academicJournals

Vol. 15(2), pp. 29-31, 13 January, 2016
DOI: 10.5897/AJB2015.15017
Article Number: 32832CB56988
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Mini Review

Plants' responses to drought and shade environments

Min Young Kwon and Su Young Woo*

Department of Environmental Horticulture, College of Natural Sciences, University of Seoul, Siripdaero 163, Dongdaemun-gu, Seoul 130-743, Republic of Korea.

Received 30 September, 2015; Accepted 9 November, 2015

Water and light are the most important environements for plants' growth. These environemts are critical factors needed not only for the survival of plants but also their production. When plants are exposed to drought condition, they change in their anatomical, physiological and biochemical properties. Drought affects plants wildly from their cell structure to growth. It causes higher plastoglobuli, lower starch grain, distortion of thylakoids, disrupted grana and swelling of chloroplast. Plants grown under enhanced light, have increased palisade parenchyma, thicker leaf, higher biomass, increased photosynthesis, lower contents of chlorophyll, carotenoid and nitrogen.

Key words: Drought, plant, shade, water.

INTRODUCTION

Plants undergo several environmental stresses such as abiotic (drought, salt, temperature, cold and light) and biotic (fungi, bacteria, insects and viruses). Among them, drought is widely known as the main factor that limits plants' growth, productivity and development (Reddy et al., 2004; Shao et al., 2008; Li et al., 2009). Recently, drought occured frequently all over the globe due to climate changes (Khaine and Woo, 2015).

Light and shade are very important environements for plants' growth in the ecosystem. These environmental factors affect plants' growth, morphology, physiology and biochemistry. Many research works have shown that light plays key role in changing the traits of plants (Lee et al., 2013; Ranade and García-Gil, 2013; Adam and Cavaleri, 2014; Kuehne et al., 2014; Lavinsky et al., 2014; Sun et al., 2014). Plants' morphological and physiological differences in growth reactions to shade or low light intensity are exceedingly important in all types of forests in the world.

This mini review covers a brief effect of light and soil moisture on plants. Especially, the morphological, physiological and biochemical changes caused by different light intensity and water contents in the soil are mentioned.

MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES UNDER DROUGHT

When plants are exposed to drought condition, anatomical, physiological and biochemical changes occur in them. Drought affects plants' growth terribly (Kivimäenpää et al.,

*Corresponding author. E-mail: wsy@uos.ac.kr. Tel: + 82 2 6490 2691.

2001; Chartzoulakis et al., 2002; Zellnig et al., 2004; Villagra and Cavagnaro, 2006; Olmos et al., 2007). Also, it makes the root systems of plants develop more than the stem system in order to facilitate water absorption from soil. To avoid water loss and evaporation by expanded leaf area, plants decrease individual leaf area, total leaf area per plant and the number of leaves per plant. Eventually, reduction of leaf area by drought decreases plants' growth and photosynthesis (Reddy et al, 2003; Shao et al., 2008).

The limitation of photosynthesis under drought is due to stomatal limitation. To keep water evaporation, plants decrease transpiration rate through stomatal closure, and intercellular CO_2 concentration is reduced (Farquhar and Sharkey, 1982). Similar results were observed in *Populus*, *Picea*, *Querqus* seedlings (Lopez-Carbonell et al., 1994; Ren et al., 2007; Yang et al., 2007).

Plants exposed to drought might cause oxidative stresses by the formation of reactive oxygen species, but, it can overcome oxidative stresses by synthesizing antioxidants (carotenoid, ascorbate and glutathione) and producing antioxidant enzymes (APX, SOD, POD and GR) and osmoprotectants (Egert and Tevini, 2002). Proline is known as osmolyte and performs osmotic adjustment, which is an important mechanism under drought condition (Faës et al., 2015). In addition, it acts as free radical scavenger to protect the cells from reactive oxygen species. Proline accumulation was reported in wheat, *Helianthus*, *Populus* (Yang et al., 2007). As mentioned previously, plants might adapt to or avoid those changes caused by environmental influences (Givnish, 1988).

MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES UNDER SHADE

Sunlights are indispensable to all living things. Especially, lights are one of the essential resources used for photosynthesis and plants' development (Zhong et al., 2014). It determines not only morphological traits such as seed germination, leaf arrangement and stem growth, but also physiological activities such as photosynthesis or rubisco activity (Lee et al, 2013; Cheung et al., 2014). The demand of lights might be different depending on species, environment and location of leaf. Some species can grow well under either high light or low light.

Plants, grown under enhanced light, have increased palisade parenchyma, thicker leaf, large leaf area, higher biomass, increased photosynthesis, lower contents of chlorophyll, carotenoid and nitrogen (Je et al., 2006;Yang et al., 2007; Huang et al., 2008; Volkova et al., 2010). However, the enhanced light might be unfavorable to growth of seedlings. Photoinhibition regarded as photosynthetic apparatus is damaged by stronger lights. It often occurs when plants accept excessive lights than required (Demming at al., 1987; Valladares and Pearcy, 1997; Niyogi, 1999; Kwon and Woo, 2015).

MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES UNDER DROUGHT AND SHADE

Light and water are the main factors that determine plants' growth and distribution. Many other studies reported morphological, physiological and biochemical changes caused by the combination of drought and shade (Sack, 2004; Aranda et al., 2005; Yin et al., 2013). There are various opinions related to the effects caused by drought and shade. First, shading alleviates the drought condition on the seedlings by lowering leaf and air temperature (Sack, 2004; Dai et al., 2009). Second, another hypothesis is that shading aggravates growth of seedlings which are exposed to drought. Allocating to more shoot, leaf area than root reduces ability to capture water from soil and diffuse water loss due to expanded leaf area (Abrams and Kuniske, 1990; Valladares and Pearcy, 1997).

CONCLUSION

Reduction of irradiance that causes thinner leaf thickness is confirmed. Leaf thickness increases due to larger palisade and spongy parenchyma. Gas exchange (photosynthesis, transpiration rate, stomatal conductance and water use efficiency) increases in response to an increase in water contents. High light and water contents in the soil have severe impacts on the morphological, physiological and biochemical characteristics of several plants. Though only few stuies have reported the interaction between light and water, these environmental factors are considered so important. Probably, most plants might adapt to or avoid those changes caused by environmental influences.

Conflict of interests

The authors have not declare any conflict of interest.

ACKNOWLEDGEMENT

This study was carried out with the support of "Forest Science and Technology Project (Project No. S211215L030210)" provided by Korea Forest Service.

Abbreviations

APX, Ascorbate peroxidase; **SOD,** superoxide dismutase; **POD,** peroxidase; **GR,** gluthatione reductase; **CO_2,** carbon dioxide.

