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Effect of sprinkler irrigation on microclimate in the winter wheat field in the North China Plain

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ABSTRACT

Sprinkler irrigation, as one of the useful technologies to increase crop production and water use efficiency, has been extensively used in the North China Plain. However, few researches related to the season-long microclimatic changes under sprinkler irrigation in this region. A field experiment was carried out to investigate the long-time effect of sprinkler irrigation on microclimate in a winter wheat (*Triticum aestivum* L.) field and compare the microclimate under both sprinkler and surface irrigation conditions from April 2001 to June 2003 in two experimental stations in the North China Plain. Results showed that air temperature, air temperature gradient from 1 to 2 m above ground surface and vapor pressure deficit (VPD) were significant lower ($P < 0.05$) in the sprinkler-irrigated field with respect to those in surface irrigation field after the first sprinkler irrigation during three winter wheat seasons. The maximum reduction in air temperature and VPD in the sprinkler-irrigated field in comparison with the surface irrigated field occurred on sprinkler irrigation days. During daytime (between 08:00 and 20:00 h), air temperature and VPD were significantly affected by sprinkler irrigation respected to night-time (between 20:00 and 08:00 h) at sprinkler irrigation intervals. Cumulative water surface evaporation, measured by using a standard pan (20 cm in diameter) placed at the top of canopy, was about 3–11% lower in the sprinkler-irrigated field respected to in the surface irrigated field from April 11 to June 4 in the three seasons. The reduction in values of difference in air temperature, vapor pressure deficit and pan evaporation in the sprinkler-irrigated field in comparison with surface irrigated field were bigger when it was hot, dry and windy with concentrated precipitation.

1. Introduction

The North China Plain (NCP), one of China's most important agricultural regions, produces 19% of the nation's food and 42% cotton (Wang et al., 2001; Zhang et al., 2003). Because of monsoon influence, rainfall is highly variable in this region. Mean annual precipitation is 500–600 mm, a majority of which occurs between June and September (Zhang et al., 2004). Annual crop actual evapotranspiration of 800–900 greatly exceeds the annual precipitation (Liu et al., 2002). Therefore, traditional irrigation techniques such as surface irrigation have been used to maintain and enhance crop growth and yield in this region (Chen et al., 2003; Mao et al., 2003; Wang et al., 2004). On the other hand, recent work (Liu et al., 2003; Sun et al., 2004) has demonstrated surface irrigation to inefficiently direct water and fertilizer amendments to crop

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Table 1 – Sprinkler and surface irrigation dates and water amount in 2001, 2002 and 2003 experimental seasons

Seasons	Irrigation methods	March		April					May					Total water amount applied (mm)
		1	27	3	9	16	21	28	1	4	9	16	21	
2000–2001	Sprinkler irrigation	–	–	63	–	–	60	–	–	–	40	30	30	223
	Surface irrigation	–	–	128	–	–	–	128	–	–	–	–	–	256
2001–2002	Sprinkler irrigation	40	30	–	–	40	–	–	40	–	–	–	–	150
	Surface irrigation	130	–	–	–	114	–	–	–	–	–	–	–	244
2002–2003	Sprinkler irrigation	–	–	–	40	–	50	–	–	48	–	–	49	187
	Surface irrigation	–	–	–	118	–	–	–	–	91	–	–	93	302

root zones by non-uniformity soil water distribution and great fluctuation of soil water content at irrigation intervals.

Alternative irrigation systems such as sprinkler irrigation, is an advanced irrigation technique for water-saving and fertigation and in accurately controlling irrigation time and water amount (Li and Rao, 2003), has been used in the NCP. The area irrigated by sprinkler irrigation increased from 46,000 ha in 1989 to 2,634,000 ha in 2003. Study on winter wheat showed that crop yield and water use efficiency in sprinkler-irrigated fields was higher than that in surface irrigated fields (Yang et al., 2000). The result of high crop yield and water use efficiency in sprinkler-irrigated field is partly because sprinkler irrigation can produce a favorable microclimate for crop growth. Tolk et al. (1995) found sprinkler irrigation resulted in crop transpiration reduction by more than 50% during irrigation process. The increasing in photosynthesis rate and reduction in leaf respiration rate at night also has been found in sprinkler-irrigated area (Chen, 1996; Yang et al., 2000).

