

Title: Flowering Development Stage in Sorghum Estimated from Optical Polarization Data

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Introduction: We tested the hypothesis that we can estimate the flowering development stage of sorghum from measurements of the polarization of the light scattered by a sorghum canopy. Such information is critically important in agricultural production forecasting. If such information were available for each sorghum field in a region, it could be interleaved with timely weather data and used in crop production models to obtain improved estimates of sorghum grain production for the region.

Methods: We constructed a tower 5.9m tall in the center of a homogenous sorghum field. We equipped two Barnes MMR radiometers with polarization analyzers at 0°, 45° and 90° on the blue, red and 2.08-2.35 μ m Landsat TM wavelength bands. The 0.76-0.90 μ m TM wavelength band was left unpolarized. Positioning the radiometers atop the tower, we collected radiance data in 44 view directions - view zenith angles of 0, 15, 30, 45, 60 and 65 degrees and view azimuth angles of 0, 45, 90, 135, 180, 225, 270, and 315 degrees – multiple times as the sun tracked across the sky during two days of data collection. From the radiance data we calculated the degree of linear polarization of the reflected light for each of the three polarized radiometer wavelength channels and for each azimuth/zenith view direction. We assembled the resulting polarization estimates into ‘DOLP hemispheres,’ each hemisphere representing the degree of linear polarization of the data collected in a complete set of the azimuth and zenith view directions within a specific time window during the day. (Typically that time window – i.e. the time in the field required to collect a hemisphere of radiance data - was less than 15 minutes.)

Results: Our experimental results support our hypothesis, showing that after the sorghum heads appeared the degree of linear polarization was a pronounced function of view/illumination direction relative to the crop row direction for all DOLP hemispheres collected through out the day. In particular for the data representing the canopy with the emergent grain head, only the DOLP hemispheres collected when the solar azimuth and the row azimuth directions coincided - or were perpendicular - displayed mirror symmetry about the principal plane. DOLP hemispheres collected for other solar azimuth directions relative to the row azimuth direction displayed pronounced asymmetry about the principal plane. We found comparison of the DOLP at 45°, 60° and 65° zenith view angles in the row direction and in the direction perpendicular to the row direction provided indication of the amount of light polarized by the leaves that was then blocked by grain heads from being received by the radiometers. Thus, comparison of the decrease of DOLP across rows and along rows signaled whether heads are present.

Conclusions: These results document that the date of the flowering development stage – the date when the sorghum grain heads have appeared and just before they begin to fill – may be estimated based upon the degree of linear polarization of the light measured just above the crop canopy. Other agriculturally important crops in the flowering development stage – wheat, barley, oats and corn (maize), for example - display

somewhat similar canopy architectural changes that presumably could be tied to changes in the measured polarization of the reflected light, interleaved with timely weather data and then used in models to obtain improved estimates of regional grain production. We expect that these results are not tied to near ground measurements; presumably canopy development stage information could also be extracted from polarized imagery acquired from air borne and space borne sensors. If this proves feasible, collection of space borne polarization imagery may be key to improving forecasts of world sorghum grain production and possibly production forecasts for other agriculturally important crops such as wheat, barley, oats and corn (maize).