ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4

Journal of Coastal Life Medicine

Drought Tolerant Nature of *Grewia* Species and *Acacia* Species

Received: 20 October 2022**, Revised:** 24 November 2022**, Accepted:** 26 December 2022

Poonam Sharma*[1], Kalpana Agarwal[1]
[1]Department of Botany, IIS (deemed to be University), Jaipur, Rajasthan, India

Keywords:
Environment, global warming, drought, leaf expansion, chlorophyll and carotenoid

Abstract
Global warming is a big issue now these days all over the world. Plants not only prevent the climate from abiotic stress like drought but also used for other purposes. It is the need of the present scenario to find out the drought tolerant taxa. The impact of drought in *Grewia tenax* and *Grewia asiatica* has not been studied so far; therefore the present study was conducted with an objective of studying the effect of drought on both *Grewia* species, by estimation of leaf expansion and pigment concentration. In the study, *Acacia nilotica* was taken as control. Relative % change in leaf length (39.97%) and leaf area (32.72%) was observed minimum in *G. tenax* whereas *G. asiatica* had the lowest relative change in chlorophyll a (35.17%) and total chlorophyll (50.46%) content. Results indicated the tolerance towards drought in *Grewia* species.

1. Introduction
Rajasthan and many other states like Karnataka, Tamil Nadu, Odisha, West Bengal and Gujarat are the most drought prone areas in India. Direct or indirect activities of people are the major reasons of environmental stress. These anthropogenic activities therefore are a major issue of concern and attention has been placed on it. Plants not only prevent the climate from abiotic stress like drought but also used for relieving and curing ailments. Thousands of indigenous plants have been used by men as a source of allopathic or traditional drugs. The increasing demand along with pollution has placed these indigenous plants under stress. Drought stress occurs due to the long dry weather condition (Nagarajan, 2003). Water is consumed by human life and livestock is also responsible for the shortage of water. The imbalance of water is harmful for standing crops (Alexander, 1993). Unavailability of good quality of water is uninterruptedly going on due to the not recharging the resources (Swami, 2001). Uneven distribution of rainfall, increasing evaporation and reduction in water holding capacity of soil are the major reasons of drought (Wery *et al*., 1994). Drought harms the vegetative growth, physiological processes and yield capacity (Hu *et al*., 2010), cellular dehydration (Manes *et al*., 2006), reduced pigment concentration (Fini *et al*., 2013) and stomatal conductance (Hoshika *et al*., 2013). Tardieu and Tuberosa, 2010, reported that leaf expansion is the key feature for identifying the water deficit stress in plants. This feature is primary visible effect of drought on plant. Absorption of light was reduced due to the reduction of leaf size and therefore effects the biomass production in plants. Leaf expansion is inversely proportional to the severity of stress. Many studies exhibited that reduced cell division and changes in leaf anatomy is the reason of reduction in leaf expansion (Poorter *et al*., 2009; Tisne *et al*., 2010 and Vile *et al*., 2012). Photosynthetic rate was supressed by unavailability of moisture. Drought is responsible for the accumulation of heavy metals like M, Zn, Mo and Cl. By this way entire vegetative growth of plant was negatively affected. This reduces the leaf expansion and plant canopy. Photosynthesis produces sugar which is used for growth and developments of plants. During moisture stresses plants survive by acquiring adaptations (Rahmati *et al*., 2018). Chlorophyll a and chlorophyll b are the important pigments of photosynthesis. Drought negatively affects the pigment concentration (Ommen *et al*., 1999 and Zobayed *et al*., 2005). Collapse of chloroplast, reduces the chlorophyll content during water deficit (Smirnoff, 1995). After rainy season chlorophyll was reported enhanced and reduced in shortage supply of water (Ashraf *et al*., 1994). Chlorophyll concentration increases in the resistant cultivars (Zaeifizade and Goliov, 2009). Genus *Grewia* is a common plant which is used all over the world. Earlier this genus was placed in Tilliaceae family but later merged in Malvaceae family. It includes 150 species with shrubs and small tress. It's distribution is spreads in sub-tropical and tropical areas all over the world. Approximate 40 species of genus *Grewia* was

identified in India. Some of the common species are *G. biloba*, *G. damine*, *G. tenax*, *G. hirsuta*, *G. lasiodiscus*, *G. optiva*, *G. tiliaefolia*, *G. flavescens* (Ullah *et al*., 2012). It is a source of economy for the local tribal people. There were many historical evidences of Genus *Grewia* in the field of folk medicine. *G. flavascens* (Juss), *G. villosa* (wild) and *G. tenax* forsk is used for the treatment of syphilis, smallpox and tuberculosis. In Tanzania it is used to cure diseases related to chest and cold (Von Maydell, 1986). Rodriaguez, 2000 and Roothaert, 2003 reported that leaves and seeds of these woody plants are the good source of nutrition for ruminant animals during dry weather. During drought when grasses and other vegetation are not available or poorly available, drought tolerant species plays a major role to fulfil the forage necessity of animals. Also, these plants are good supplement for the animals living in Mediterranean regions. In the absence of these plants, animals eat toxic and thorny vegetation (Van, 2007). Dev *et al*., 2017, reported that species of *Grewia* can be easily grown in abiotic stress like drought and salinity. *Grewia* is not so much exposing about the fodder properties associated to this plant (Van Looy, 2008). *Grewia asiatica* is one of the important species which can be easily grown about 1,000 m of height even in dry weather conditions. It can be grown in rocks, fine sand, clay and limestone. It is a deciduous plant and shade off leaves in winter season. Therefore, protection is required from winters. Its fruits require warm climatic conditions for ripening and contain minerals, proteins, vitamins in better quantity (Yadav, 1999). Fruits are good source of phytochemicals like flavonoids, phenolics, tannins and anthocyanin. Its plant parts are useful to cure many diseases like leaves having anticancer, antiplatelet, antimicrobial activities; bark contain anti-inflammatory and analgesic activities (Zia-Ul-Haq *et al*., 2013). *Grewia tenax* is an endangered species of Indian Thar desert. Venkatesan *et al*., 2019 suggested that its germplasm should be stored for future perception. It provides timber, fodder, fiber, fuelwood. Plant parts contain medicinal properties. It can be grow easily in drought prone areas and by this way keeps the land fertile. All soil types are suitable for this species. Nutritionally its fruits are important and dehydrate for further use in future (Sharma & Patni 2012). *Acacia* is a known drought tolerant genus and has a potential water conserving mechanism (Aref & El-Juhany, 1999). It acquires some adaptation to sustain in the arid environments. Its roots are thin and deeply inserted in search of water; likewise small size of leaf reduces the loss of water. This species is a good example of morphological plasticity and soil conservator during drought (Ibrahim *et al*., 1998 and El atta *et al*., 2012). It can be grown at -1°C to 50°C temperature (Bargali and Bargali, 2009).

