IJABBR- 2014- eISSN: 2322-4827

International Journal of Advanced Biological and Biomedical Research

Journal homepage: www.ijabbr.com

Review Article

Effects of Climate Change and Drought-Stress on Plant Physiology

Vahi Alizadeh*[1], Vahid Shokri[2], Amir Soltani[1], Mohammad Ali Yousefi[3]

[1]*Islamic Azad University, Meibod Branch, Meibod, Iran*
[2]*Islamic Azad University, Qaemshahr Branch, Qaemshahr, Iran*
[3]*Islamic Azad University, Branch, Dezfoul, Iran*

ARTICLE INFO

Article history:
Received: 05 Dec, 2014
Revised: 29 Jan, 2015
Accepted: 27 Feb, 2015
ePublished: 30 Mar, 2015

Key words:
Plant
Drought
Climate
Physiology
Stress

ABSTRACT

Drought is still limited in most crops is produced. Morphological and physiological knowledge to improve drought resistance under drought conditions created problems important is the fact each of these genetic relationships and processes associated with the exact amount of important plant and grain yield is unknown. The other hand, heritability of grain yield under water is reduced. Improve the performance of drought tolerant cultivars based on morphological and physiological components of plant modification as an important solution is proposed. One of the key predictions of climate change is that, in some regions, droughts are likely to increase in frequency and severity. This will have significant implications for the long-term viability of plant populations, especially where water availability plays a key role in delineating species ranges. However, while drought and overall aridity are known to be strong determinants of plant species distributions at the landscape level, much less is known about the ways in which plant populations respond to changes in drought regime, or the long-term impacts that extreme droughts have on plant community composition, structure, and function. While it is known that drought can cause significant re-structuring of plant communities, relatively few studies have quantified the environmental and biological factors that promote plant survivorship under acute moisture stress, especially in topoedaphically heterogeneous landscapes. The capacity for evolution to rescue plant populations faced with increasingly severe drought from extinction is also poorly understood. This places severe restrictions on our ability to predict the impacts of climate change on plant populations in many environments worldwide. In this paper a review Effects of climate change and Drought-stress on plant physiology.

INTRODUCTION

Severe drought stress may impair many plant functions but the main effect is reduction of carbon fixation. This, in turn, may differentially affect plant growth and production depending on many variables such as the length of the stress, the vegetative status of the crop, and the occurrence of other environmental stress (e.g., high light irradiance and high temperatures). One of the most well known responses to drought stress is stomatal closure and the subsequent increase of resistance to $CO2$diffusion in leaves (Kaiser, 1987). The concentration of $CO2$ at the site of its fixation (the chloroplast) may be further restricted by resistances inside the leaf mesophyll (Loreto et al., 1992). These resistances are

---

***Corresponding Author:** Vahi Alizadeh, Islamic Azad University, Meibod Branch, Meibod, Iran

also likely to increase in water-stressed leaves (Cornic and Massacci, 1996; Loreto *et al.,* 1997).

Summer crops of the Mediterranean region generally experience recurrent drought stress episodes during their vegetative and reproductive cycles. Irrigation water is a limited resource and water-saving practices are highly encouraged. It is therefore important to determine whether drought stress causes physiological consequences in field-grown plants that are a) transient and unable to affect plant growth and crop yield, or b) persistent and limiting plant growth and crop yield (Delfine *et al,* 2001).

The human influence on the earth's climate is becoming more and more obvious. Climate observations prove the existence of a global warming trend: global average temperature has increased by 0.88C since 1900 (Hansen et al., 2006) and the 12 hottest years observed globally since 1880 all occurred between 1990 and 2005.The European heat wave of 2003 was a drastic demonstration of the extent of impacts we need to expect more often in the future (Schar and Jendritzky, 2004; Ciais et al., 2005). Latest climate change scenario projections for Europe suggest that by 2100 temperatures will increase between about 28C in Ireland and theUK, up to about 38C in central Europe and 4–58C in the northern.

The changes in climate will also have associated consequences for biotic (frequency and consequences of pest and disease outbreaks) and a biotic disturbances (changes in fire occurrence, changes in wind storm frequency and intensity) with strong implications for forest ecosystems (lindner et al., 2010). In this paper a review Effects of climate change and Drought-stress on plant physiology.

