Water Use and Water Productivity of Sugarbeet, Malt Barley, and Potato as Affected by Irrigation Frequency

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ABSTRACT

Successful irrigation management is one of the most important agronomic practices for achieving profitable yield and maximizing crop water productivity (CWP) while maintaining environmental quality by minimizing water losses to runoff and deep drainage. This study was conducted to compare the influence of two irrigation frequencies on crop water use (CWU) and CWP of sugarbeet (Beta vulgaris L.), malt barley (Hordeum vulgare L.), and potato (Solanum tuberosum L.) on a sandy loam soil in the semiarid northern Great Plains. The irrigation frequencies compared were: high frequency (HF) irrigation with biweekly application of small irrigation quantities, and the conventional low frequency (LF) with weekly application of large irrigation quantities. Irrigation frequency was varied based on either 15 mm (HF) or 30 mm (LF) cumulative crop evapotranspiration replacements. Seasonal CWU amounts were determined using the water balance equation of sugarbeet, malt barley, and potato under HF and LF irrigations for 2007, 2008, 2009, 2010, and 2011. No significant differences due to irrigation frequency were found for yield, CWU, and CWP of sugarbeet (root and sucrose), malt barley, or potato. Small differences in CWU values between HF and LF irrigations were due to variations in soil moisture content in the soil profile and drainage losses below the 0.91-m soil depth. Conventional LF irrigation thus can sustain yield, improve water use, and reduce net economic input as feasibly as HF irrigation practices when a self-propelled automated sprinkler system is used on a sandy loam soil.

The development of precise water management practices is one of the most critical aspects of irrigated agriculture for improving yield, maximizing crop water use efficiency (CWUE), meeting crop quality requirements, and reducing the adverse impacts on groundwater quality. Crop water use efficiency originates in the economic concept of crop productivity and therefore is now known as CWP. The CWP varies significantly according to specific soil, climatic and management conditions under which the crop is grown (www.fao.org/Landandwater/aglw/cropwater; Zwart and Bastiaanssen, 2004). Crop water productivity is defined as “the amount of water required per unit of yield and is a vital parameter to assess the performance of irrigated and rainfed agriculture” (www.fao.org/Landandwater/aglw/cropwater).

Water is an essential factor for plant physiological functions, thus, the amount and frequency of water applied during irrigation are important in crop production and quality. Water is an important factor in barley, sugarbeet, and potato production. Sugarbeet and potato crops are relatively sensitive to moisture stress and not tolerant of prolonged drought over much of the growing season, so they need relatively high soil moisture levels to achieve high yields and quality. Soil moisture levels should be maintained between 50 and 70% of available moisture content in the active rootzone of these three crops over the growing season to achieve optimal yield and quality (www.fao.org/Landandwater/aglw/cropwater; Dunham 1993; Lynch et al., 1995; Opena and Porter, 1999; Faberio et al., 2003).

The seasonal water requirements for barley range between 390 and 430 mm for optimum yield depending on variety, and crop and water management. However, malt barley may require more water over the growing season than feed or hay barley (www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr1245). The water use efficiency per unit harvested grain yield for barley is approximately 11.5 kg ha⁻¹ mm⁻¹ (Hills et al., 1990; http://sugarbeet.ucdavis.edu/sbchap.html). The quality of barley grain is an important consideration in malt production, and irrigation management during grain development stages affects the protein content and quality in grains.

Sugarbeet requires a considerable amount of water during the growing season, about 6.5 mm per day; actual crop evapotranspiration ranges between 900 and 1200 mm of water in a growing season depending on location, time of year, time and method of water application, and climatic conditions (Hills et al., 1990; Dunham 1993; Faberio et al., 2003). Research over the last several decades has shown that crop water use efficiency of sugarbeet ranges between 9.60 and 17.5 kg m⁻³ or 96 and 175 kg ha⁻¹ mm⁻¹ (Howell et al., 1987; Hills et al., 1990; Dunham, 1993; Faberio et al., 2003; Rinaldi and Vonella, 2006; Gonzalez-Dugo and Mateos, 2008; Morillo-Velarde, 2010; and Topak et al., 2011).

Several research studies have shown that potato plants have low tolerance for soil moisture stress due to the sparse and

Abbreviations: CT, conventional tillage; CWP, crop water productivity; CWU, crop water use; CWUE, crop water use efficiency; ET, evapotranspiration; ETC, crop evapotranspiration; HF, high frequency; LF, low frequency; PCAP, passive capillary water fluxmeter; SLM, sucrose loss to molasses; ST, strip tillage.