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Effect of Liquid Mulch on the Transpiration Rate and Water Use Efficiency of Drip-irrigated Cotton

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Abstract

This study was carried out to address the ever severer white pollution issue in the cotton fields of arid areas and to primarily stop the increase of film residuals in cotton fields. The feasibility of replacing plastic films with liquid mulch in combination with drip irrigation was evaluated. A bucket experiment was conducted to investigate the effects of liquid mulch on the transpiration rate and water use efficiency (WUE) of drip-irrigated cottons. A total of 5 treatments were set up: liquid mulch (1900 kg/hm2) coupled with drip irrigation (LFD1), liquid mulch (2200 kg/hm2) coupled with drip irrigation (LFD2), liquid mulch (2500 kg/hm2) coupled with drip irrigation (LFD3), plastic film coupled with drip irrigation (PFD) and drip irrigation without mulch (NFD or control). The results showed that in the bud stage, the peak value of cotton leaf transpiration rate in LFD3 was 0.95 mmol•m-2•s-1 (or 21.99%) higher than that in control but 0.39 mmol•m-2•s-1 (or 6.89%) lower than that in PFD. The WUE in LFD3 was the highest in any cotton growth stage among the treatments. The peak value of WUE in the seedling and bud stages was 16.90% and 15.03%, respectively higher in LFD3 than in control. When used at an appropriate dosage, liquid mulch can lower the transpiration rate and significantly raise the WUE of drip-irrigated cottons, thus paving the way towards high yields. In addition, liquid mulch has no negative effects on the soil environment and thus is of important research value and good application prospect in light of drip-irrigated cottons in arid areas.

Keywords: *liquid mulch; drip-irrigated cotton; transpiration rate; water use efficiency*

1. Introduction

Mulching can effectively regulate and conserve soil moisture and raise crop water production efficiency. Therefore, it is an effective measure to save water resource, raise crop yield and improve crop quality. As plastic film mulching can greatly raise the yield and quality of cotton, it is widely used in Xinjiang, the most important cotton production area in China. However, due to the long term use of plastic films and ineffectiveness of the recycle measures, more and more film residuals are left in the soils in most areas of Xinjiang. The film residuals cause severe pollution to the soils and the environment, which is a recognized challenge [7-9]. Liquid mulch is an organic polymer. After diluted with water and sprayed, liquid mulch forms a black cured film on soil surface which can effectively inhibit the evaporation of soil moisture and raise soil temperature[4] [10]. Crop transpiration is the basis for the formation of crop yield and economic yield. Regulating crop stomatal resistance to reduce ineffective transpiration is an important approach to raise the effectiveness of crop transpiration. There are many factors that influence crop water use efficiency (WUE) which varies with crop varieties and genotypes. Environmental factors such as soil moisture, atmospheric humidity, air temperature and atmospheric CO2 concentration exert significant influences on WUE as well [11]. Much research on the effects of liquid mulch on crop transpiration rate and WUE has been focused on wheat, corn and peanut. The study by Yin *et al*. [13] showed

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that with liquid mulch, leaf TR increased by 52% in the maturity stage of peanut, which was favorable for yield increase. Yan [15] found that black liquid mulch had good biological effects, well-coordinated the wheat yield components and significantly raised water production efficiency in dry lands. It was reported by Cui *et al*. [2] that black liquid mulch displayed good ecological effects on winter wheat planted in dry lands during dry years: winter wheat yield was 2188.5 kg/hm2, 17.95% higher than that in control; WUE was 0.78 kg/m3, 22.26% higher than that in control. The research by Li [3] demonstrated that compared with control (no mulch), liquid mulching positively influenced corn yields and WUE: corn yield rose by 3.70%, 35.40% and 57.00% and corn WUE increased by 5.30%, 8.90% and 9.20% when the plants were irrigated with 75%, 65% and 55% of the lower limit of the irrigation quota, respectively. It was documented by Zhou *et al*. [16] that liquid mulching significantly raised the one hundred-grain mass of corn, raised the corn grain yield by 3.48%, 1.48% and 3.79% in high, medium and low irrigation treatments, respectively, and raised the corn WUE by 6.59%, 7.30% and 9.17% in high, medium and low irrigation treatments, respectively, compared with control. Relatively little research on the effects of liquid mulch on plant transpiration rate and WUE is focused on drip-irrigated cotton, especially in Xinjiang where drip irrigation under mulch is widely used. Therefore, in this study, an experiment was conducted on drip-irrigated cotton with liquid mulch to investigate the effects of liquid mulch on the transpiration rate and WUE of drip-irrigated cotton. The findings are expected to provide theoretical and technological supports for the scientific application of liquid mulch in fields.