Climate change

Climate change has already triggered species distribution shifts in many parts of the world. Increasing impacts are expected for the future, yet few studies have aimed for a general understanding of the regional basis for species vulnerability. We projected late 21st century distributions for 1,350 European plants species under seven climate change scenarios. Application of the International Union for Conservation of Nature and Natural Resources Red List criteria to our projections shows that many European plant species could become severely threatened (Gerten et al, 2004). More than half of the species we studied could be vulnerable or threatened by 2080. Expected species loss and turnover per pixel proved to be highly variable across scenarios (27– 42% and 45– 63% respectively, averaged over Europe) and across regions (2.5– 86% and 17– 86%, averaged over scenarios). Modeled species loss and turnover were found to depend strongly on the degree of change in just two climate variables describing temperature and moisture conditions. Despite the coarse scale of the analysis, species from mountains could be seen to be disproportionably sensitive to climate change (60% species loss). The boreal region was projected to lose few species, although gaining many others from immigration. The greatest changes are expected in the transition between the Mediterranean and Euro-Siberian regions (Edwards and Richardson, 2004).

Drought-stress

Drought is a major environmental stress factor that affects the growth and development of plants. Drought or soil water deficit can be chronic in climatic regions with low water availability or random and unpredictable due to changes in weather conditions during the period of plant growth. The effects of drought are expected to increase with climate change and growing water scarcity. Water is an increasingly scarce resource given current and future human population and societal needs, putting an emphasis on sustainable water use (Rosegrant and Cline, 2003). Thus, an understanding of drought stress and water use in relation to plant growth is of importance for sustainable agriculture. Plants, being sessile, have evolved specific acclimation and adaptation mechanisms to respond to and survive short- and long-term drought stresses. Analysis of these protective mechanisms will contribute to our knowledge of tolerance and resistance to stress. The complex responses to environmental stress, from perception to transcriptional and physiological changes, need to be considered at a global systems biology level to study the multiple interactive components in this biological process (Krishnan and Pereira, 2008).

Global gene expression analysis showed a substantial down-regulation of many photosynthetic genes under pDr wilting drought compared with a subtle change under mDr In Arabidopsis, more than 50% of the photosynthate is stored as starch (Zeeman and Rees, 1999). Therefore, we examined the gene expression data for effects of both drought treatments on starch biosynthesis and degradation. Two enzymes in starch biodegradation, a-amylase and b-amylase, were induced under pDr with expression log2 ratios of 1.5 and 3, respectively. Under mDr, onlyb-amylase was induced, with a log 2 ratio of 0.4. To validate these observations, plants were sampled for starch quantification from both drought treatments. The highest accumulation of starch in wild type Arabidopsis plants was found to be in the late afternoon (at the end of the daily photoperiod; Caspar et al., 1985).

The Importance of Extreme Climatic Events and Drought

Public awareness of the importance of extreme climatic events is growing (Beniston and Stephenson 2004). This is perhaps due in large part to the impacts of events such as the 2003 European heatwave (Schär et al. 2004), which caused up to 45,000 heat-related deaths (Patz et al. 2005), the 2010 Russian heatwave (Dole et al. 2011), and the disastrous 1950‘s to 1980‘s drought in the West African Sahel (Dai et al. 2004; Cook 2008). While longer-term climatic reconstructions (e.g., Manrique and Fernandez-Cancio 2000; Stahle et al. 2007) suggest that the occurrence and impacts of such climatic events are not new (e.g., Acuna-Soto et al. 2005, Benson et al. 2007), there is now a growing concern that anthropogenic global warming (Hansen et al. 2006) could increase the severity and frequency of extreme climatic events (Katz and Brown 1992, Beniston and Stephenson 2004) in the future. Indeed, evidence now exists on both global and regional scales in support of this prediction (Collins et al. 2000; Easterling et al. 2000). Major changes to the earth‘s climate are likely to challenge the sustainability of natural and agro-ecosystems globally. Food production is the bedrock that underpins human societies (Bell et al. 2004; Tubiello et al. 2007), and historical evidence from pre-Columbian Anasazi and Classical Period Mesoamerican societies in North and Central America (Acuna-Soto et al. 2005, Benson et al. 2007) illustrate the disastrous impacts that losses in agricultural production due to severe climatic events can have on human populations. From an ecological perspective, climate change also represents a major threat to the conservation of globalbiodiversity. Numerous plant and animal species have already undergone significant range shifts in response to recent climate change (Walther et al. 2002, Kelly and Goulden 2008), and such changes are likely to continue into the future as species‘ climatic niches move across the landscape. Indeed, it is argued that that in the absence of rapid implementation of strategies to reduce global greenhouse gas emissions, these and other processes will likely be commit a large proportion of the earth‘s biota to extinction (Thomas et al. 2004). By disturbing plant populations and derived ecosystem functions that depend on complex species interactions, extreme climatic events are likely to play a central mechanistic role (Parmesan et al, 2000).

