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Photosynthesis across leaf-canopy-field scales and radiative forcing of a chlorophyll deficient soybean mutant.

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An increase in surface albedo is considered a bio-geophysical engineering strategy to mitigate the additional radiative forcing caused by greenhouse gases emissions. Considering the broad geographical range and the area of agricultural lands, crops characterized by increased canopy albedo could potentially provide a good opportunity to implement such a short-wave radiation management strategy. Highly reflective Chlorophyll-deficient mutants are rather common in plants, but their mitigation potential has not yet been investigated.

Here we present the methods and the results of a multi-scale and multi-technique study that considered photosynthetic, optical and biophysical parameters of the MinnGold mutant, a soybean accession isolated by the University of Minnesota (USA), which is characterized by significantly reduced chlorophyll content (Chl). This spontaneous mutant was extensively compared with commercial high-yielding green soybean varieties within the experiments conducted over a period of three years (2015-2017). Steady-state photosynthesis measurements performed at full canopy cover using portable gas exchange systems considered both the leaf and the canopy scale. The eddy covariance method was used during an entire seasonal crop cycle to compare the field-level latent and sensible heat fluxes of the mutant and the green soybean cultivar, in a replicated design. Canopy transpiration was measured by means of heat-balance sap-flow gauges. Leaf and canopy optical properties (light reflectance, transmittance and absorbance within the photosynthetically active radiation range), and the down- and up-welling radiation above the canopy and the at soil surface (shortwave and longwave radiation components) were measured together with air temperature, humidity and soil temperature. Differences in radiative forcing between the mutant and the green plants were measured in the field over two consecutive seasons. Biomass production and yields were measured in a dedicated field trial that was replicated over a wide latitudinal gradient from 39° to 52° of latitude.

The results showed that the introduction of this Chl-deficient mutant over a crop cycle lasting 100-110 days could lead to a substantial reduction of the shortwave radiative forcing by app. 2.4 W m^{-2} over the entire year. Such a mitigation effect was obtained at a cost of small reductions in grain yield, which were on average in the order of 20%. Yield differences between the mutant and the wildtype varied a lot with the latitude, being larger in northern than in southern locations. On the other hand, increased albedo in the mutant led to a significant decrease in transpiration and to a consistent increase in water use efficiency. The conclusion is that Chl-deficient mutants may be a readily available option to increase canopy reflectance to mitigate part of the recent additional radiative forcing. It is expected that dedicated breeding programs will improve yield level of these mutants and that other studies will soon examine field performances of other Chl-deficient mutants in other crop species.