2. Materials and Methods

Outline of the Study Area. The experiment was conducted in April-October, 2014 and in the experimental station (85o59′E, 44o19′N) of the Key Laboratory of Modern Water-saving Irrigation Corps of Shihezi University at the western suburb of Shihezi City, Xinjiang. The site has an elevation of 412 m and an average surface slope of 6‰. The average annual sunshine duration amounts up to 2865 h, the accumulated temperature of above 10 °C and of above 15 °C are 3463.5 °C and 2960.0 °C, respectively, and the frost-free period lasts 170 days. The annual average temperature is 7.7±0.90 °C. Within a year, the highest temperature occurs in July when the average temperature is 25.4±0.74 °C while the lowest temperature occurs in January when the average temperature is −5.5±2.07 °C. The annual precipitation is 213±56.7 mm, and the annual evaporation capacity is 1342±413 mm [14].

Experimental Materials. The MingruiTM liquid mulch used in this study was produced by the Mingrui Chemical Engineering Science and Technology Ltd. in Yangling, Shaanxi. And the common plastic film and irrigation tape were produced by Tianye Co. Ltd. in Xinjiang. The cotton variety was Xinluzao48.

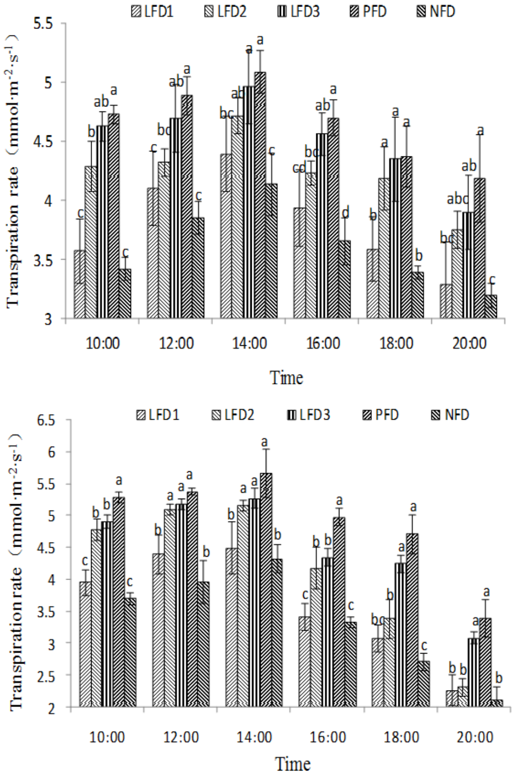
Experimental Design. A total of 15 plastic buckets of size 0.52 m×0.45 m×0.35 m (height upper inner diameter lower inner diameter) were used in the bucket experiment. The buckets were filled with medium loam with average bulk density of 1.37 kg/m3. A total of five treatments were set up in triplicate: liquid mulch (1900 kg/hm2) coupled with drip irrigation (LFD1), liquid mulch (2200 kg/hm2) coupled with drip irrigation (LFD2), liquid mulch (2500 kg/hm2) coupled with drip irrigation (LFD3), plastic film (50 kg/hm2) coupled with drip irrigation (PFD) and drip irrigation without mulch (NFD or control). Cotton seeds were sown on April 21st, 2014 using the “dry seeding wet germination” approach. An equilateral triangle was drawn within the central 15-20 cm area of each bucket, and then 2-3 cotton seeds were sown in each of the three vertices. Irrigation water was supplied using two irrigation tapes with emitter spacing of 30 cm and the designed flow rate of the emitters of 1.6 L/h. The buckets were so arranged along the two irrigation tapes that each bucket was irrigated by two emitters. Liquid mulch was uniformly applied to the soil surface in two-fold diluted concentration on April 22nd using conventional agro atomizer. Same irrigation and fertilization were applied to the treatments. The irrigation quota was 378 mm with about 35 mm each time for a total of twelve times for the entire growth period. The irrigation water was local deep phreatic water with a salinity of 1.3 g/L. Fertilizers were applied with irrigation water at 832 kg/hm2 (urea: potassium ammonium phosphate=2:1). Other management measures were the same as those taken for common cotton fields.

Determination methods. Plant transpiration rate (TR) determination was performed on leaves of the same position and age on the main stem on one cloudless sunny day in each growth stage using a handheld photosynthesis system (CI-340, USA). Each time, three readings were taken.