2. Materials and Methods

For the present study *Grewia tenax*, *Grewia asiatica* and *Acacia nilotica* were taken to identify the effect of drought. Materials was collected in the month of October and May and subjected to estimation of leaf growth and determination of pigment content in leaf samples.

1. Estimation of leaf growth

1.1 Estimation of leaf length and leaf width

Leaf length was measured by a ruler without included petiole.

Similarly with the help of ruler leaf width was measured at the widest part of the leaf.

1.2 Estimation of leaf area

The number of grid count relates to the definite area of leaf sample. The leaf area is calculated by the following equation:

Area of Leaf sample = B x N

Where N = Number of 1cm blocks covered by sample

B = Area of 1 block in graph paper

2. Estimation of pigment concentration

Pigments, including carotenoid and chlorophyll contents were quantitatively estimated by method of Arnon's (1949). Obtained results were compared with the control. Collect all the fresh leaf samples and weighed 250 mg. Samples were ground in pestle and mortar to make slurry. In this slurry 10 ml of 80% acetone was poured. Obtained mixture was centrifuged and takes out supernatant. Repeat this process till leachate became colorless. The obtained supernatant was taken together and raises the volume up to 25ml by using acetone (80%). The mixture was reserved in dark. By using spectrophotometer optical density (O.D.) of the mixture was read at different

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

wave lengths of 480 nm, 510nm, 645nm, 652nm and 663nm. The testers were analyzed in duplicates. Chlorophyll and carotenoid concentrations were calculated from the optical densities with the following formulation:

Chlorophyll a (mg/gm) = 12.7 (OD 663) – 2.69(OD 645) X v/1000xw

Chlorophyll b (mg/gm) = 22.9 (OD 645) – 4.68 (OD 663) X v/1000xw

Total chlorophyll (mg/gm) = OD 652 X 1000/34.5Xv/1000Xw

Carotenoid mg/gm = 7.6 (OD 480) – 1.49 (OD 510) X v/1000 X w

Where O.D. = Optical Density

V = Final volume of 80% acetone (25ml)

W = Weight of leaf samples (0.25gm)

3. Results and Discussion

Leaf length: The leaf length examined in *G. tenax* was 3.75 cm & 2.23 cm; in *G. asiatica* 19.78 cm & 11.73 cm and 6.16 cm & 2.26 cm in *A. nilotica*, in post rain & drought leaf samples respectively (Figure 1.1). There was a reduction in leaf length in all the three genera as an effect of drought, i.e. 1.52 cm in *G. tenax*; 8.05 cm in *G. asiatica* & 3.9 cm in *A. nilotica*. Changes recorded accounted to 39.97%, 40.23% and 63.27% in *G. tenax*, *G. asiatica* and *A. nilotica* respectively (Figure 1.4). According to the above data, minimum reduction of leaf length was in *G. tenax*, it can be conveniently concluded that it is exhibiting the maximum level of tolerance towards dry conditions.

Leaf Width: A decline in leaf width in drought samples was also observed in all the three generas. The declined leaf width in *G. tenax*, *G. asiatica* and *A. nilotica* was 2.1 cm; 8.22 cm and 0.99 cm accounting to a change of 59%; 45.21% and 22.56% respectively (Figure 1.4).

Leaf Area: Results obtained from this study indicated downfall of 3.48 cm^2; 198.22 cm^2 and 0.99 cm^2 in drought leaf samples with counted mean value 32.72%; 70.16% and 49.06% in *G. tenax*, *G. asiatica* and *A. nilotica* respectively (Figure 1.4). Relative % Change in Leaf Expansion: The present study demonstrated a significant enlargement in *A. nilotica* (63.27%), *G. tenax* (59.00%) and *G. asiatica* (70.16%) in leaf length, leaf width and leaf area parameters respectively. The results reiterate the fact that *Acacia nilotica* is the drought resistant tree of Rajasthan. The results of our study related to leaf expansion were similar to the observations of Nelissen *et al*., 2013. Sperry, 2000 observed the reduced transpiration rate during drought which may cause the reduction in leaf size, leaf number (Galle *et al*., 2007). Less availability of water in the soil reduces the activity of xylem. This indicates the plant sensitivity towards drought and seems in the form of reduced leaf expansion (Shumway *et al*., 1991). Wahid *et al*., 2005 also have the similar views that drought decline the rate of transpiration and then negatively affect the leaf size and yield. During moisture stress leaf width and leaf length was decreased due to the less stomatal activity (Craufurd *et al*., 2000). It is proved by many studies that leaf area decreases with the increase of severity of drought. It includes all the morphological and physiological characteristic and imbalances. Plants adjust root-shoot ratio and osmotic potential to survive during drought. This adaptation was firstly visible in the form of declines leaf length, leaf width and leaf area (Schuppler *et al*., 1998; Abrams, 1990; Xu *et al*., 2009).

Chlorophyll a: Among collected leaf testers of *G. tenax*, *G. asiatica* and *A. nilotica* chlorophyll a concentration was 0.70 mg/ml & 0.01 mg/ml; 0.28 mg/ml & 0.18 mg/ml and 1.49 mg/ml & 0.16 mg/ml in (post rain & drought testers) respectively (Figure 2.1). It was decreased by 0.69 mg/ml; 0.1 mg/ml and 1.33 mg/ml in drought testers comprising mean percent change of 99.16%; 35.17% and 89.40% in *G. tenax*, *G. asiatica* and *A. nilotica* respectively (Figure 2.5).

