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Experiences in field phenotyping: from hand-helds to UAVs

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Increasing the throughput and accuracy of field phenotyping is among the foremost challenges in crop research methodology. Options for “high-throughput phenotyping” are evolving rapidly, but relative advantages remain uncertain. Experiences with durum wheat (*Triticum durum*) and other irrigated crops in Arizona, where we have tested hand-held frames with cameras, carts, tractors and unmanned aerial vehicles (UAVs or “drones”), illustrates tradeoffs among usability, cost and data quality. An A-frame support for a digital camera allows imaging at fixed height and orientation with high resolution and minimal electronics. “Proximal sensing carts” can carry more diverse cameras and sensors while allowing for geopositioning and data logging. Tractors can support larger, more complex instrument systems, be configured to multiple crop rows, and protect the operator from high temperatures. Capabilities of fixed-wing and rotary unmanned aerial vehicles (UAVs) are improving rapidly with respect to cost, usability and quality of imaging systems. Beyond these options are more highly engineered and costlier solutions such as rail-mounted field scanners. Comparisons of canopy cover, vegetation reflectance indices and canopy temperature in 260 durum lines from an international diversity panel grown at Maricopa, AZ suggest reasonable consistency among simpler measurements. In 2016 using manual RGB imaging and tractor-mounted IR thermometers and active reflectance sensors, normalized difference vegetation index (NDVI) increased with differences in canopy cover ($r = .94$, $P < .001$), but canopy temperature (CT) decreased with cover ($r = -.75$, $P < .001$), suggesting a cover threshold below which CT was biased by inclusion of the soil surface. Similar relations are seen in comparisons from 2017, including for NDVI measured from UAVs. Among challenges in selecting phenotyping systems based on proximal or remote sensing are matching the instrumentation to the questions at hand and anticipating how simple variation in crop structure may bias measurements of more fundamental traits.