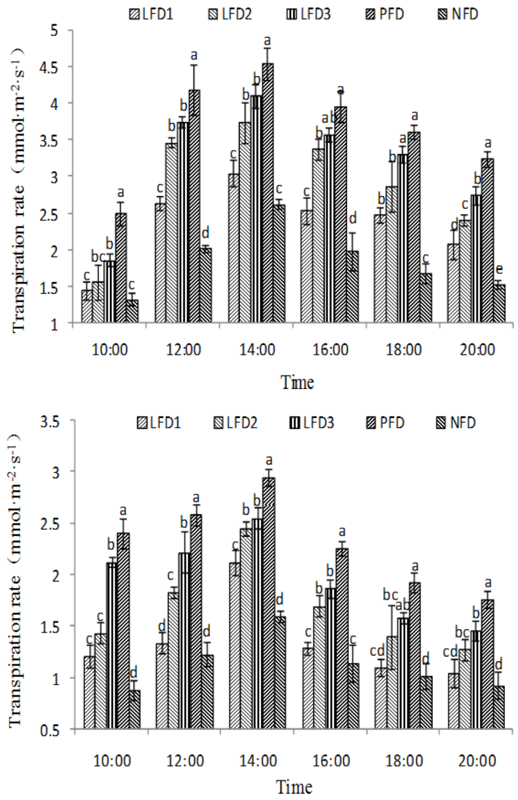
3. Results and Analyses

Effects of liquid mulch on the transpiration rate of drip-irrigated cotton. Transpiration plays an important role in crop uptake of water and nutrients. It can regulate crop energy status and stomatal aperture as well. The accumulation of a certain amount of matter requires a certain amount of water. However, both water and matter rely on the actual transpiration of the crop, and transpiration rate is an important index of crop dry matter accumulation and WUE. Fig. 1 shows the cotton transpiration rates in the different treatments. As can be seen, within a day, crop transpiration rate first increased with the increasing light intensity and air temperature and the decreasing air humidity to its maximum at around 14:00, and then decreased with the decreasing light intensity and air temperature and the increasing air humidity. Environmental factors had an obvious effect on transpiration rate changes. In the bud stage, the peak value of transpiration rate increased by 0.17 mmol·m-2·s-1 and 0.84 mmol·m-2·s-1 in LFD1 and LFD2, respectively, compared with that in control. The peak value of transpiration rate in LFD3 increased by 0.95 mmol·m-2·s-1 (or 21.99%) compared with that in control but decreased by 0.39 mmol·m-2·s-1 (or 6.89%) compared with that in PFD. In the flower and boll stage, there were significant differences ($P<0.05$) in crop transpiration rate between the treatments with mulch and control without mulch. The peak value of transpiration rate in LFD1 increased by 0.42 mmol·m-2·s-1 compared with that in control. The peak value of transpiration rate in LFD3 increased by 1.47 mmol·m-2·s-1 (or 56.32%) compared with that in control but decreased by 0.44 mmol·m-2·s-1 (or 9.73%) compared with that in PFD.

Effects of liquid mulch on leaf WUE of drip-irrigated cotton. Water is one of the major factors deciding plant distribution and crop yield [12]. Maintaining a normal water balance in plant body is one of the important measures that ensure healthy growth and high yield of plants [5, 6]. Plant leaf WUE is the instant ratio of leaf net photosynthetic rate and transpiration rate, reflects the relationship between CO2 assimilation and water consumption, is affected not only by plant physiological structure and morphological features but also by external environmental factors such as soil moisture and nutrients, and changes with photosynthetic capacity and transpiration intensity. The effects of mulching on cotton leaf WUE are shown in Fig. 2. As can be seen, the diurnal variation of WUE was similar in different growth stages: increasing with time in the morning, reaching its maximum at around 12:00-14:00 and then decreasing with the overall WUE higher in the morning than in the afternoon. The apparently different transpiration rates resulted in apparently different WUE in different growth stages. In any growth stage, the WUE in LFD3 was the highest with its peak value 16.90% and 15.03% higher than that in control in the seedling stage and bud stage, respectively, indicating that liquid mulch at an appropriate dosage can effectively raise leaf WUE and pave the way towards high yield for drip-irrigated cotton.