Chlorophyll b: According to obtained results of *G. tenax*; *G. asiatica*; and *A. nilotica* chlorophyll b concentration was 0.63 mg/ml & 0.08 mg/ml; 0.73 mg/ml & 0.23 mg/ml and 0.68 mg/ml & 0.32 mg/ml in (post rain & drought leaf samples) respectively (Figure 2.2). Thus declined growth was seen in drought samples of all plants with listed mean value of 87.56%; 67.83% and 52.95% in *G. tenax*; *G. asiatica*; and *A. nilotica* respectively (Figure 2.5).

Total Chlorophyll: According to the relative readings of total chlorophyll concentration reduction of 141.89 mg/ml; 47.51 mg/ml and 187.16 mg/ml was perceived in experimental count of drought leaf samples associated with 95.65%; 50.46% and 80.32% in *G. tenax*; *G. asiatica* and *A. nilotica* respectively (Figure 2.5).

Carotenoids: It was reported that leaf carotenoids concentration was lessened by 0.02 mg/ml; 0.52 mg/ml and 0.11 mg/ml in *G.tenax* (post rain); *G. asiatica* (drought) and *A. nilotica* (drought) leaf samples accounting to -37.78%; 94.03% and -77.46% respectively. Relative % Change in pigment concentration: Mean change in relative pigment concentration was presented in figure 2.5. It was identified that chlorophyll a (99.16%), chlorophyll b (87.56%), and total chlorophyll (95.65%) was significantly higher in *G. tenax* whereas carotenoids concentration (94.03%) was higher in *G. asiatica*. Results showed the tolerable nature of *G. tenax* during scarcity of water. Chlorophylls are the important variable on which photosynthesis depends. Hence, study of these pigments is essential to understand the ecosystem functioning (Singsaas *et al*., 2004). Plants adjust chlorophyll to survive in the abiotic stress but still this hypothesis needs more investigations in reference to particular natural forest trees (Reich *et al*., 2007; Han *et al*., 2011; Liu *et al*., 2012). Chlorophyll is directly related to the temperature and water availability (Yamane *et al*., 2000; Yin *et al*., 2006). Chlorophyll a, chlorophyll b and total chlorophyll were reported reduced during drought (Hussein *et al*., 2008). However photosynthesis does not affected and controlled by chlorophyll only (Zhou *et al*., 2015; Feller, 2016; Lamaoui *et al*., 2018). Biochemistry of leaf, stomatal and mesophyll conductance (Grassi & Magnani, 2005) are also the unavoidable factors related to photosynthesis when drought occurs. Jaleel *et al*., 2008b reported that degradation of chlorophyll content during arid period in *Catharanthus roseus*. Similar findings were observed by Mssacci, 2008 and Tahkokorpi *et al*., 2007 in cotton plant and *Vaccinium myrtillus* respectively during drought stress. Our results are similar to the above studies in case of chlorophyll a, chlorophyll b and total chlorophyll. Total carotenoids concentration was higher in *G. tenax* and *A. nilotica* which was similar to the findings observed by Farooq *et al*., 2009 which showed the fact of higher chlorophyll and carotenoid content when leaf expansion was reduced during water deficit.

4. Conclusion

Each and every local area some traditional plants are present. These native vegetations have their own significance. Likewise with Rajasthan *Grewia* species like *G. tenax* and *G. asiatica* are native plant species. These are now threatened as a result of ignorance of local taxa. These plant species are economically beneficial to the local population because they have medicinal values and many other advantages such as forage, horticulture, fuel. Rajasthan is a semi-arid and arid state of India. These species are capable of developing within the climate of the state. Relative percentage change in parameters like leaf length; leaf area and carotenoid content are least in *G. tenax*. *G. asiatica* showed minimum relative change in chlorophyll a and total chlorophyll content. These results indicate that *G. tenax* and *G. asiatica* are drought tolerant species as compared to *A. nilotica*. In spite of the study of phytochemical substances, these *Grewia* species are still unexplored in terms of the stress caused by drought. It needs further investigation to increase the green cover of the state as well as for other benefits associated with these species.

References:

[1] Abrams, M. D. (1990), "Adaptations and responses to drought in *Quercus* species of North America". *Tree physiology*, **7**(1-2-3-4): 227-238.

[2] Agriculture and Biological Sciences **4**(6): 936–941.

[3] Alexander, D. (1993), *Natural Disasters*, University of California (UCL) Press and Chapman & Hall, New York, 632.

[4] Aref, I. M., & El-Juhany, L. I. (1999), "Effects of water deficit on the growth of *Acacia* asak, *A. tortilis* and *A. gerrardi"*. Mansoura University. *Journal of Agriculture Science*, **24**(10): 5627-5636.

[5] Arnon, D. I. (1949), "Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*". *Plant physiology*, **24**(1): 1.

[6] Ashraf, M. Y., & Wu, L. (1994), "Breeding for salinity tolerance in plants", *Critical Reviews in Plant Sciences*, **13**(1): 17-42.

[7] Bargali, K., & Bargali, S. S. (2009), "*Acacia nilotica*: a multipurpose leguminous plant", *Nature and Science*, **7**(4): 11-19.

[8] Craufurd, P. Q., Wheeler, T. R., Ellis, R. H., Summerfield, R. J., & Prasad, P. V. (2000), "Escape and tolerance to high temperature at flowering in groundnut (*Arachis hypogaea* L.)",

The Journal of Agricultural Science, **135**(4): 371-378.

[9] Dev, R., Sharma, G. K., Singh, T., Dayal, D., & Sureshkumar, M. (2017), "Distribution of *Grewia* species in Kachchh Gujarat, India: taxonomy, traditional knowledge and economic potentialities".

[10] El Atta, H. A., Aref, I. M., Ahmed, A. I., & Khan, P. R. (2012), "Morphological and anatomical response of *Acacia ehrenbergiana* Hayne and *Acacia tortilis* (Forssk) Haynes subspp. *raddiana* seedlings to induced water stress", *African Journal of Biotechnology*, **11**(44): 10188-10199.

