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Ridge-furrow planting of alfalfa (*Medicago sativa* L.) for improved rainwater harvest in rainfed semiarid areas in Northwest China

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Abstract

In rainfed semiarid areas of northwestern China, alfalfa (*Medicago sativa* L.) is usually cultivated in flat fields with spaced rows. The yield of the crop is normally low because of insufficient moisture in the soil. The purpose of this study was to examine the effect of soil ridging and plastic film, covering the ridges, on rainwater harvest and alfalfa yield and to identify the optimal design of the ridge-furrow system. In this system the ridges served as the runoff area and the furrows as the infiltration area, where alfalfa was grown. Three ridge width (RW) measured at the bottom of the ridge, namely 30, 45 and 60 cm, were tested under the condition of the ridge-furrow systems with or without plastic film covering the ridge. These treatments were compared with the flat soil (FS) planting system, having neither ridge nor plastic cover. No matter what RW (or in the case of FS spacing between planting belts), the width of furrow (planting belt) was the same as 0.6 m. Soil moisture was measured at 7–10 day intervals, in 10 cm increments, to soil depth of 2 m. Rainwater harvests were measured from two additional plots without planting, representing the covered ridge (CR) and uncovered ridge (UR) systems, respectively. The results showed that in terms of average alfalfa yield on a total area basis, ridge type and ridge width both had significant effects, with CR being better than UR, and UR in turn being better than FS. The 2-year average annual yield of alfalfa was 5114 kg DM ha^{-1} for CR, 2531 kg DM ha^{-1} for UR, and 1927 kg DM ha^{-1} for FS. For the CR treatments, the ridge width (RW) of 0.3 m resulted in higher yield (5528 kg DM ha^{-1}) than RW of 45 cm (5095 kg DM ha^{-1}) and 60 cm (4719 kg DM ha^{-1}). For the UR treatments, yields with 30 cm RW (3088 kg DM ha^{-1}) were higher than with 45 cm RW (2434 kg DM ha^{-1}) and 60 cm RW (2071 kg DM ha^{-1}). The results also showed that the CR planting system had additional advantage of collecting more rainwater to improve plant effective soil moisture. In conclusion, the CR with a RW of 0.3 m and furrow width of 0.6 m is recommended for improved rainwater utilization and improved alfalfa yield in the semiarid areas where alfalfa production is largely rainfed.

Keywords: Rainwater harvest; Ridge; Furrow; Soil moisture; Semiarid area; Alfalfa

1. Introduction

Alfalfa (*Medicago sativa* L.) is one of the most important forage crops in the world because of its high nutritive quality, yield, drought-resistance and good adaptation to various climatic and soil conditions and therefore, is reputed as the ‘‘queen’’ of the forages. Alfalfa was first introduced into China by Mr. Zhang

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Qian of the Han Dynasty during his diplomatic mission to Western Asia in 119 BC and now is the forage crop with the largest acreage in China, especially in the northwest of the country. It is estimated that over 1 million ha of farmland are used for alfalfa production in China, accounting for three-quarters of the total area of forage crops and introduced pastures in China (Sun, 2001; Wan et al., 2004). In Gansu province alone, where this research has been performed, the land area under alfalfa is about 0.37 million ha (Gen et al., 1995). Alfalfa has proved to be one of the most important forage crops in many areas in China for its high productivity and the contributions to soil and water conservation and nitrogen economy in the soil through symbiotic nitrogen fixation (Li et al., 2002; Kelner et al., 1997). However, the hydrological effects and water demand of alfalfa are still controversial, with the concern of soil water exhaustion if alfalfa is planted in the vast areas of northwestern China where water resources are very limited. It was reported that alfalfa extracted so much soil water through evapotranspiration that a distinctive and permanent dry layer was formed within the root zone (Zhao et al., 2004), and the soil water content at the dry layer was near wilting point (Al-Rumikhani, 2002; Han, 1990; Li, 2002). Luxurious water consumption by alfalfa as reported may further worsen the soil moisture condition and therefore lead to further ecological deterioration in the rainfed dry areas. Asseng and Hsiao (2002) nevertheless argued that perception of alfalfa as soil moisture depleter was not justified because alfalfa can improve soil moisture condition through increasing vegetation interception and enhancing soil infiltration.

Whether alfalfa is a soil water spender or not, it is clear that water scarcity is the most limiting factor for expanding alfalfa production in the arid and semiarid zones of northwestern China. Despite the concern of water balance, alfalfa has currently been the plant of highest priority for vegetation restoration in the eroded areas and at the same time for economic benefits. In this context, it is important to research into suitable methods for alfalfa planting aiming at improved crop yield but also soil water conservation in the areas with limited water supply especially in the rainfed sloping areas. The prevailing planting system of alfalfa is growing the crop in spaced rows on a flat surface. Irrigation is required if a better crop yield is to be achieved with the low annual precipitation ranging from 250 to 450 mm in the semiarid areas. However, irrigation is impossible for many alfalfa growers because of the lack of water and therefore, the most promising option for alfalfa growers in the areas is making efficient use of the rainwater that can be made available during the growing season through innovative planting method that encourage better rainwater harvest and utilization.

Rainwater harvesting has been adopted historically by many households in the semiarid areas to provide water storage for both family use and irrigation (Zhao et al., 1995; Zhu et al., 1994). There have been many techniques to trap rainwater (Abu-Awwad, 1999; Boers and Ben-Asher, 1982; Boers et al., 1986). The combination of ridge and furrow with gravel mulching in crop field may be one of the most effective methods, which have been practiced by farmers for many years to gather and utilize rainwater (Li et al., 2000). Use of plastic film covers has led to further increase in yields of cereal and vegetable crops in the semiarid areas. In these practices, the conventional method commonly adopted is planting crops on film-covered ridges. However, the inverse pattern, that is planting crops within the furrows while keeping the covered ridges free of planting for rainwater harvesting, has not been reported in the limited literature and not found in practice. It is possible that such a ridge-furrow system cannot only increase the yield of alfalfa by improving water availability to plants within the furrows, but also conserve the soil and water from erosion. To determine how this renovation technique of ridge-furrow planting system affects alfalfa yield as well as soil moisture level, a field plot experiment was conducted from 2002 to 2003, which involved ridges covered or uncovered with plastic film and furrows planted to alfalfa. In such a planting system, the ridges are intended to act as runoff areas for rainwater harvesting and the furrows as planting belts. In this study, ridge type (ridge covered with plastic film or kept bare) and ridge bottom width were evaluated and compared with flat soil surface, which served as a control. The results obtained are analyzed in terms of changes in both alfalfa yield and soil moisture.

2. Materials and methods

2.1. Description of the study site

The field experiment was conducted during 2002 and 2003 at the Gaolan Agroecology Experimental Station, Gansu Province, northwestern China, with a latitude of 36°13′30″N and longitude of 103°47′23″E, and an elevation of 1690 m above sea level. The annual mean maximum and minimum air temperature at the site were 20.7 and −9.1 °C, respectively, and the annual mean temperature was 8.4 °C. The annual mean pan evaporation was 1785.6 mm and the annual mean precipitation