Using soil hydraulic properties for an efficient starch potato irrigation management

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Increasing world population and food demand require solutions to secure world nutrition with less water use. For potato growth and yield and quality ensuring, optimal conditions are between 50% plant available water content and field capacity. Thus, close attention to soil hydraulic properties, weather and phenological characteristics is mandatory for an efficient irrigation management using soil moisture or evapotranspiration-based irrigation management tools.

As a first step toward combining soil moisture- and evapotranspiration-based approaches, we present the results of a field experiment (27 ha) during the growing season in 2021 on a loamy-sand starch potato field in Mecklenburg-Western Pomerania, Germany. Four different irrigation levels were set up using a gun sprinkler irrigation system. In addition to the farmer´s common irrigation (100%), two deficit (80% and 90%) and one abundant (120%) irrigation levels were applied. The 100% irrigation corresponds to a total irrigation level of 119.39 mm (cumulative water supply = 374.49 mm), supplied during five events, each scheduled according to monitored root-zone moisture and weather forecast. The laboratory determined soil hydraulic properties are typical for a loamy sand with soil moisture of 0.207 m³ m-³ at field capacity, 0.039 m³ m-3 at permanent wilting point, and a saturated hydraulic conductivity of 173 cm d-1. The soil moisture dynamics were simulated in each treatment using the evapotranspiration-based AMBAV model and the soil hydraulic properties-based HYDRUS-1D software environment. In-situ soil moisture measurements, observed in three-time replicates per experimental plot in 10 cm increments up to a depth of 60 cm, were used for validation.

All irrigation levels impacted plant available water, even in subsoil layers. Plant available water declines below 100% after few days in the 80% and the 90% treatment. The 100% treatment leads to soil moisture depletions slightly below field capacity. The 120% irrigation results in plant available water exceeding 100% until the next irrigation event. Soil moisture simulations provide reliable results in subsoil layers when compared to measured soil moisture (RMSE (AMBAV) = 0.0489 m³ m-³; RMSE (HYDRUS-1D) = 0.0334 m³ m-³). In topsoil, the modeled soil moisture varied stronger, both in variability over time and in comparison with ground truth data (RMSE (AMBAV) = 0.1176 m³ m-³; RMSE (HYDRUS-1D) = 0.0422 m³ m-³), mainly due to the effects of evapotranspiration and the heterogeneity in potato dam soil hydraulic properties.

The results confirm the ecological, sustainable, and economical capability of a deficit irrigation level for high-amylopectin potatoes grown on a loamy sand, based on soil hydraulic properties and optimal ranges of plant available water content for potato production. We conclude that accurate gun sprinkler irrigation management may be enabled in agricultural practice using soil hydraulic properties, depletions of plant available water content and cultivar-specific optimal plant available water ranges, all combined in ready-to-use soil-plant-atmosphere-nexus simulation tools. Both model environments are appropriate foundations for irrigation management. AMBAV's lower input parameter requirements ensure a slightly greater dispersion of the results. HYDRUS-1D accurately estimates soil moisture dynamics but is characterized by a higher parameterization effort.