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# Rainfall concentration for increasing corn production under semiarid climate

*Xiaolong Ren*[a], *Zhikuan Jia*[a,*], *Xiaoli Chen*[b]

[a] Research Center of Dryland Farming in Arid and Semiarid Areas, Northwest A&F University, Yangling, Shaanxi 712100, China
[b] State Key Laboratory of Soil Erosion and Dryland Farming, Institute of Soil Erosion and Water Conservation, CAS, Yangling, Shaanxi 712100, China

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ABSTRACT

The ridge and furrow farming of rainfall concentration (RC) system is being promoted to increase water availability to crops for improving and stabilizing agricultural production in the semiarid Loess region of northwest China. In the system, plastic-covered ridges serve as rainfall harvesting zones and furrows serve as planting zones. In recent years, however, the current RC practices are still confined to rural family units for very limited supplemental irrigation purposes. To adopt this system for large-scale use in the semiarid region and bring it into full play, it is necessary to test the befitting rainfall range for RC farming. A field study (using corn as an indicator crop) combined with rainfall simulation was designed to determine the effects of RC practices on soil water content, crop yield and water use efficiency (WUE) under three rainfall levels (230 mm, 340 mm and 440 mm) during the growing seasons of 2006 and 2007. The results indicated that with the rainfalls ranging within 230–440 mm, RC system can increase soil water content in 0–100 cm and temperature conditions in the topsoil (0–10 cm) in furrows by 5–12% and 0.7–1 °C, respectively. The corn seedlings emerged 1–2 days earlier, the developmental stages generally occurred earlier, and the plant height and total dry matter all significantly increased ($P < 0.05$). In 2006, compared to conventional flat (CF) practice, the grain yield and WUE in the RC system increased by 75.4% and 73.3%, respectively at 230 mm rainfall, and by 36.7% and 40.2%, respectively at 340 mm rainfall, but there was no significant difference between the $RC_{440}$ and $CF_{440}$ patterns. In 2007, the grain yield and WUE were 82.8% and 77.4%, respectively higher in the $RC_{230}$ plots than in the $CF_{230}$ plots, 43.4% and 43.1%, respectively higher in the $RC_{340}$ plots than in the $CF_{340}$ plots, and 11.2% and 9.5%, respectively higher in the $RC_{440}$ plots than in the $CF_{440}$ plots. Combining yield and WUE, it could be concluded that the optimal rainfall upper limit for RC system is below 440 mm rainfall in the experiment. In the case of corn, the adoption of RC practice in the 230–440-mm rainfall area will make the system more attractive during the whole growth period and offer a sound opportunity for sustainable farming under semiarid climate.



## 1. Introduction

The Loess plateau of northwest China is situated in the upper and middle reaches of the Yellow River (33°43′–41°16′N and 100°54′–114°33′E). It covers a total area of 624,000 km$^2$. Annual precipitation ranges from 200 mm to 750 mm, with 70% of rainfall falling between June and September, often in the form of heavy thunderstorms (Li, 2000). This has in turn led to an

* Corresponding author. Tel.: +86 29 87080168; fax: +86 29 87080168.
E-mail addresses: zhikuan@tom.com, rxlcxl@yahoo.com.cn (Z. Jia).
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increase in the scale and severity of soil erosion. Apart from this, the rainy season in this region does not coincide with growth stages for most crops. As a result, droughts are a common occurrence. Hence, the key to increase agricultural productivity in this region lies in how to maximize utilization of precipitation by collecting water of light rains, retaining runoff from heavy rainstorms and reducing unproductive evaporation (Li et al., 2001).

Rainwater harvesting has been used for many years in semiarid areas to solve problems of domestic and irrigation water shortages (Zhu et al., 1994; Zhao et al., 1995). There have been many techniques to trap rainwater (Boers and Ben Asher, 1982; Boers et al., 1986; Abu-Awwad, 1999). The ridge and furrow rainwater harvesting (RFRH) with mulches has been suggested to be one of the most effective measures to reduce the cost of cultivation, to increase water use efficiency (WUE) as well as to optimize yield (Li et al., 2000a). RFRH is a rainwater harvesting system developed in Loess plateau and Northwest China where dry land farming is prevalent. In these regions, especially in semiarid mountainous area, the traditional cultivation of corn is to plant on the flat. In the middle of the growing period, one of the cultivation measures is to heap soils on the top layer around the roots of the corn plants. To obtain maximum storage of moisture under any rainfall condition, the soil needs to absorb as much water as possible when it rains and keep water loss due to evaporation or transpiration to a minimum. The results of many studies have indicated that this system can prolong the period of moisture availability and enhance production of agricultural crops by collecting water from light rain, and retaining surface runoff from heavy rain (Cater and Miller, 1991; Li et al., 2000, 2001; Li and Gong, 2002; Tian et al., 2003; Xie et al., 2005; Jia et al., 2006; Zhang et al., 2007). Li et al. (2001) reported that the use of RFRH system could significantly improve soil moisture storage and topsoil temperature, and make seedlings emerge earlier. Wang et al. (2004) also indicated that the combination of RFRH and mulches could increase crop WUE and biological yields, and reduce costs.

