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Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate

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ABSTRACT

Quantifying the local crop response to irrigation is important for establishing adequate irrigation management strategies. This study evaluated the effect of irrigation applied with subsurface drip irrigation on field corn (*Zea mays* L.) evapotranspiration (ETc), yield, water use efficiencies (WUE = yield/ETc, and IWUE = yield/irrigation), and dry matter production in the semiarid climate of west central Nebraska. Eight treatments were imposed with irrigation amounts ranging from 53 to 356 mm in 2005 and from 22 to 226 mm in 2006. A soil water balance approach (based on FAO-56) was used to estimate daily soil water and ETc. Treatments resulted in seasonal ETc of 580–663 mm and 466–656 mm in 2005 and 2006, respectively. Yields among treatments differed by as much as 22% in 2005 and 52% in 2006. In both seasons, irrigation significantly affected yields, which increased with irrigation up to a point where irrigation became excessive. Distinct relationships were obtained each season. Yields increased linearly with seasonal ETc ($R^2 = 0.89$) and ETc/ETp ($R^2 = 0.87$) (ETp = ETc with no water stress). The yield response factor (ky), which indicates the relative reduction in yield to relative reduction in ETc, averaged 1.58 over the two seasons. WUE increased non-linearly with seasonal ETc and with yield. WUE was more sensitive to irrigation during the drier 2006 season, compared with 2005. Both seasons, IWUE decreased sharply with irrigation. Irrigation significantly affected dry matter production and partitioning into the different plant components (grain, cob, and stover). On average, the grain accounted for the majority of the above-ground plant dry mass (≈59%), followed by the stover (≈33%) and the cob (≈8%). The dry mass of the plant and that of each plant component tended to increase with seasonal ETc. The good relationships obtained in the study between crop performance indicators and seasonal ETc demonstrate that accurate estimates of ETc on a daily and seasonal basis can be valuable for making tactical in-season irrigation management decisions and for strategic irrigation planning and management.

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1. Introduction

Irrigation water supplies are decreasing in many areas of the US Great Plains due to extended drought periods, decline in groundwater levels, litigation among states related to surface water allocations, and diversion of water from irrigation to environmental and municipal uses (McGuire, 2004; McGuire and Fischer, 1999; Lingle and Franti, 1998). Water shortages have heightened the importance of water in agricultural production in the area and have triggered recent regulations affecting irrigation water use. Such regulations include installation of water meters on pumping stations, moratoriums on drilling new wells, and limitations in groundwater pumping to fixed multi-year water allocations. Under these conditions, it is important to know how much yield can be expected from a given water allocation for each alternative crop, which is especially important for field corn (*Zea mays* L.), the most important irrigated crop in the region.

In the semiarid environment of west central Nebraska, water allocations that result in crop water stress can have a significant impact on corn growth, development, and yield. Knowing how much yield can be expected from a given water allocation, however, is complicated by the fact that corn yield is affected not only by the amount of seasonal irrigation, but also by irrigation timing. Also, yield is affected by other sources of water available to the crop in addition to irrigation. These sources include water stored in the soil profile at crop emergence and effective rainfall occurring during the growing season. Many researchers have shown how corn grain yield can be affected by irrigation timing (Jurgens et al., 1978; NeSmith and Ritchie, 1992; Bryant et al., 1992; Jama and Ottman, 1993). Most of these studies show that corn yield is most affected by water stress when it occurs during the reproductive stages (tasselling, silking, pollination, or grain filling). In Nebraska, the reproductive growth stages coincide with the period of peak crop evapotranspitation (ETc) requirement, making stress during these stages even more significant.

Other studies have linked yields reduction to a reduction in ETc or transpiration, and some researchers have developed different yield versus ETc relationships for different growth stages (Jensen, 1968; Hanks, 1974; Nairizi and Rydzewski, 1977; Barrett and Skogerboe, 1978; Doorenbos and Kassam, 1979; Gilley et al., 1980; Schneekloth et al., 1991; Klocke et al., 2004). Payero et al. (2006b), however, showed that the reported yield versus ETc relationships for corn are not consistent and vary with location, which is likely due to differences in rainfall pattern, soil and crop characteristics, management practices, and weather conditions.

In Nebraska, research on irrigation has previously focused on sprinkler and surface systems (Gilley et al., 1980; Schneekloth et al., 1991; Hergert et al., 1993; Klocke et al., 2004; Payero et al., 2005, 2006a,b; Schneekloth et al., 2006). However, due to the current and expected limited water supplies, interest in subsurface drip irrigation (SDI) systems to irrigate row crops in Nebraska is growing. Although studies with SDI-irrigated corn have been conducted in other states (Ayars et al., 1999; Camp, 1998; Caldwell et al., 1994; Howell et al., 1997; Lamm et al., 1995; Lamm and Trooien, 2003), local information on the response of corn growth, yield and other crop–water dynamics with SDI is very limited. The agronomic response of the crop to irrigation with SDI is needed to be able to evaluate the economic and technical feasibility of using SDI under local conditions and provide scientifically based practical information to the users on best management practices for SDI-irrigated corn. The objective of this study was to evaluate how different seasonal irrigation depths applied with SDI affected the soil water balance, seasonal evapotranspiration, yield, water use efficiency, and dry matter production of corn in the semiarid climate of west central Nebraska.

2. Materials and methods

2.1. Site description

Field experiments were conducted during the 2005 and 2006 growing seasons. The experiments were located at the University of Nebraska-Lincoln West Central Research and Extension Center, in North Platte, Nebraska (41.1°N: 100.8°W: 861 m above sea level). The climate at North Platte is semiarid, with average annual precipitation of approximately 508 mm and reference evapotranspiration of 1403 mm (USDA, 1978).

Table 1 – Seasonal total and monthly irrigation depths (mm) applied to each corn irrigation treatment (T1–T8) during the 2005 and 2006 growing seasons at North Platte, Nebraska

Year	Month	Treatment							
		T1	T2	T3	T4	T5	T6	T7	T8
2005	July	53	61	87	87	107	104	105	106
	August	0	15	15	66	114	150	188	225
	September	0	0	0	0	0	0	13	25
	Total	53	76	102	153	221	254	306	356
2006	June	8	4	8	8	8	8	8	8
	July	13	62	89	121	124	120	123	176
	August	0	0	0	0	39	46	65	41
	September	0	0	0	0	13	0	1	0
	Total	22	66	97	130	184	173	197	226