CHAPTER 6

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The investigations discussed within were designed primarily to have (a) deeper understanding of the structural, physiological and biochemical responses of the tea plant to water stress (b) identification of the factors responsible for improving resistance to water stress and finally (c) ameliorative measures to be adopted against drought by the application of chemicals.

(1) The various responses of the tea plant to water stress, viz. drought and waterlogging, can be expressed at four levels: (a) developmental or anatomical (b) morphological or structural (c) physiological and (d) biochemical or metabolic.

(2) The morphological responses of the tea plant to water stress can be viewed through its effects on various components of growth and hence the responses of leaf, stem and root.

(3) The inhibition of leaf growth could be assessed from the reduction in leaf blade thickness, leaf area and number of new leaves formed and accelerated leaf shedding.
(4) Both drought and waterlogged conditions were found to inhibit terminal, radial as well as lateral growth of the shoot. The inhibition of shoot growth was reflected in the reduction of height of the plant, length and number of lateral branches and thickness of stem.

(5) Various aspects of root growth were affected by different water stress treatments to varying degrees. The reduction in depth and volume of the root system, depth of the effective root zone, length and number of the primary roots were observed in response to water stress.

(6) Anatomy of leaf, stem and root reveals that the composition of the internal organisation of the tea plant was badly affected by exposure to different levels of water stress. The reduction in the leaf blade thickness following shrinkage due to internal plant water stress was associated with the observed reduction in the thickness of palisade and spongy parenchyma tissue, area of xylem and phloem, xylem : phloem ratio in the leaf mid-rib and volume and area of the vascular elements in the leaf petiole.

(7) The area of xylem, phloem and xylem : phloem ratio in stem and root sections were significantly reduced in both drought and waterlogged conditions. As compared
to stem, the anatomical attributes of the vascular elements in roots were more affected and the extent of reduction was more under waterlogged condition than under drought.

(8) Water stress reduced the rate of translocation as well as fixation and distribution of $^{14}$C assimilates. The pattern of distribution of the radioactive carbon to different parts of the water stressed tea plants did not correspond to that in the unstressed control plants. The maximum reduction of translocated radio-active carbon was observed in the root system of the treated plants.

(9) The observed inhibition in the fixation of $^{14}$CO$_2$ in leaves of tea caused by water stress resulted in significant reduction in the rate of photosynthesis.

(10) Water stress increased stomatal diffusion resistance with simultaneous reduction in transpiration rate. Water stress also decreased leaf water potential. However, unlike drought, the progress towards increase or decrease in these parameters was gradual and slow in case of waterlogged conditions, sometimes requiring 20-30 days till exhibition of apparent demarcation from that in the control plants.
(11) Root : shoot ratio and dry weight : fresh weight ratio in leaves increased under both drought as well as waterlogged conditions. The increase was relatively more in plants exposed to drought than those exposed to waterlogged condition.

(12) Dry weight accumulation was significantly reduced by water stress. Both drought and waterlogged condition decreased specific leaf weight. Between two states of waterlogged condition, the reduction in specific leaf weight was more in completely submerged condition than in partially submerged condition.

(13) Area and perimeter of the stomatal aperture were significantly reduced by waterlogging.

(14) Both drought and waterlogged conditions reduced the amount of total chlorophyll content in leaves of the tea plant. Water stress also reduced chlorophyll a:b ratio. Further, the reduction was found to be more in waterlogged than in droughty condition. The stress imposed by complete submergence exhibited the highest effect on degradation of chlorophyll.

(15) Water stress significantly increased the amount of total soluble sugars in leaf, stem and root. The increase was more in drought than in waterlogged condition.
It was also higher in leaves than in stems and roots.
In response to drought, there was higher rate of accumulation of non-reducing sugars than reducing sugars.

(16) Both drought and waterlogged conditions reduced the amount of starch in roots which was more in drought than in waterlogging.

(17) Proline and epicuticular wax were found to accumulate in tea leaves in response to low leaf water potential under conditions of soil moisture deficits.

(18) The tea plant exhibited pronounced and quicker response to the parameters of plant water relationships, such as, water potential, relative turgidity, water saturation deficit, leaf water content, stomatal diffusion resistance and transpiration rate than other parameters.

(19) Higher plant water status was associated with higher water potential, relative turgidity, leaf water content and lower water saturation deficit.

(20) Drought tolerant and susceptible categories of clones differed in their diurnal, mid-day and seasonal pattern of stomatal diffusion resistance, rate of transpiration and water potential at different canopy positions.
(21) Drought tolerant clones exhibited relatively higher rate of stomatal diffusion resistance, accompanied by lower rate of transpiration and higher shoot water potential under identical field moisture stress conditions.

(22) The build up of plant water status in drought tolerant category of clones via increased stomatal diffusion resistance in response to field moisture stress conditions was manifested in increased water potential and higher leaf water content.

(23) Drought tolerant clones exhibited higher rate of photosynthesis, specific leaf weight, dry weight : fresh weight ratio of leaves and relatively higher root : shoot ratio under identical condition of water stress.

(24) Most of the drought tolerant clones exhibited significantly smaller leaf area.

(25) In respect of the area of stomata, no significant clonal difference was observed between two clones with contrasting drought tolerance studied. However, it was found to be significantly different in stomatal aperture area, density of stomata, leaf hairs and stomatal index.

(26) Accumulation of proline and deposition of epicuticular wax in the leaves of drought tolerant clones were higher
under conditions of soil moisture deficits. Degradation of chlorophyll was low in drought tolerant clones when subjected to different regimes of water stress.

(27) Drought tolerant clone TV1 exhibited quicker recovery potential, higher leaf water potential, stomatal diffusion resistance and lower transpiration rate than clone TV21, categorised as drought susceptible.

(28) Among several chemicals evaluated for their antitranspirant properties, Rallidhan (1000 & 2000 μ g/ml), Antistress (300 μ g/ml), PMA (10 & 25 μ g/ml), ABA (10 & 25 μ g/ml), CCC (500 μ g/ml) and Vaporgard (2.5 & 5%) generated promising results.

(29) These antitranspirants, when applied as foliar sprays in young as well as mature teas, induced rapid stomatal closure and increased stomatal diffusion resistance, water potential, relative turgidity, specific leaf weight and finally water use efficiency in the treated plants. Simultaneously, these substances reduced both transpiration as well as evapotranspiration and also the rate of withering in the treated leaves when subjected to soil moisture deficit condition.

(30) Large scale application of Rallidhan and Antistress formulations in two tea gardens representing two drought
prone areas of the Brahmaputra Valley revealed that the potentially effective antitranspirants can be successfully used for alleviating the harmful effects of plant water stress during periods of drought. Because, these chemicals satisfy the requirements of inducing effectively the drought tolerance for about three months without affecting the health and productivity of the bushes.

(31) Foliar application of Muriate of Potash (K₂O) (1 & 2%) alone and in combination with Magnesium Sulphate (MgSO₄) (1%) could increase water potential, relative turgidity and specific leaf weight and finally crop yield in tea.

(32) Jalashakti, a super-absorbent of water (10 or 20 gms/pot) alone or in combination with mulch could considerably delay the time of wilting under conditions of soil moisture deficits.

The implication of these findings on various responses of the tea plant to water stress has been discussed in the light of the adaptation of the tea plant to harmful situations imposed by water stress. This study is expected to assist directly or indirectly in breeding strategies for resistance to water stress and thus executing the plant improvement programmes. Further investigations on how water stress interacts with the enzyme systems within the plant body will
further supplement our knowledge for identification of the adaptive metabolic traits which have specific importance in breeding for drought resistance, especially in drought-prone areas.