Corn (*Zea mays* L.) is one of the most popular grain crops in the semiarid Loess plateau region of northwestern China. In recent years, some new cultivating systems, such as ridge-planted and hole-planted have been developed. In order to ensure higher yield, using ridges as the surface, a method in contrast to the ridge planting has been tested in these areas (Chen, 1995; Li et al., 2000a; Tian et al., 2003). However, the current rainwater concentration (RC) practices have not been promoted widely in semiarid areas, which are still confined to remote mountainous regions for very limited supplemental irrigation purpose. To adopt this system more effectively and for large-scale use, this study was designed to combine artificial rainfall with ridge and furrow methods of RC to determine befitting rainfall amount range for improving corn production under semiarid climate. Unfortunately, there is limited literature on this subject and little practice experience using in ridges for RC in corn farming systems.

This paper describes a pattern of corn planting with $RC_{230}$–$RC_{440}$ (from $RC_{230}$ to $RC_{440}$) using the ridge and furrow farming system. The ridges act as runoff areas for RC and the furrows as the planting zones. The objectives of the present study is to explore: (1) the effect of RC pattern on corn grain yield and WUE, (2) the effect of RC pattern on soil water content in various soil layers and (3) the establishment of the befitting rainfall range for water harvesting under semiarid climate. The results obtained are in the hope to produce scientific support for giving useful guidelines to farmers of semiarid regions on how to optimize agro-management practices for water-saving and high-yielding corn cultivation.

## 2. Materials and methods

### 2.1. *Study site description*

This study was conducted during 2006 and 2007 at the experimental station of Crop Specimen Farm in Northwest A&F University, Shaanxi Province, northwestern China, with a latitude of 34°20′N and longitude of 108°04′E, and an elevation of 466.7 m above sea level. The annual mean maximum and minimum air temperature at the site were 42 °C and −19.4 °C, respectively, and the annual mean temperature was 12.9 °C. The total yearly sunshine duration was 2196 h and the no frost period was 220 days. The annual mean pan evaporation was 993.2 mm and the annual mean precipitation was 550 mm. The frequency distribution of rainfall events below the average for the reference period of 1965–2005 were about once 4 years (rainfall $\leq$ 230 mm), 2 years (230 mm $<$ rainfall $<$ 440 mm) and 4 years (rainfall $\geq$ 440 mm), respectively during corn growing season. The rainfall amount during the months of April–October in 2006 was 325 mm and in 2007 was 334 mm. The soil in the top 1.2 m was Eum-Orthrosols (Chinese soil Taxonomy), and with mean bulk density of 1.35 g $cm^{-3}$. The average field capacity and permanent wilting point of the root zone soil in the crop field were 22% and 7%, respectively. The readily available N, P and K were 53.12 mg $kg^{-1}$, 22.34 mg $kg^{-1}$ and 97.37 mg $kg^{-1}$, respectively. The organic matter content of 0–20 cm topsoil and pH were 1.08% and 7.59%, respectively. Prior to the experiment, in 2005, the site was planted to spring wheat with about 220 fallow days before corn was sown in 2006.

In the rainfall simulation, three total seasonal rainfall, 230 mm, 340 mm and 440 mm, were, respectively corresponding to the light rain, moderate rain and large rain in nature. The partition of rainfall amount derived from the spatial and temporal characteristics of rainfall distribution in the semi-arid region of north China over 50 years. A rainfall of 10–20 mm was seen as a considerable rainfall in the semi-arid region in China. And about 80% of the rainfall events were in the range of 5–50 mm and $I_{10}$ (maximum rainfall intensity in 10 min) was 30 mm $h^{-1}$, which was not a constant but an averaged value determined by standard rain gauge over consecutive 3 weeks. The data analysis also indicated that about 80% of the total amount of the annual rainfall resulted from rainstorms with over 10 mm of rainfall (Wang and Zhai, 2003). Thus, the minimum and maximum of a rainfall event were 5 mm and 50 mm, respectively in the experiment. Over 10 mm of rainfall was divided into sub-rainfall with equal to or less than 10 mm of rainfall and with about 2 h intervals of each rainfall event. The intervals of two rainfall events were between 5 and 15 days during corn growing season. Provided the above conditions were met, the frequency distribution of rainfall was set