CLIMATE CHANGE

Climate, pollution and California's crops

Historical and projected impacts of tropospheric ozone and climate change on California's most valuable perennial crops indicate that opportunities exist to improve crop yields through pollution mitigation.

Justin McGrath

Annual crops provide the majority of calories in human and livestock diets, but high-value perennial crops, despite lower production than annual crops, account for a large proportion of economic output and provide key nutrients. Perennial breeding programmes require more time than annual programmes and it is more difficult for farmers to change cultivars. Thus the ability to adapt to changes in climate and pollution is slowed in perennial cropping systems, which could significantly impact farming livelihoods and food security.

Tropospheric ozone is a common pollutant that can damage plants because it is highly reactive and after passing through the stomata on the leaf surface, produces free radicals when reacting with compounds in the wet cell-wall surfaces within a leaf¹. Furthermore, it is agriculturally significant, since concentrations often exceed the threshold required to cause damage². In this issue of *Nature Food*, Hong et al.³ examine the historical effects of ozone pollution and temperature on a variety of perennial crops representing roughly 40% of California's agricultural economic value.

Unlike many previous studies that have extrapolated from small experiments to large regions, Hong and colleagues use historical data collected from the region between 1980 and 2015 to directly estimate effects. Since the effects in small experiments depend to some degree on uncontrolled factors, such as local rainfall, care must be taken when extrapolating to other regions to ensure that effect sizes are appropriate. The authors avoid this issue by measuring the entire region of interest — similar approaches have been used to examine yield loss due to ozone in annual crops^{4,5}.

Of the 20 most valuable perennial crops produced in California, Hong and colleagues show that crop losses due to tropospheric ozone have been substantial for some crops — a 20% yield loss in table grapes, for example. For other crops, such as strawberries, losses were much lower at 2%. The smaller losses are in part due to inherent resistance to ozone damage, but also due to

lower ozone concentrations in regions where those crops are grown. That crop losses have decreased in line with ozone concentrations signals that reducing ozone concentrations is a viable strategy to improve the yield of some perennial crops. The cost of reducing ozone concentrations would need to be weighed against the value of lost crop production, which the authors estimate is currently a substantial US\$1 billion per year for the crops examined in their study, with the understanding that there are also losses in other crops. Interestingly, the authors find little effect of elevated temperature on the yield of most crops, except walnuts and almonds, possibly because irrigation is widespread in these regions, potentially mitigating a primary effect of elevated temperature.

Yield projections in California for several crops in 2050 are positive compared to today, in large part because of the predicted continued decline in ozone concentrations. For table grapes, however, some growing regions are expected to be much warmer, offsetting gains from reduced ozone concentrations and resulting in a net decrease compared to today. For almonds, ozone has little effect on yield, so temperature effects dominate, and yields are expected to decline in all regions examined.

Observational studies such as this avoid issues of scaling from small experiments, but because these studies are not controlled, predictors in the model can be correlated, thus confounding interpretations. For example, if ozone concentration and temperature were highly correlated, it would not be clear how much of the yield change could be ascribed to each factor. That was a possibility in the present study because the reactions that produce ozone are temperature and light dependent. The authors show that in this data set the correlation between ozone and temperature is low, giving confidence that they have properly attributed yield effects to the two influences.

Given the tradeoffs between small controlled experiments and large observational studies, the two approaches

complement each other well. The findings of Hong and colleagues add historical context to numerous experiments showing crop losses due to ozone⁶, and give valuable estimates of the cost of pollution and climate change, as well as regional predictions that give farmers and policy makers information about where to focus their efforts.

Notably, in a field with considerable pessimism regarding the ability to mitigate the impacts of climate change, the authors present an upbeat result regarding the success and tangible positive impacts of reducing tropospheric ozone concentrations. Understanding how perennial crops have responded to past climate and predicting their future response will allow breeders, farmers and policy makers to plan, rather than react, and make better management decisions regarding these systems.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the US Department of Agriculture. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture. USDA is an equal opportunity provider and employer. □

Justin McGrath

USDA ARS Global Change and Photosynthesis Research Unit, Urbana, IL, USA.
e-mail: justin.mcgrath@usda.gov

Published online: 16 March 2020
<https://doi.org/10.1038/s43016-020-0052-7>

References

1. Fiscus, E. L., Booker, F. L. & Burkey, K. O. *Plant Cell Environ.* **28**, 997–1011 (2005).
2. Mills, G. et al. *Atmos. Environ.* **45**, 5064–5068 (2011).
3. Hong, C. et al. *Nat. Food* <https://doi.org/10.1038/s43016-020-0043-8> (2020).
4. McGrath, J. M. et al. *Proc. Natl Acad. Sci. USA* **112**, 14390–14395 (2015).
5. Burney, J. & Ramanathan, V. *Proc. Natl Acad. Sci. USA* **111**, 16319–16324 (2014).
6. Mills, G. et al. *Atmos. Environ.* **41**, 2630–2643 (2007).