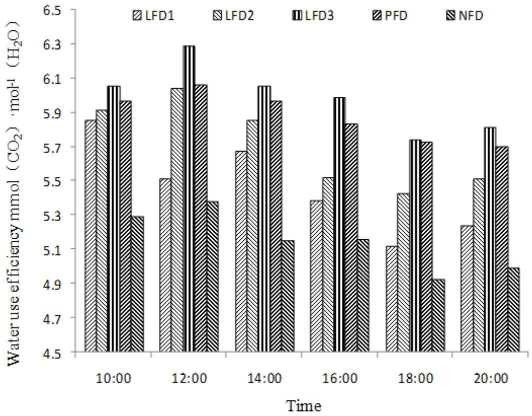
Seedling Stage (June 11th) Bud Stage (June 26th)

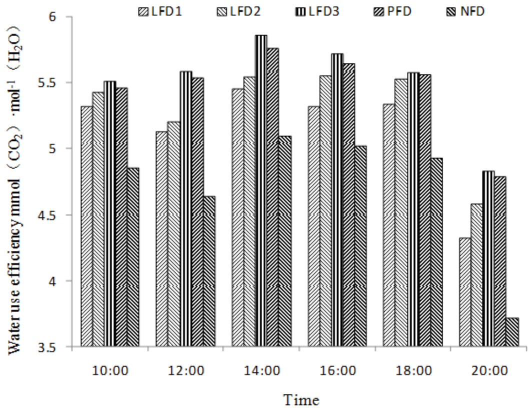


Flower and Boll Stage (August 14th) Boll-opening Stage (August 29th)

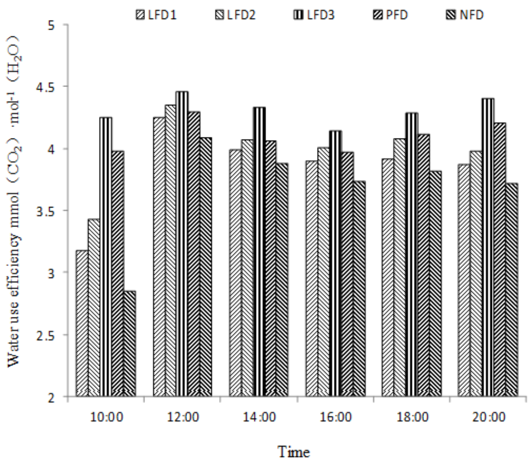
Figure 1. Diurnal Variation of Transpiration Rate (TR) of Drip-irrigated Cotton in Different Growth Stages. Different Letters Denote Significant Differences (P<0.05)

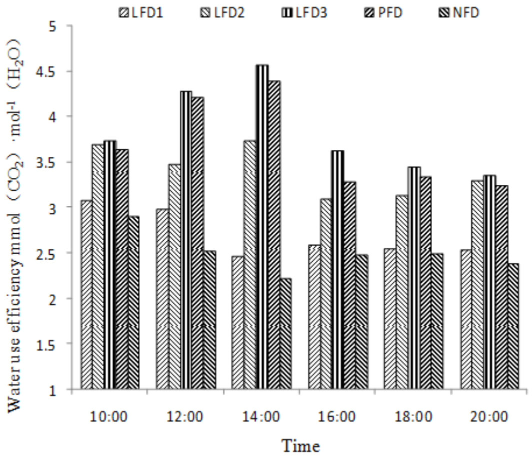
The effects of liquid mulch on the transpiration rate and WUE of drip-irrigated cotton have been analyzed above. The findings showed that in the bud stage, the peak transpiration rate in LFD3 increased by 0.95 mmol·m-2·s-1 (or 21.99%) compared with that in control but decreased by 0.39 mmol·m-2·s-1 (or 6.89%) compared with that in PFD. In any growth stage, leaf WUE was the highest in LFD3 with its peak value increasing by 16.90% and 15.03% in the seedling and bud stages, respectively, compared with that in control, indicating that liquid mulch can lower the transpiration rate and significantly raise the WUE of drip-irrigated cotton and thus build a good foundation for high yield. In this study, as cotton was grown in a bucket, which limited the growth of cotton especially the roots to some degree. Thereby, field experiment should be conducted in future studies to investigate in depth the effects of liquid mulch dosage and application frequency on the transpiration rate and WUE of drip-irrigated cotton and develop a corresponding technical guide for liquid mulch application.