In the past several decades, many studies have been carried out all over the world for investigating water evaporation and the microclimate change pattern of the sprinkler-irrigated field. During sprinkler irrigation, water evaporation were from droplets, canopy interception and wet soil surface (Frost and Schwalen, 1955; Dylla and Shull, 1983; Norman and Campbell, 1983; Steiner et al., 1983; Kohl et al., 1987; Walter, 1988; Ayars et al., 1991; Thompson et al., 1997; Li and Rao, 2000; Tarjuelo et al., 2000). The evaporation process cools the droplets, enabling heat to be drawn from the air through which the droplets pass and add water vapor to the atmosphere (Kohl and Wright, 1974). Thompson et al. (1993b) found that direct evaporation of water droplets is less than 1% of total water applied. However, a total amount of energy equivalent to 24% of the net radiation during sprinkler irrigation transferred from plant environment to the water droplets as they were warmed during flight and after they affected the canopy and soil. By studying the downwind effect of droplets evaporation for sprinkler spray, Kohl and Wright (1974) showed that the air temperature generally reduced less than 1 °C and vapor pressure increased by 0.8 hPa. Tolk et al. (1995) found that vapor pressure deficit (VPD) and air temperature in canopy decreased significantly during and following sprinkler irrigation. Thompson et al. (1993b) indicated that air temperature above canopy in the irrigated area was decreased quickly with 4–7 °C lower than that outside the irrigated area in the first 10 min after the start of sprinkler irrigation. Meanwhile, dry bulb temperature above the canopy of the corn was approximately the same as that outside the irrigated area in 60 min after irrigation. Chen (1996) found that the average daytime vapor pressure and relative humidity increased, while soil temperature and canopy temperature decreased in the sprinkler-irrigated mulberry field. Some models were also developed to simulate field microclimate under sprinkler irrigation (Washington and Larry, 1988a,b; Thompson et al., 1993a,b). Based on the relationship between sprinkler and field microclimate, spraying a small amount of water (from 1.0 to1.5 mm water) by using sprinkler irrigation system also has been studied to regulate field microclimate for dry-hot-wind protection (Liu et al., 2004). However, to our knowledge, all researches in the available present literatures were about the field microclimate changes during the period of sprinkler

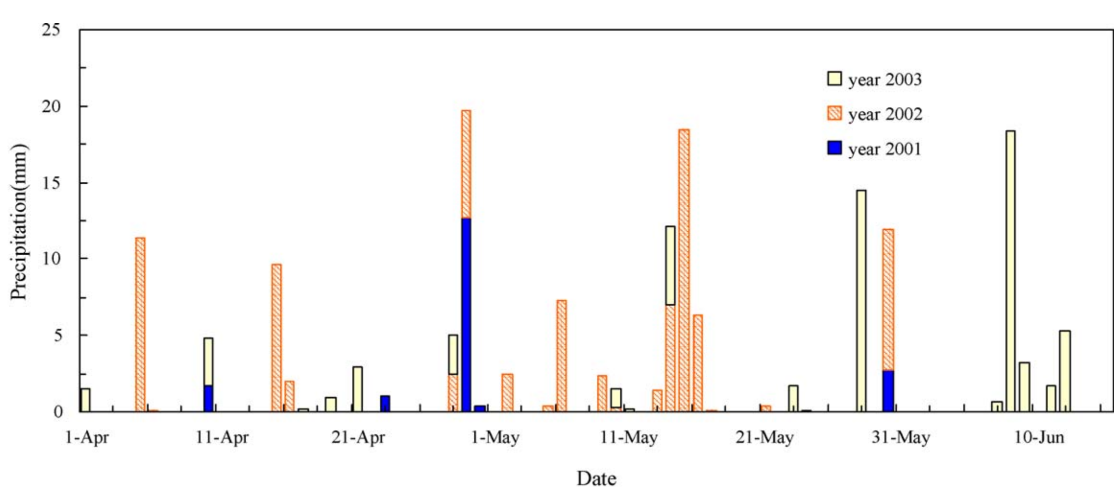

Fig. 1 – Precipitation distribution from April 1 to winter wheat harvest day in 2001, 2002 and 2003.