[11] Farooq M., Wahid, A., Kobayashi, N., Fujitad, D., & Basra, S.M.A. (2009), "Plant drought stress: effects, mechanisms and management", *Agronomy for Sustainable DevelopmentI*, **29**: 153–188.

[12] Feller, U. (2016), "Drought stress and carbon assimilation in a warming climate: reversible and irreversible impacts", *Journal of Plant Physiology*, **203**:84–94.

[13] Fini, A., Bellasio, C., Pollastri, S., Tattini, M., & Ferrini, F. (2013), "Water relations, growth, and leaf gas exchange as affected by water stress in *Jatropha curcas*", *Journal of Arid Environments*, **89**: 21-29.

[14] Galle, A., Haldimann, P., & Feller, U. (2007), Photosynthetic performance and water relations in young pubescent oak (*Quercus pubescens*) trees during drought stress and recovery", *New Phytologist*, **174**(4): 799-810.

[15] Grassi, G., & Magnani, F. (2005), "Stomatal, mesophyll conductance and biochemical limitations to photosynthesis as affected by drought and leaf ontogeny in ash and oak trees", *Plant, Cell & Environment*, **28**(7): 834-849.

[16] Han, W. X., Fang, J. Y., Reich, P. B., Woodward, F., & Wang, Z. (2011), "Biogeography and variability of eleven mineral elements in plant leaves across gradients of climate, soil and plant functional type in China", *Ecology letters*, **14**: 788–796.

[17] Hoshika, Y., Omasa, K., & Paoletti, E. (2013), "Both ozone exposure and soil water stress are able to induce stomatal sluggishness", *Environmental and Experimental Botany*, **88**: 19-23.

[18] Hu, L., Wang, Z., & Huang, B. (2010), "Diffusion limitations and metabolic factors associated with inhibition and recovery of photosynthesis from drought stress in a C3 perennial grass species", *Physiologia plantarum*, **139**(1): 93-106.

[19] Hussein, M.M., Kassab, O.M., & Ellil, A.A. (2008), "Evaluating water stress influence on growth and photosynthetic pigments of two sugar beet varieties", *Research Journal of Agriculture and Biological Sciences*, **4**(6): 936–941.

[20] Ibrahim, J. G., & Chen, M. H. (1998), "Prior distributions and Bayesian computation for proportional hazards models", *Sankhya: The Indian Journal of Statistics*, Series B, 48-64.

[21] Jaleel, C.A., R. Gopi and R. Panneerselvam, (2008b), "Growth and photosynthetic pigments responses of two varieties of *Catharanthus roseus* to triadimefon treatment", *Comptes Rendus Biologies*, **331**: 272–277.

[22] Lamaoui, M., Jemo, M., Datla, R., & Bekkaoui, F. (2018), "Heat and drought stresses in crops and approaches for their mitigation", *Frontiers in chemistry*, **6**: 26.

[23] Liu, C., Wang, X., Wu, X., Dai, S., He, J., and Yin, W. (2012), "Relative effects of phylogeny, biological characters and environments on leaf traits in shrub biomes across central Inner Mongolia, China". *Journal of Plant Ecology*, **6**: 220–231.

[24] Manes, F., Vitale, M., Donato, E., Giannini, M., & Puppi, G. (2006), "Different ability of three Mediterranean oak species to tolerate progressive water stress", *Photosynthetica*, **44**(3): 387-393.

[25] Mssacci, A., Nabiev, S.M., Pietrosanti, L., Nematov, S.K., Chernikova, T.N., Thor, K., & Leipner, J. (2008), "Response of photosynthetic apparatus of cotton (*Gossypium hirsutum*) to the onset of drought stress under field conditions studied by gas-exchange analysis and chlorophyll fluorescence imaging". *Plant Physiology and Biochemistry*, **46**: 189–195.

[26] Nagarajan, R. (2003), "Drought: Assessment, Monitoring, Management and Resource Conservation", Capital Publishing Company, New Delhi, 312.

[27] Nelissen, H., Rymen, B., Coppens, F., Dhondt, S., Fiorani, F., & Beemster, G. T. (2013), "Kinematic analysis of cell division in leaves of mono-and dicotyledonous species: a basis for understanding growth and developing refined molecular sampling strategies", *Plant organogenesis: Methods and protocols*, 247-264.

[28] Ommen, O. E., Donnelly, A., Vanhoutvin, S., Van Oijen, M., & Manderscheid, R. (1999), Chlorophyll content of spring wheat flag leaves

