron-transport chain activity in chloroplasts, oxygen accumulation and ATP-synthesis which results in relative effects on growth and yield (Ogren and Oquist, 1985; Nogues *et al*., 2002). There is also an imbalance light capture and its utilization in the chloroplast due to drought stress which also cause the reduction photosynthetic activities (Foyer and Noctor, 2000). Decrease in photosynthesis under severe drought stress is also due to the decrease in Rubisco activity (Bota, 2004). Due to the inhibition of $CO_2$ assimilation and imbalance generation and utilization of electrons by down regulation of photosystem I and II activity in the chloroplast, quantum yield changes and dissipation of excess light energy takes place, thereby finally leads to generation of reactive oxygen species (ROS) (Asada, 1999; Reddy *et al*., 2014; Farzaneh Razavi, 2012).

Ratio of chlorophyll 'a', 'b' and 'carotenoids' also changes due to drought stress with the resistant cultivars having higher chlorophyll content (Farooq, *et al*., 2009). Strawberry varieties grown in natural condition have more chlorophyll content as compared to the varieties cultivated under protected environment at different soil moisture levels (Nezhadahmadi *et al*., 2015). Depending upon the cultivars tolerance, yield and fruit size also decreases as a result of drought stress in strawberry (Johnson *et al*., 2009;Grant *et al*., 2010; Erdogan *et al*., 2016; Adak *et al*., 2017).

### Biochemical changes under drought stress

Proline content of the plant is considered to be an indicator of drought tolerance, osmoregulation and protection of a plant (Molassiotis *et al*., 2006). In strawberry, plants subjected to drought stress accumulate more amount of proline than the normal ones (Ghaderi *et al*., 2015; Sun *et al*., 2015). The higher proline content conceivably be due to increase activity of the enzymes involved in proline biosynthesis *viz*, ornithineaminotransferase and pyrroline 5-carboxylate reductase, as well as due to the prevention of proline oxidase, proline catabolising enzymes (Debnath, 2008).

With the increase in severity of drought stress, strawberry plants tend to acclimate and develop adaptive mechanisms to contrive limited water availability. Soluble carbohydrates especially sucrose tends to increase under drought stress with decrease in starch content to ameliorate the osmotic adjustment (Farzaneh Razavi, 2012; Yordanov *et al*. 2000) and resulted in increased fruit quality and taste (i.e greater sweetness and sugar/acid ratio) of strawberry (Bordonaba and Terry, 2010). Reactive oxygen species (ROS) signalling is significantly affected during drought stress resulting into oxidative damage to the cells. ROS such as $H_2O_2$ increases in the leaves and roots of drought stressed strawberry plants (Nucleolus *et al*., 2012). The increased in $H_2O_2$ resulted in the production of antioxidants such as catalase (CAT), peroxidase (POX) and superoxide dismutase (SOD) and alters plant acclimation responses to water deficit (Miller *et al*., 2010; Suzuki *et al*.; 2012). The detoxification of ROS is mainly based on the mechanisms of both the enzymatic and non-enzymatic antioxidant *i.e.* non-enzymatic antioxidants include ascorbic acids (AsA), glutathione (GSH), tocopherol (vitamin E), flavonoids, alkaloids and carotenoids whereas enzymatic antioxidants include superoxide dismutase (SOD), peroxidases (POX), catalase (CAT), glutathione reductase (GR), glutathione-S-transferase (GST), *etc.* (Mittler, 2002). Total antioxidant capacity (TAC content considerably increased in stressed plants of 'Elsanta' strawberry under prolonged drought stress, while the CAT activity decreased and APX and SOD activity tended to decline under drought stress (Farzaneh Razavi, 2012).

However, with the severity and duration of the drought plant cannot cope up with the oxidative damage and as a result the antioxidant enzymes tends to decrease as the drought stressed becomes severe (Sun *et al*., 2015). Changes in protein content occur under drought stress either qualitatively or quantitatively depending upon the cultivars, severity and duration of the stress (Neocleous *et al*., 2012)

## CONCLUSION

The level of drought stress in strawberry depends upon the nature, severity, duration and cultivars leading to the changes in their physiological and biochemical response. This responses cause the plant to alter their growth and developmental process resulting in the loss of yield and quality of the fruit. Under drought stress conditions, strawberry plants have specific tolerance mechanism at certain alleviated stress level by inhibiting the production of ROS by the antioxidant such as SOD, CAT, POX, AsA, *etc*. and prevent the oxidative damage of the plant cell. However, there is less research on strawberry stress and further studies would be required to identify cultivars tolerant to drought stress.

**Conflict of interst:** None.

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