CONCLUSION

The results of this and other studies reinforce the central argument that extreme drought events are likely to be key drivers of ecosystem change under anthropogenic global warming. Even on short timeframes, drought can significantly re-structure plant communities, but deeper, more prolonged events have the potential to cause catastrophic mortality of plant populations and to drive persistent changes in the spatial distributions of dominant species. In a static climatic regime, plant populations may, over time, be able to recover from such events, but today we are faced with a different situation: the frequency and duration of drought (as with other extreme events) is, in some regions, expected to increase. Under these conditions, changes in plant populations caused by extreme drought may well be permanent. The implications for biodiversity conservation and agricultural production are obvious, especially in systems where water limitation is a key determinant of community composition and structure.

At present, there are too few data available to make general predictions concerning the role that evolutional rescue is likely to play in maintaining plant population fitness against a backdrop of increasingly severe drought. Evidence from the temperate grassland system presented above suggests that once drought mortality becomes high enough, the survival of individual plants increasingly reflects local or micro-variation in soil moisture, and drought tolerance traits are rendered effectively neutral to selection. However, for most plant populations the potential for evolutionary rescue is likely to reflect a more complex interplay between spatial heterogeneity in water availability, amount and heritability of genetic variance for drought-related traits, and the role of demographic factors that facilitate or limit adaptation. With so few contemporary case studies to draw on, this an area ripe for further research.

REFERENCES

Acuna-Soto R., Stahle D. W., Therrell M. D., Gomez Chavez S. and Cleaveland M. K. (2005) Drought, epidemic disease, and the fall of the classic period cultures in Mesoamerica (AD 750-950). Hemorrhagic fevers as a cause of massive population loss. Medical Hypotheses 65: 405-409.

Bell G. and Gonzalez A. (2009) Evolutionary rescue can prevent extinction following environmental change. Ecology Letters 12: 942-948.

Beniston M. and Stephenson D. B. (2004) Extreme climatic events and their evolution under

Beniston M. and Stephenson D. B. (2004) Extreme climatic events and their evolution under changing climatic conditions. Global and Planetary Change 44: 19.

Benson L., Peterson K. and Stein J. (2007) Anasazi (pre-Columbian native Americans) migrations during the middle-12th an late 13th centuries – were they drought induced? Climatic Change 83: 187-213.

Caspar T, Huber SC, Somerville C(1985) Alterations in growth, photosynthesis, and respiration in a starchless mutant ofArabidopsis thaliana(L.) deficient in chloroplast phosphoglucomutase activity. Plant Physiol79:11–17.

Certini, G., 2005. Effects of fire on properties of forest soils: a review. Oecologia 143,1–10.

changing climatic conditions. Global and Planetary Change 44: 1-9.

Collins D. A., Della-Marta P. M., Plummer N. and Trewin B. C. (2000) Trends in annual frequencies of extreme climatic events in Australia. Australian Meterological Magazine 49: 277-292.

Cook K. H. (2008) The mysteries of the Sahel droughts. Nature Geoscience 1: 647-648.

Cunningham S. A., Summerhayes B. and Westoby M. (1999) Evolutionary divergences in leaf structure and chemistry, comparing rainfall and soil nutrient gradients. Ecological Monographs 69: 569-588.

Dai A., Lamb P. J., Trenberth K. E., Hulme M., Jones P. D. and Xie P. (2004) The recent Sahel drought is real. International Journal of Climatology 24: 1323-1331.

DELFINE, S., LORETO, F. & ALVINO, A. 2001. Drought-stress effects on physiology, growth and biomass production of rainfed and irrigated bell pepper plants in the Mediterranean region. Journal of the American Society for Horticultural Science, 126, 297-304.

Dole R., Hoerling M., Perlwitz J., Eischeid J., Pegion P., Zhang T., Quan X. W., Xu T. and Murray D. (2011) Was there a basis for anticipating the 2010 Russian heat wave?

