Increasing Precipitation Decreases Water Use Efficiency of Alfalfa (*Medicago sativa* L.) in a Semiarid Region

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Abstract
Alfalfa (*Medicago sativa* L.) plays an important role within the integrated farming systems in Northwestern Loess Plateau of China, because of its traits on a high productivity, prolonged growing season, and excellent nutritive value. However, water use efficiency (WUE) is a crucial indicator for forage production under different water conditions in the semiarid regions. To explore the responses of alfalfa growth and water use to precipitation variability, we set precipitation shelters to manipulate precipitation scenario as 30% precipitation increased (P+30), normal precipitation (CK), and 30% precipitation decreased (P-30) with the measurement of dry matter yield and soil water content. An alfalfa variety Zhongmu No.1 was sown in autumn of 2018 and harvested at flowering. Soil water was sampled in the depth of 0-2.0 m by a soil auger in 2019. The results showed that the total biomass yield for three cuts among the precipitation treatments had significant difference (P<0.05), with 12125.5, 11685.3, and 11167.2 kg ha^{-1} under treatment P+30, CK and P-30, respectively. The WUE of dry matter yield in P-30 treatment had the highest value, higher 25.5% and 10.3% than that in P+30 and CK treatment, respectively (P<0.05). We conclude that increasing precipitation could not improve the WUE of alfalfa, which indicates the wide adaptability of alfalfa in variable rainfall conditions in semiarid region.

Introduction
Alfalfa (*Medicago sativa* L.) is a common high-quality leguminous forage to support the livestock production in Loess Plateau regions of China, however, alfalfa's production was strongly restricted by the uneven precipitation. Li and Huang (2008) reported that soil water storage at planting and growing season precipitation are critical water resources for plant growth in the Loess Plateau of China and 30% of yield for alfalfa is mainly dependent on the soil water storage at planting (Li, 2002). However, there was little knowledge on the investigation about how alfalfa consume soil water over the growing season. Therefore, the objective of this study is to analysis the evapotranspiration (ET) and water use efficiency (WUE) of alfalfa under different precipitation conditions.

Methods and Study Site
The experiment was conducted at Qingyang Loess Plateau Experimental Research Station of Lanzhou University (35°39′ N, 107°51′ E; elevation 1298 m). We designed three precipitation situations by using rain shelters to simulate 30% precipitation increased (P+30), normal precipitation (CK), and 30% precipitation decreased (P-30). The alfalfa was sown in late

August of 2018, and three cutting periods were imposed in 2019 (June 6, August 4, and September 17). Soil samples were taken by 40 mm diameter augers in the depth of 0-2 m (every 20 cm soil layer served as a soil sample) from each plot at sowing and harvest stages and dried at 105°C for 48 hours to calculate soil water content. The ET (kg ha^{-1} mm^{-1}) and WUE (mm) were calculated by using the equations (1) and (2), respectively (Wan et al. 2007):

$$ET_i=P_i+\Delta S \qquad (1)$$

ET represents the alfalfa's water use, and ET_i expressed as ET in the i_{th} cutting period (kg ha^{-1} mm^{-1}). P_i is the precipitation (mm) at the same time as ET_i, and ΔS is the change of soil water storage (mm) from the sowing stage to the first cutting period, second cutting period, and third cutting period.

$$WUE_i=Y_i/ET_i \qquad (2)$$

where WUE_i (mm) is the WUE at the same time as ET_i, and Y_i represents the alfalfa's dry matter production in the i_{th} cutting period (kg ha^{-1}).

Results

Dry matter production under different precipitation situations

There was no significant difference in dry matter production of alfalfa during the three cutting periods (Fig.1). Total dry matter production of alfalfa in P+30 treatment was the greatest, which was 3.8% and 8.6% greater than that under CK and P-30 treatment, and there was significant difference with P+30 and P-30 treatment (P<0.05).

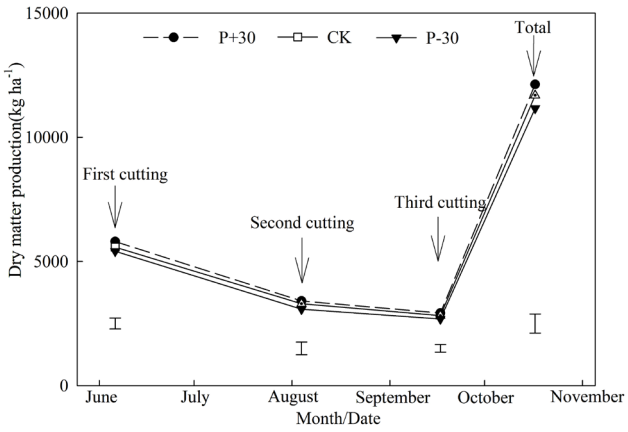

Fig.1 Dry matter production of alfalfa for 3 cut under different precipitation situations

Evapotranspiration and water use efficiency under different precipitation situations

The evapotranspiration of alfalfa under different precipitation situations had significant difference (P<0.05; Table 1). The ET_1, ET_2, and ET_3 of alfalfa in P+30 treatment had the greatest value among the three precipitation situations, respectively, indicating that increasing precipitation enhanced alfalfa's water use. The total ET of alfalfa in P+30 treatment was 17.9% and 35.7% greater than that in CK and P-30 treatment, respectively (P<0.05). The WUE_1, WUE_2, and WUE_3 of alfalfa in P-30 treatment had a greatest value of for alfalfa among the three precipitation situations (P<0.05). At the third cutting times, the WUE_3 of alfalfa in P+30 treatment was the least among the three precipitation situations (P<0.05). The

total WUE of alfalfa in P-30 treatment had the greatest value, greater 25.5% and 10.3% than that in P+30 and CK treatment.

Table 1. Evapotranspiration and water use efficiency of alfalfa under different precipitation situations

Treatment	The first cutting		The second cutting		The third cutting		Total	
	ET_1 /mm	WUE_1 /kg ha^{-1} mm^{-1}	ET_2 /mm	WUE_2 / kg ha^{-1} mm^{-1}	ET_3 /mm	WUE_3 / kg ha^{-1} mm^{-1}	ET /mm	WUE / kg ha^{-1} mm^{-1}
P+30	374.7±12.8b	15.5±0.7b	277.6±20.3b	12.3±1.0b	138.5±77.0a	21.1±0.5c	790.8±70.2c	15.3±0.6c
CK	352.5±17.9a	15.8±0.7b	259.6±15.6a	12.7±1.3b	58.5±36.8a	48.2±5.0b	670.6±37.4b	17.4±0.6b
P-30	309.7±14.0a	17.5±1.1a	207.0±5.0a	14.9±1.6a	66.2±27.0a	40.6±2.1a	582.9±25.4a	19.2±1.0a

Discussion

The water use efficiency of alfalfa grassland was directly proportional to water supply, and the change rate of water use efficiency was greater than that of alfalfa dry matter accumulation. Therefore, the water use efficiency of alfalfa was inversely proportional to precipitation (Feng et al.2016; Kang et al.2020). We provide scientific guidance and theoretical basis for the stable development of agriculture in the dryland of the Loess Plateau under three precipitation situations. Alfalfa system in decreasing precipitation had greater water use efficiency, but could reduce the dry matter production of alfalfa. We concluded that precipitation increasing 30% reduced the water use efficiency of alfalfa and enhanced the alfalfa's evapotranspiration.

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