Seedling Stage (June 11th) Bud Stage (June 26th)





Flower and Boll Stage (August 14th) Boll-opening Stage (August 29th)

Figure 2. Diurnal Variation of Leaf WUE in Different Growth Stages of Drip-irrigated Cotton Discussion

Liquid mulch is an effective, non-toxic and harmless cover material for crop cultivation and can be transformed to organic fertilizer after degradation by organisms and light [1]. It can be used not only for food and cotton crops but also for fruits, vegetables and other crops. But its property needs to be improved so that it can last for the entire growth period of crop and after that can be completely degraded. Compared with plastic films whose long term use results in severe pollution in cotton fields by its residuals, liquid mulch is of low cost, suitable to various landforms, applicable in a short time, and of good ecological effects. Liquid mulch application can significantly improve the economic benefit, ecological benefits and social benefit of cotton fields.

4. Conclusions

Liquid mulch is applicable in agriculture production and of great potential in terms of the urgent need of environmental protection and water-saving in agricultural production and the sustainable and efficient development of agriculture. Liquid mulch has significant effects on the transpiration rate and WUE of drip-irrigated cotton. Liquid mulch applied at an appropriate dosage can lower the transpiration rate and significantly raise the WUE of drip-irrigated cotton, building a good foundation for high yield. The results of this study show that a proper dosage of liquid mulch is 2500 kg/hm2.

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References

[1] R. Bai and Q. Zhang, “Application of functional polymer materials in the management of land desertification in Shanxi Province”, Agricultural Science of Shanxi, vol. 31, no. 3, **(2003)**, pp. 87-91.
[2] H. Cui, H. Jing, H. Zhao, J. Zhang and J. Wang, “The ecological effects of black liquid mulch on winter wheat in dry lands”, Chinese Journal of Eco-agriculture, vol. 14, no. 1, **(2006)**, pp. 73-75.
[3] G. Chang, “The yield and WUE of wheat and corn with liquid mulch”, Yellow River, **vol.** 34, no. 9, **(2012)**,pp. 88-90.
[4] B. Chen, R. Wang and G. Cheng, “Application of emulsified asphalt in agriculture”, Petroleum Asphalt, vol. 15, no. 2, **(2001)**, pp. 44-47.
[5] Z. Ding, “Effects of several antitranspirants on plant stomatic opening and water loss through

transpiration", Journal of Northwest Agricultural College, vol. 2, **(1985)**, pp.76-83.
[6] R. A. Fletcher, "Triadimefon a plant multi-protectant. Plant Cell Physiol, vol. 26, **(1985)**, pp. 7-15.
[7] H. Kanehiro, "Plastic Litter pollution in the Marine Environment", Journal of the Mass Spectrometry Society of Japan, vol. 47, no. 6, **(1999)**, pp. 319-321.
[8] Z. Huang and L. Shan, "Technical route and approaches of agricultural construction on dry lands", Agricultural Research in Arid Regions, vol. 18, no. 2, **(2000)**, pp. 1-6.
[9] P. Roy, P. Surekha and C. Rajagopal, "Surface oxidation of low-density polyethylene films to improve their susceptibility toward environmental degradation", Journal of Applied Polymer Science, vol. 122, **(2001)**, pp. 2765-2773.
[10] B. Wang, C. Luo and K. Wang, "Advanced in worldwide soil moisture conservation technologies", World Forestry Research, vol. 10, no. 2, **(1997)**, pp. 37-43.
[11] H. Wang and C. Liu, "Crop water use efficiency: Connotation and advances", Advances in Water Science, vol. 11, no. 1, **(2000)**, pp. 99-104.
[12] S. Wang, "The physiological mechanisms of drought resistance of plants", Advances in Plant Physiology and Biochemistry, vol. 2, **(1983)**, pp. 120-133.
[13] G. Yin, N. Tong, L. Hao, J. Gu and Z. Liu, "Effects of different mulching materials on soil temperature and peanut leaf photosynthesis", Agricultural Research in Arid Regions, vol. 30, no. 6, **(2012)**, pp. 44-49.
[14] C. Yan, "Yield enhancing effect of black liquid mulch on winter wheat in dry land", Shanxi Agricultural Science, vol. 30, no. 3, **(2002)**,pp. 7-9.
[15] C. Yang, Y. Luo, L. Sun, R. Gan, N. Wu, Y. Zhang and J. Abudouwaili, "Effects of irrigation water salinity on cotton growth in the Manas Basin", Resource Science, vol. 34, no. 4, **(2012)**, pp. 660-667.
[16] X. Zhou, C. Li, X. Qiang and D. Guo, "Effects of liquid mulch on dry matter accumulation and water use efficiency of sprinkling irrigated corn.", Transactions of the CSAE, vol. 26, no. 1, **(2010)**, pp. 43-48.

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