Easterling D. R., Meehl G. A., Parmesan C., Changnon S. A., Karl T. R. and Mearns L. O. (2000) Climate extremes: Observations, modeling, and impacts. Science 289: 2068-2074.

Edwards, M. & Richardson, A. J. (2004) Nature430, 881–884.

Gerten, D., Schaphoff, S., Haberlandt, U., Lucht, W. & Sitch, S. (2004)J.Hydrol. (Amersterdam)286,249–270.

Hansen J., Sato M., Ruedy R., Lea D. W. and Medina-Elizade M. (2006) Global temperature change. Proceedings of the National Academy of Sciences 103: 14288-14293.

Hansen, J., Ruedy, R., Sato, M., Lo, K., 2006. GISS Surface Temperature Analysis. Global Temperature Trends: 2005 Summation. NASA Goddard Institute for Space Studies and Columbia University Earth Institute, New York, NY 10025,USA.

Kaiser W.M. 1987. Effect of water deficit on photosynthetic capacity. Physiol. Plant. 71:142–149.

Katz R. W. and Brown B. G. (1992) Extreme events in a changing climate: variability is more important than averages. Climatic Change 21: 298-302.

Kelly A. E. and Goulden M. L. (2008) Rapid shifts in plant distribution with recent climate change. Proceedings of the National Academy of Sciences 105: 11823-11826.

Krishnan A, Pereira A(2008) Integrative approaches for mining transcriptional regulatory programs in Arabidopsis. Brief Funct Genomics Proteomics7:264–274.

LINDNER, M., MAROSCHEK, M., NETHERER, S., KREMER, A., BARBATI, A., GARCIA-GONZALO, J., SEIDL, R., DELZON, S., CORONA, P. & KOLSTRÖM, M. 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecology and Management, 259, 698-709.

Loreto F., P.C. Harley, G. Di Marco, and T.D. Sharkey. 1992. Estimation of mesophyll conductance to CO_2 flux by three different methods. Plant Physiol. 98:1437-1443.

Loreto F., S. Delfine, and A. Alvino. 1997. On the contribution of mesophyll resistance to CO2 diffusion to photosynthesis limitation during water and salt stress. Acta Hort. 449:417–422.

Parmesan C., Root T. L. and Willig M. R. (2000) Impacts of extreme weather and climate on terrestrial biota. Bulletin of the American Meteorological Society 81: 443-450.

Patz J. A., Campbell-Lendrum D., Holloway T. and Foley J. A. (2005) Impact of regional climate on human health. Nature 438 doi: 10.1038/nature04188.

Rosegrant MW, Cline SA. (2003) Global food security: challenges and policies. Science302:1917–1919.

Scha¨r, C., Jendritzky, G., 2004. Hot news from summer 2003. Nature 432, 559–560.

Schär C., Vidale P. L., Lüthi D., Frei C., Häberli C., Liniger M. A. and Appenzeller C. (2004)

Stahle D. W., Fye F. K., Cook E. R. and Griffin R. D. (2007) Tree-ring reconstructed megadroughts over North America since A.D. 1300. Climatic Change 83: 133-149.

The role of increasing temperature variability in European summer heatwaves. Nature 427:

Thomas C. D., Cameron A., Green R. E., Bakkenes M., Beaumont L. J., Collingham Y. C., Erasmus B. F. N., Ferreira de Siqueira M., Grainger A., Hannah L., Hughes L., Huntley B., van Jaarsveld A. S., Midgley G. F., Miles L., Ortega-Huerta M. A., Townsend Peterson A., Phillips O. L. and Williams S. E. (2004) Extinction risk from climate change. Nature 427:145-148.

Tubiello F. N., Soussana J. F. and Howden S. M. (2007) Crop and pasture response to climate change. Proceedings of the National Academy of Sciences 104: 19686-19690.

Walther G. R., Post E., Convey P., Menzel A., Parmesan C., Beebee T. J. C., Fromentin J. M., Hoegh-Guldberg O. and Bairlein F. (2002) Ecological responses to recent climate change. Nature 416: 389-395.

Zeeman SC, Rees T. (1999) Changes in carbohydrate metabolism and assimilate export in starch-excess mutants of Arabidopsis. Plant Cell Environ22:1445–1453.