LETTER

Do nonlinear temperature effects indicate severe damages to US crop yields under climate change?

Based on historical analyses of crop yield in the US, productivity would (depending on the climatic scenario) nonlinearly and dramatically decrease by 30–82% above threshold values of 29 °C (corn), 30 °C (soybean), and 32 °C (cotton) (1). We believe that this is a rather pessimistic view.

Crop yields still increase because of the development and adoption of new technologies and improved farm management. Recently, technology was reported as the most important driver of productivity change (2), outweighing the effects of climate change and increasing CO_2. Between 1961 and 2007, the yield rate of gain for corn in the US was 0.11 ton ha^{-1} yr^{-1} (3). In this period, average US corn yields increased by 240%, from 3.9 tons ha^{-1} yr^{-1} to 9.4 tons ha^{-1} yr^{-1} (4). Some have predicted that advances in agronomics, breeding, and biotechnology will lead to an average corn yield in the US of just >20 tons ha^{-1} yr^{-1} in 2030 (5).

High temperatures (and also water stress) have different effects on plants at different developmental stages and are not always problematic. In Brazil for instance, farmers successfully increased the productivity of soybeans, maize, and cotton during the last decade, despite the fact that the cumulative days of exposure to temperatures above the threshold values is far greater than in the US. In the state of Mato Grosso for example, with ≈8% of the worldwide soybean production and 52% of the Brazilian cotton production, the maximum average day temperature [data between 1961 and 1990, INMET (6)] exceeds 35 °C for 118 days per year, of which 75 days are in the average soybean-growing season (October–May). Still, the average production of soybeans was ≈3.1 tons ha^{-1} yr^{-1} in 2008, thereby exceeding the average yield in the US in 2008 (2.8 tons ha^{-1} yr^{-1}). A similar picture holds for cotton. According to the USDA, the cotton yield in Brazil in 2006/2007 was 1.4 tons ha^{-1} yr^{-1} compared to 0.9 tons ha^{-1} yr^{-1} in the US.

These examples demonstrate that Brazilian farmers have managed to boost productivity, despite relatively long periods of exposure to temperatures above the mentioned threshold values (1). This also suggests that temperatures higher than currently experienced in the US do not necessarily need to coincide with lower crop yields and that already existing technology and future advances (new varieties, optimized farm management, biotechnology, etc.) can overrule the negative effect of increasing temperatures on yield, as observed in the presented historical data.

***B. G. Meerburg*[a,1], *A. Verhagen*[a], *R. E. E. Jongschaap*[a], *A. C. Franke*[a], *B. F. Schaap*[a], *T. A. Dueck*[b], *and A. van der Werf*[a]**

[a]*Plant Research International B.V. and* [b]*Greenhouse Horticulture, Wageningen University and Research Centre, P.O. Box 616, 6700 AP, Wageningen, The Netherlands*

1. Schlenker W, Roberts MJ (2009) Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proc Natl Acad Sci USA* 106: 15594–15598.
2. Ewert F, et al. (2005) Future scenarios of European agricultural land use: I. Estimating changes in crop productivity. *Agric Ecosys Environ* 107:101–116.
3. Edgerton M (2009) Productivity to meet global needs for feed, food, and fuel. *Plant Physiol* 149:7–13.
4. FAO, FAOSTAT Database. Available at www.fao.org. Accessed September 8, 2009.
5. Duvick DN (2005) The contribution of breeding to yield advances in maize (*Zea mays* L.). *Adv Agron* 86:83–145.
6. INMET, Instituto Nacional de Meteorologia. Available at www.inmet.gov.br/. Accessed September 13, 2009.

Author contributions: B.G.M., A.V., R.E.E.J., A.C.F., B.F.S., T.A.D., and A.v.d.W.

The authors declare no conflict of interest.

[1]To whom correspondence should be addressed. E-mail: bastiaan.meerburg@wur.nl.

www.pnas.org/cgi/doi/10.1073/pnas.0910618106