A study of genetic progress due to selection reveals a negative effect of climate change on bread wheat yield in France

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The evolution of bread wheat yield is a recurrent purpose in the area of agronomic sciences, due to the major role of this cereal in human food supply. In France, bread wheat yield has evolved very slowly during the 19th century and the first half of the 20th century, and then has strongly increased for more than 4 decades. However, a stagnation of bread wheat yield has been observed since the middle of the 1990s, and the possibility of a decline in breeding progress has been questionned.

Basically, yield evolution depends on the release of new varieties by breeders (which can lead to genetic progress), and on the evolution of agricultural practices (which can lead to agronomic progress). To assess the genetic contribution to yield trend, wehave considered two independent long time series of yield data: one corresponding to the registration trials conducted in France from 1976 to 2010,in which the best genotypes selected by French breeders are compared, and the other corresponding to trials from the INRA bread wheat breeding programme along the 1970-2010 period.As far as only elite lines are concerned, these datasets have enabled us to study the evolution of the potential bread wheat yield in France.

The raw data exhibited the same trend to stagnation as observed on national yield in the farms. However,to isolate the genetic contribution to yield trend, the agro-environmental variations that occurred during the study period have to be removed. After correction of these “year” effects, it appearedthat potential yield has increased regularly from the 1970s up to now, with quite a high rate (about 0.1t ha^{-1}yr^{-1}in intensive conditions). This genetic progress was even higher without fungicide (about 0.13tha^{-1}yr^{-1}), which underlines that breeding efforts for productivity and for resistance to diseases could have at least partially additive results. From a physiological point of view, this continuous trend is not surprising as the highest yields observed in our datasets were around 10t/ha, far from the physiological limit for bread wheat, which is evaluated at 15-16t/ha.

So, our study demonstrated that the stagnation of bread wheat yield in France did not correspond to a slowing down in genetic progress. Moreover, as registration and breeding trials were as free as possible from agronomic limiting factors, our results indicated that climatic factors constituted the main explanation to this degradation.Indeed, in France, climate change has led to a general warming, with an increase in annual mean temperatures of about 0.05°C yr^{-1} since 1990, associated to higher frequencies for winter and spring droughts. These climatic factors have negative effects on wheat physiology, as drought during the stem elongation leads to a decrease in vegetative dry matter (with a concomitant reduction in number of grains per m^2), and as drought and/or high temperatures during grain filling lead to reduced grain weight.

Our study pointed outthat, since the end of the 1980s, genetic progress has been partly or totally counterbalanced by the adverse effects of climate change. That underlines the fragility of intensive agriculture, which appears all the more sensitive to climate as yields are high.During the last years, some studies devoted to the impact of global warming on agriculture have stated increases in crop productivity, at least for western and northern Europe. The beneficial effects expected from the increase of atmospheric CO_2 concentration were the principal factors advanced for these positive speculations. However, the different models used could prove to be quite optimistic, as our results based on real yield data indicate that, for the last 2 decades, the negative effects of drought and high temperatures on wheat physiology have been preponderant comparatively to the positive effects of CO_2.