grown under elevated CO_2 concentrations and other environmental stresses within the 'ESPACE-wheat'project, *European Journal of Agronomy*, **10**(3-4): 197-203.
[29] Poorter, H., Niinemets, U., Poorter, L., Wright, I. J., & Villar, R. (2009), "Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis", *New phytologist*, **182**(3): 565-588.
[30] Rahmati, M., Mirás-Avalos, J.M., Valsesia, P., Lescourret, F., Génard, M., Davarynejad, G.H., Bannayan, M., Azizi, M. and Vercambre, G. (2018), "Disentangling the effects of water stress on carbon acquisition, vegetative growth, and fruit quality of peach trees by means of the QualiTree model", *Frontiers in Plant Science*, **9**: 3.
[31] Reich, P. B., Wright, I. J., & Lusk, C. H. (2007), "Predicting leaf physiology from simple plant and climate attributes: a global GLOPNET analysis", *Ecological Applications*, **17**(7): 1982-1988.
[32] Rodriaguez, L. S. N. (2000), "Balanced vs. slightly unbalanced selection". *Heredity*, **84**(685): 691.
[33] Roothaert, R., Franzel, S., & Kiura, M. (2003), "On-farm evaluation of fodder trees and shrubs preferred by farmers in central Kenya", *Experimental Agriculture*, **39**(4): 423.
[34] Schuppler, U., He, P. H., John, P. C., & Munns, R. (1998), "Effect of water stress on cell division and Cdc2-like cell cycle kinase activity in wheat leaves", *Plant physiology*, **117**(2): 667-678.
[35] Sharma, N., & Patni, V. (2012), "*Grewia tenax* (Frosk.) Fiori.-a traditional medicinal plant with enormous economic prospectives", *Asian Journal of Pharmaceutical and Clinical Research*, **5**(3): 28-32.
[36] Shumway, D. L., Steiner, K. C., & Abrams, M. D. (1991), "Effects of drought stress on hydraulic architecture of seedlings from five populations of green ash", *Canadian Journal of Botany*, **69**(10): 2158-2164.
[37] Singsaas, E. L., Ort, D. R., & Delucia, E. H. (2004), "Elevated CO_2 effects on mesophyll conductance and its consequences for interpreting photosynthetic physiology", *Plant, Cell & Environment*, **27**(1): 41-50.
[38] Smirnoff, N. (1995), "Antioxidant systems and plant response to the environment", *Environment and plant metabolism: Flexibility and acclimation*, 243-317.
[39] Sperry, J. S. (2000), "Hydraulic constraints on plant gas exchange", *Agricultural and forest meteorology*, **104**(1): 13-23.
[40] Swami, S. K. (2001), "Management of drought in India. UNDP Subregional Seminar on Drought Mitigation", Iran, 28–29.
[41] Tahkokorpi, M., Taulavuori, K., Laine, K., & Taulavuori, E. (2007), "After- effects of drought related winter stress in previous and current year stems of *Vaccinium myrtillus* L". *Environmental and Experimental Botany*, **61**: 85–93.
[42] Tardieu, F., & Tuberosa, R. (2010), "Dissection and modelling of abiotic stress tolerance in plants", *Current opinion in plant biology*, **13**(2): 206-212.
[43] Tisne, S., Schmalenbach, I., Reymond, M., Dauzat, M., Pervent, M., Vile, D., & Granier, C. (2010), "Keep on growing under drought: genetic and developmental bases of the response of rosette area using a recombinant inbred line population", *Plant, Cell & Environment*, **33**(11): 1875-1887.
[44] Ullah, W., Uddin, G., & Siddiqui, B. S. (2012), "Ethnic uses, pharmacological and phytochemical profile of genus *Grewia"*, *Journal of Asian natural products research*, **14**(2): 186-195.
[45] Umucalılar, H. D., Gülşen, N., Coşkun, B. E. H. İ. Ç., Hayirli, A., & Dural, H. U. S. E. Y. I. N. (2007), "Nutrient composition of mistletoe (*Viscum album*) and its nutritive value for ruminant animals", *Agroforestry Systems*, **71**(2): 77-87.
[46] Van Looy, T., Carrero, G. O., Mathijs, E., & Tollens, E. (2008), "Underutilized agroforestry food products in Amazonas (Venezuela): a market chain analysis", *Agroforestry systems*, **74**: 127-141.
[47] Venkatesan, K., Patidar, A., Singh, M., Kumar, M., Kumawat, R.N., Dev, R., Uchoi, J., Kumar, A., Mertia, D.S. and Singh, J.P., (2019), "Distribution, associated vegetation, conservation and utilization of *Grewia tenax*: an important underutilized shrub species of the Thar Desert of India", *Plant Genetic Resources*, **17**(1): 73-80.
[48] Vile, D., Pervent, M., Belluau, M., Vasseur, F., Bresson, J., Muller, B., Granier, C. and Simonneau, T., (2012), "Arabidopsis growth under prolonged high temperature and water deficit: independent or interactive effects?", *Plant, cell & environment*, **35**(4), 702-718.

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

[49] Von Maydell, H. J. (1986), "Trees and Shrubs of the Sahel", G.T.Z. Scientific Books, Germany, pp 525.
[50] Wahid, A., Rasul, E., Rao, R., & Iqbal, R. (2005), "Photosynthesis in leaf, stem, flower and fruit", *Handbook of photosynthesis*, **2**: 479-497.
[51] Wery, J., Silim, S.N., Knights, E.J., Malhotra, R.S., Cousin, R. (1994), "Screening techniques and sources and tolerance to extremes of moisture and air temperature in cool season food legumes", *Euphytica*, **73**: 73–83.
[52] Xu, F., Guo, W., Wang, R., Xu, W., Du, N., & Wang, Y. (2009), "Leaf movement and photosynthetic plasticity of black locust (*Robinia pseudoacacia*) alleviate stress under different light and water conditions", *Acta Physiologiae Plantarum*, **31**: 553-563.
[53] Yadav, A. K. (1999), "Phalsa: A potential new small fruit for Georgia", *Perspectives on new crops and new uses*, 348-352.
[54] Yamane, Y., Shikanai, T., Kashino, Y., Koike, H., & Satoh, K. (2000), "Reduction of Qa in the dark: another cause of fluorescence F o increases by high temperatures in higher plants", *Photosynthesis Research*, **63**: 23-34.
[55] Yin, C., Berninger, F., and Li, C. (2006), "Photosynthetic responses of *Populus przewalski* subjected to drought stress", *Photosynthetica*, **44**: 62–68.
[56] Zaefyzadeh, M., Quliyev, R. A., Babayeva, S., & Abbasov, M. A. (2009), "The effect of the interaction between genotypes and drought stress on the superoxide dismutase and chlorophyll content in durum wheat landraces", *Turkish Journal of biology*, **33**(1): 1-7.
[57] Zhou, X., Welsch, R., Yang, Y., Álvarez, D., Riediger, M., Yuan, H., Fish, T., Liu, J., Thannhauser, T.W. and Li, L. (2015), "*Arabidopsis* OR proteins are the major posttranscriptional regulators of phytoene synthase in controlling carotenoid biosynthesis", *Proceedings of the National Academy of Sciences*, **112**(11), 3558-3563.
[58] Zia-Ul-Haq, M., Stanković, M. S., Rizwan, K., & De Feo, V. (2013), "*Grewia asiatica* L., a food plant with multiple uses", *Molecules*, **18**(3): 2663-2682.
[59] Zobayed, S. M. A., Afreen, F., & Kozai, T. (2005), "Temperature stress can alter the photosynthetic efficiency and secondary metabolite concentrations in St. John's wort", *Plant Physiology and Biochemistry*, **43**(10-11): 977-984.