REFERENCES

Abrams MD, Kuniske ME (1990). Leaf structural characteristics of 31

Hardwood and Conifer tree species n central Wisconsin: Influence of light regime and shade-tolerance rank. For. Ecol. Manage. 31:245-253.
Adam PC, Cavaleri MA (2014). Light drives vertical gradients of leaf morphology in a sugar maple (*Acer saccharum*) forest. Tree Physiol. 34(2):146-158.
Aranda I, Castro L, Pardos M, Gil L, Pardos JA (2005). Effects of theinteraction between drought and shade on water relations, gasexchange and morphological traits in cork oak (*Quercus suber*L.) seedlings. For. Ecol. Manage. 210:117-129.
Chartzoulakis K, Patakas A, Kofidis G, Bosabalidis A, Nastou A (2002). Water stress affects leaf anatomy, gas exchange, water relations and growth of two avocado cultivars. Sci. Hortic. 95:39-50.
Cheung CYM, Poolman MG, Fell DA, Ratcliffe RG, Sweetlove LJ (2014). A diel flux balance model captures interactions between light and dark metabolism during Day-Night cycles in C_3 and Crassulacean acid metabolism leaves.Plant Physiol. 165:917-929.
Dai Y, Shen Z, Liu Y, Wang L, Hannaway D, Lu H (2009). Effects of shade treatments on the photosynthetic capacity, chlorophyll fluorescence, and chlorophyll content of *Tetrastigma hemsleyanum* Diels et Gilg. Environ. Exp. Bot. 65:177-182.
Demming B, Winter K, Kruger A, Czygan FC (1987). Photoinhibition and zeaxanthin formation in intact leaves a possible role of the xanthophyll cycle in the dissipation of excess light energy. Plant Physiol. 84:218-224.
Egert M, Tevini M (2002). Influence of drought on some physiological parameters symptomatic for oxidative stress in leaves of chives (*Allium schoenoprasum*).Eviron. Exp. Bot. 48:43-49.
Faës P, Deleu C, Aïnouche A, Le Cahérec F, Montes E, Clouet V, Gouraud AM, Albert B, Orsel M, Lassalle G, Leport L, Bouchereau A, Niogret MF (2015). Molecular evolution and transcriptional regulation of the oilseed rape proline dehydrogenase genes suggest distinct roles of proline catabolism during development. Planta 241(2):403-419
Farquhar GD, Sharkey TD (1982). Stomatal conductance and photosynthesis. Ann. Rev. Plant Physiol. 33:317-345.
Givnish TJ (1988). Adaptation to sun and shade: a whole-plant perspective. Aust. J. Plant Physiol. 15:63–92.
Huang X, Yin C, Duan B, Li C (2008). Interaction between drought and shade on growth and physiological traits in two *Populus cathayana* populations. Can. J. For. Res. 38:1877-1887.
Je SM, Son SG, Woo SY, Byun KO, Kim CS (2006). Photosynthesis and chlorophyll contents of *Chloranthus glaber* under different shading treatments. Kor. J. Agric. For. Meteorol. 8(2):54-60.
Khaine I, Woo SY (2015). An overview of interrelationship between climate change and forests. For. Sci. Technol. 11(1):1-8.
Kivimäenpää M, Sutinen S, Medin EL, Karlsson PE, Selldén G (2001). Diurnal changes in microscopic structures of mesophyll cells of *Norway spruce*, *Picea abies* (L.) Karst. and effects of ozone and drought. Ann. Bot. 88:119-130.
Kuehne C, Nosko P, Horwath T, Bauhus J (2014). A comparative study of physiological and morphological seedling traits associated with shade tolerance in introduced red oak (*Quercus rubra*) and native hardwood tree species in southwestern Germany. Tree Physiol 34(2):184-193.
Kwon MY, Woo SY (2015). Anatomical differences of *Ulmus pumila* seedlings under different water irrigation and light intensity. For. Sci. Technol. 11(4):228-230..
Lavinsky AO, Gomes FP, Mielke MS, França S (2014). Photosynthetic acclimation in shade-developed leaves of *Euterpe edulis* Mart (Arecaceae) after long-term exposure to high light. Photosynthetica 52(3):351-357.
Lee KA, Lee SH, Woo SY (2013).Rubisco activity and gene expression of tropical tree species under light stress. Afr. J. Biotechnol. 12(20): 2764-2769.
Li FL, Bao WK, Wu N (2009). Effects of water stress on growth, dry matter allocation and water-use efficiency of a leguminous species, *Sophora davidii*. Agrofor. Syst. 77:193-201.
Lopez-Carbonell M, Alegre L, Vanonckelen H (1994). Effects of water stress on cellular ultrastructure and on concentration of endogenous abscisic acid and indole-3-acetic acid in *Fatsia japonica* leaves. Plant Growth Regul.14:29-35.
Niyogi KK (1999). Photoprotection revisited: Genetic and molecular approaches. Ann. Rev. Plant Physiol. Plant Mol. Biol. 50:333-359.
Olmos E, Sanchez-Blanco MJ, Ferrandez T, Alarcon JJ (2007). Subcellular effects of drought stress in *Rosmarinus officinalis*. Plant Biol. 9:77-84.
Ranade SS, García-Gil MR (2013). Ecotypic variation in response to light spectra in Scots pine (*Pinus sylvestris* L.). Tree Physiol 33(2): 195-201.
Reddy AR, Chaitanya KV, Vivekanandan M (2004). Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. J. Plant Physiol. 161:1189-1202.
Reddy TY, Reddy VR, Anbumozhi V (2003). Physiological responses of groundnut (*Arachis hypogaea* L.) to drought stress and its amelioration: A critical review. Plant Growth Regul. 41:75-78.
Ren J, Dai WR, Xuan ZY, Yao YN, Korpelainen H, Li CY (2007). The effect of drought and enhanced UV-B radiation on the growth and physiological traits of two contrasting poplar species. For. Ecol. Manage. 239:112-119.
Sack L (2004). Responses of temperate woody seedlings to shade and drought; do trate-offs limit potential niche differentiation? Oikos 107: 110-117.
Shao HB, Chu LY, Abdul-Jaleel C, Zhao CX (2008). Water-deficit stress-induced anatomical changes in higher plants. C R Biol. 331: 215-225.
Sun W, Ubierna N, Ma JY, Walker BJ, Kramer DM, Cousins AB (2014). The coordination of C_4photosynthesis and the CO_2-concentrating mechanism in Maize and *Miscanthus* × *giganteus* in response to transient changes in lightquality.Plant Physiol. 164:1283-1292.
Valladares F, Pearcy RW (1997). Interactions between water stress, sun-shade acclimation, heat tolerance and photoinhibition in the sclerophyll *Heteromeles arbutifolia*. Plant Cell Environ. 20:25-36.
Villagra PE, Cavagnaro JB (2006). Water stress effects on the seedling growth of *Prosopis argentina* and *Prosopis alpataco*. J. Arid Environ. 64:390-400.
Volkova L, Bennett LT, Merchant A, Michael T (2010). Shade does not ameliorate drought effects on the tree fern species *Dicksonia antarctica* and *Cyathea australis*. Trees 24:351-362.
Yang Y, Liu Q, Han C, Qiao YZ, Yao XQ, Yin HJ (2007). Influence of water stress and low irradiance on morphological and physiological charachteristics of *Picea asperata* seedlings. Photosynthetica 45(4): 613-619.
Yin Y, Adachi Y, Ye W, Hayashi M, Nakamura Y, Kinoshita T, Mori IC, Murata Y (2013). Difference in abscisic acid perception mechanisms between closure induction and opening inhibition of stomata. Plant Physiol. 163:600-610.
Zellnig G, Zechmann B, Perktold EA (2004). Morphological and quantitative data of plastids and mitochondria within drought-stressed spinach leaves. Protoplasma 223:221-227.
Zhong XM, Shi ZS, Li FH, Huang HJ (2014). Photosynthesis and chlorophyll fluorescence of infertile and fertile stalks of paired near-isogenic lines in maize (*Zea mays* L.) under shade conditions. Photosynthetica 52(4):597-603.