Tables and Figures

Table 1.1: (Relative Leaf Length in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

Time	***Grewia tenax*** Mean ± S.D.	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	3.75± 0.36	19.780±0.1.46	6.160±0.25
Drought	2.230±0.21	11.730±0.94	2.260±0.34

Table 1.2 (Relative Leaf Width in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

Time	***Grewia tenax*** Mean	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	3.55± 0.15	18.11±0.1.77	4.38±0.16
Drought	1.45±0.15	9.89±0.95	3.39±0.21

Table 1.3 (Relative Leaf Area in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

Time	***Grewia tenax*** Mean ± S.D.	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	10.51± 0.77	278.27±41.33	2.16±0.37
Drought	7.04±0.36	80.05±4.73	1.10±0.24

Table 1.4 (Relative % Change in Leaf Expansion *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

G. tenax Mean ± S.D.	***G. asiatica*** Mean ± S.D.	***A. nilotica*** Mean ± S.D.
39.97±8.49	40.23±8.0	63.27±5.61

Table 2.1 (Relative Chlorophyll a Concentration in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

Time	***Grewia tenax*** Mean ± S.D.	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	0.70± 0.00	0.28±0.00	1.49±0.00
Drought	0.00±0.00	0.18±0.00	0.15±0.00

Table 2.2 (Relative Chlorophyll b Concentration in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and DR)

Time	***Grewia tenax*** Mean ± S.D.	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	0.63± 0.00	0.73±0.01	0.67±0.00
Drought	0.07±0.00	0.23±0.00	0.31±0.00

Table 2.3 (Total Chlorophyll Concentration in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

Time	***Grewia tenax*** Mean ± S.D.	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	148.32±4.64	94.07±3.14	233.01±1.06
Drought	6.44±0.33	46.55±0.10	45.84±0.57

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

Table 2.4 (Relative Carotenoids Concentration in *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

Time	***Grewia tenax*** Mean ± S.D.	***Grewia asiatica*** Mean ± S.D.	***Acacia nilotica*** Mean ± S.D.
Post Rain	0.05±0.00	0.54±0.00	0.13±0.00
Drought	0.07±0.00	0.03±0.00	0.23±0.00

Table 2.5 (Relative % Change in Pigment Concentration *G. tenax*, *G. asiatica* and *A. nilotica* in Post Rain and Drought)

G. tenax Mean ± S.D.	***G. asiatica*** Mean ± S.D.	***A. nilotica*** Mean ± S.D.
39.97±8.49	40.23±8.0	63.27±5.61

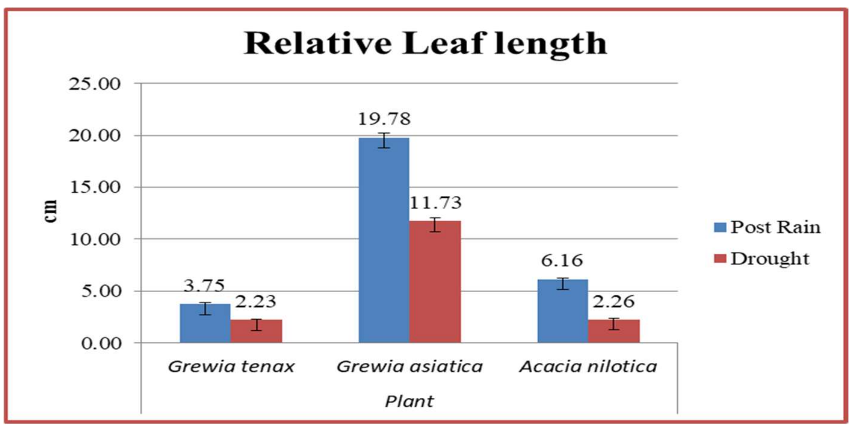


Figure: 1.1

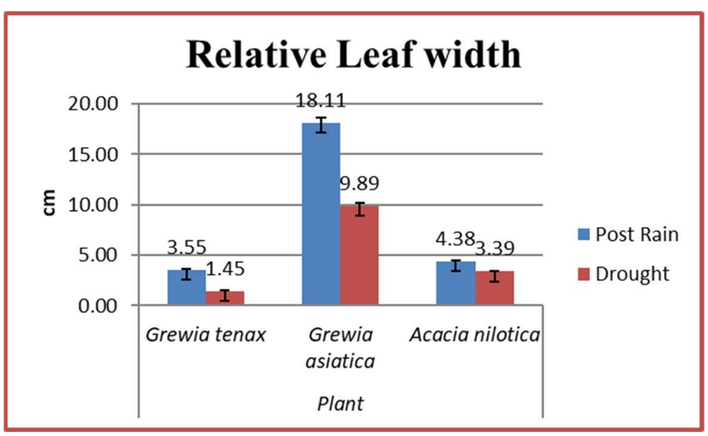


Figure: 1.2

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

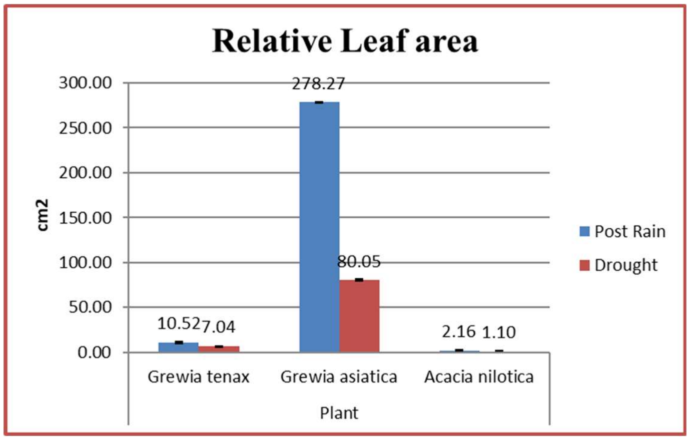


Figure: 1.3

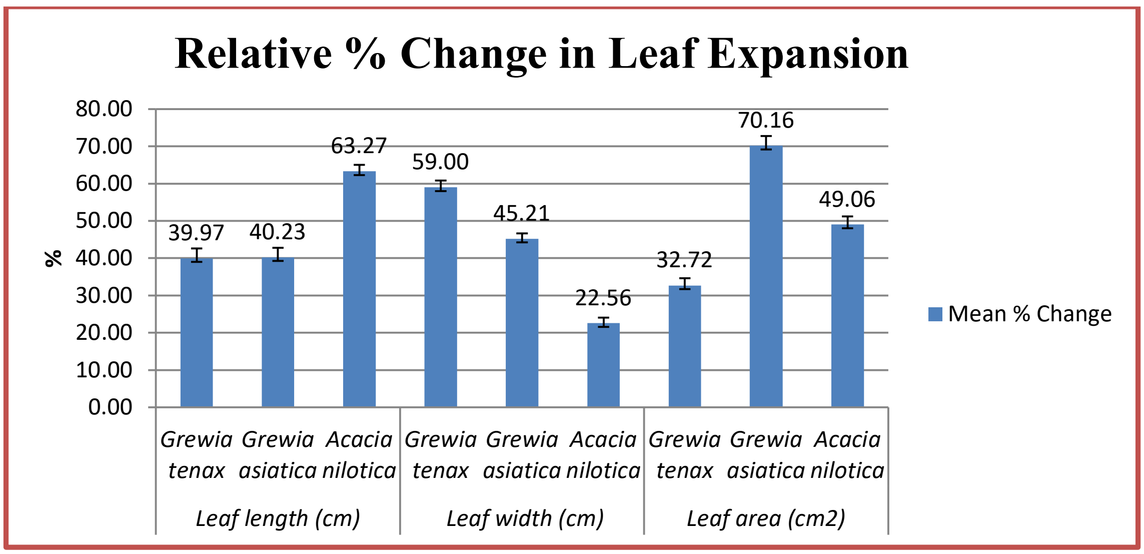
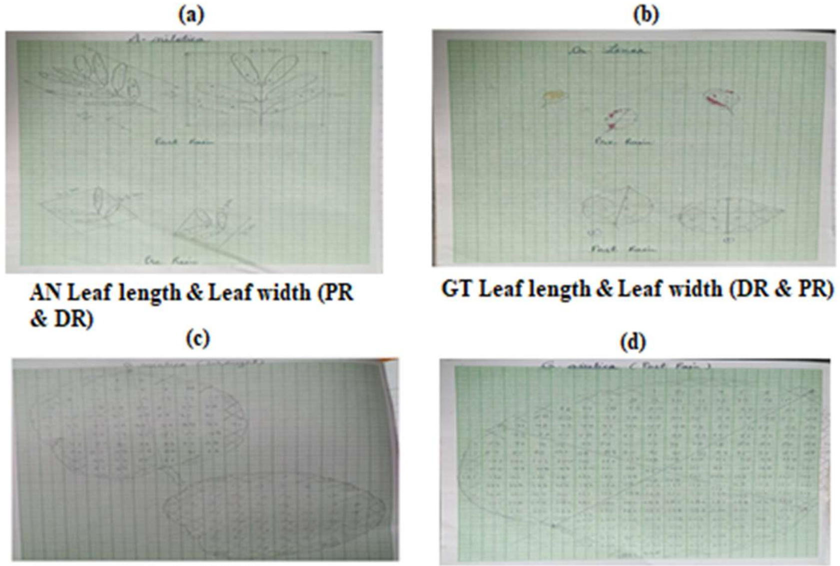


Figure: 1.4

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

(a) (b)



AN Leaf length & Leaf width (PR & DR)

GT Leaf length & Leaf width (DR & PR)

(c) (d)

GA Leaf length & Leaf width (DR)

GA Leaf length & Leaf width (PR)

Figure: 1.5

PR- Post Rain; DR- Drought
AN- *Acacia nilotica*; GT- *Grewia tenax*; GA- *Grewia asiatica*

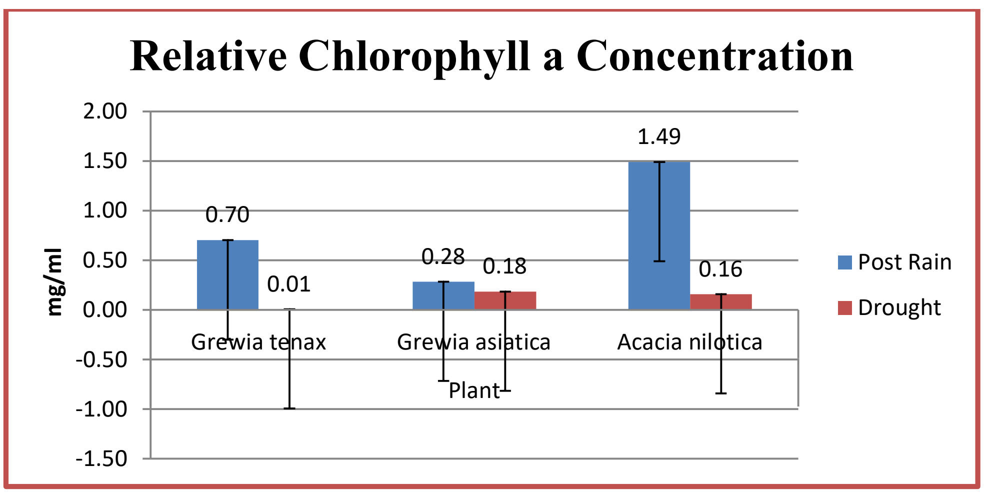


Figure 2.1

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

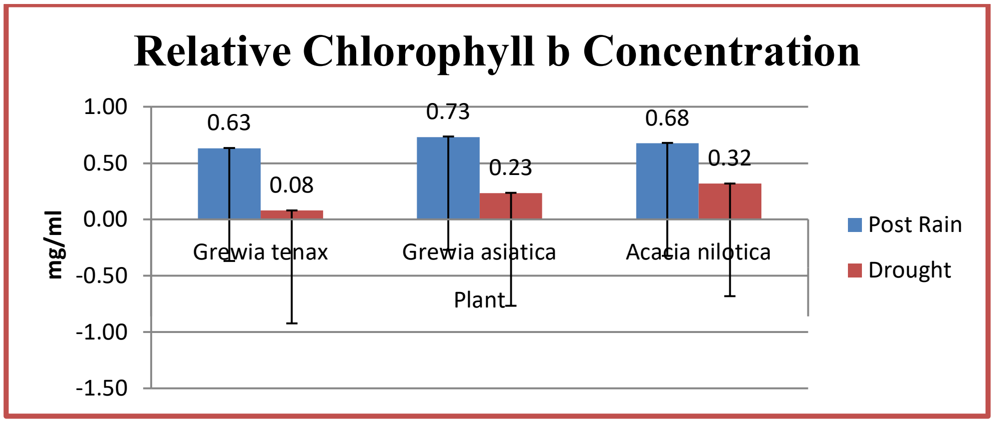


Figure 2.2

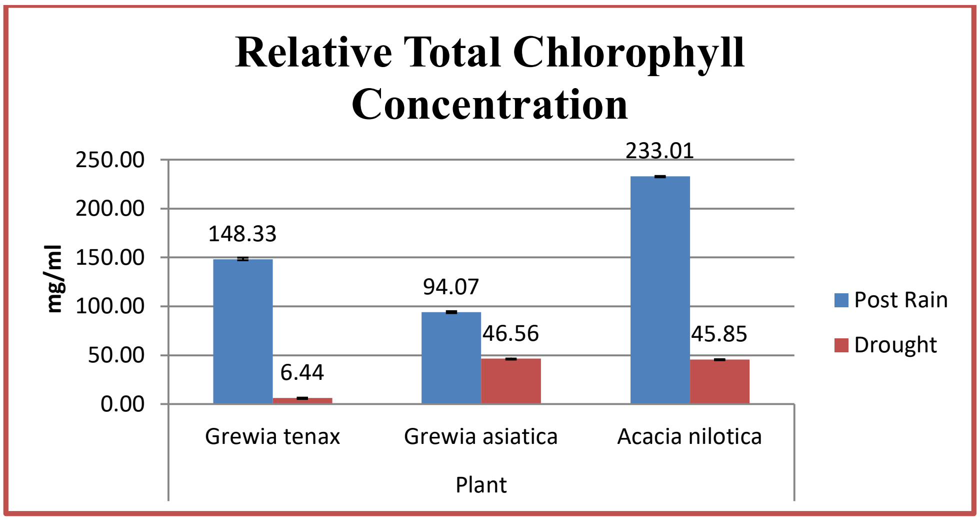


Figure: 2.3

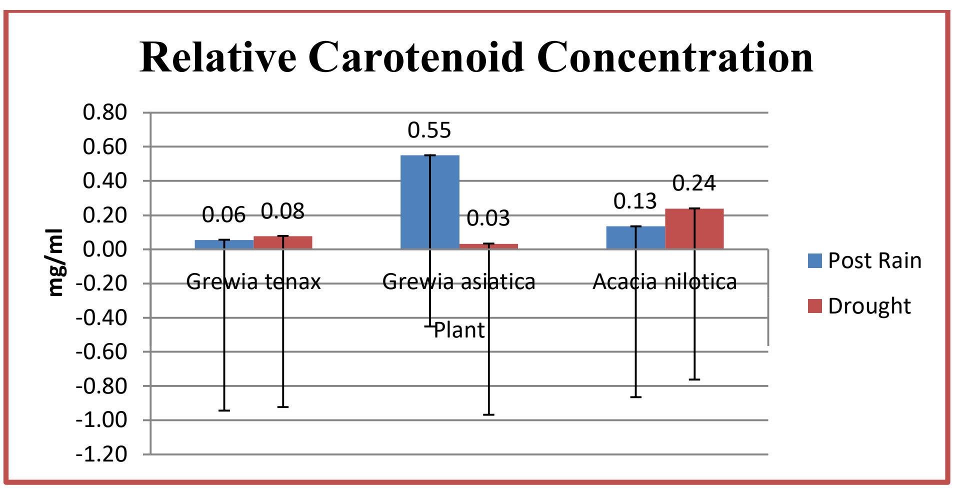


Figure: 2.4

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

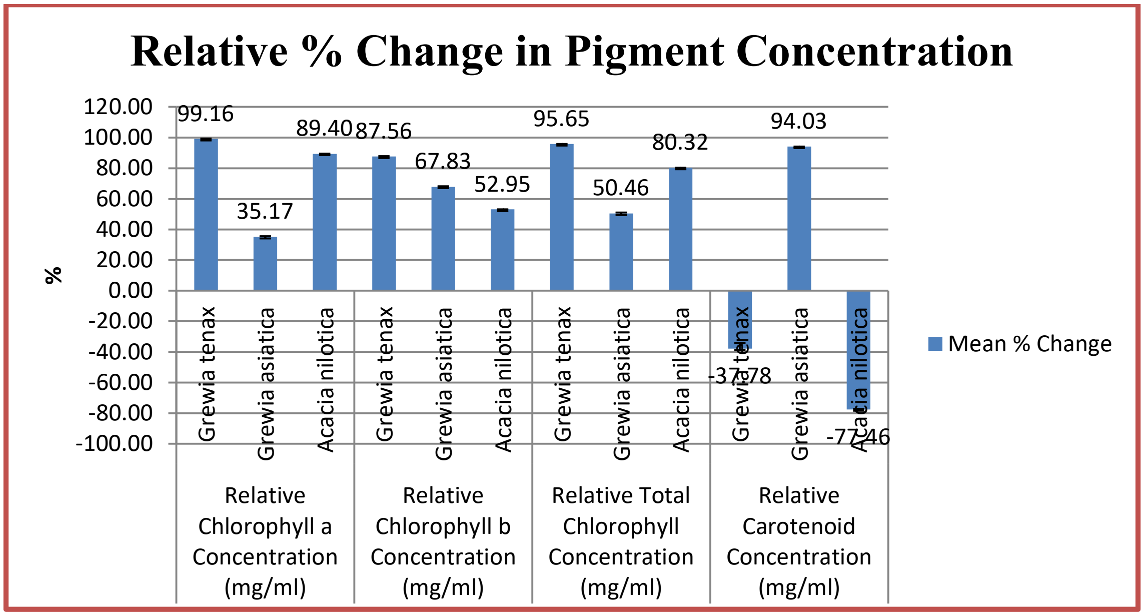


Figure: 2.5