Effect of Regulated Deficit Irrigation on Potato under-Mulched Drip Irrigation

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Abstract. In order to study the effects of water deficit on potato under-mulched drip irrigation, the paper interpreted the effects of water deficit at different growth stages on growth characteristics, yield, quality and the water use of potato under-mulched drip irrigation. The results showed that mild water deficit treatment in potato tuber forming period can effectively reduce excessive plant branches and contribute to the increase of crop yield. Meanwhile, the total sugar content, protein and starch content can be improved, and the content of organic acids was significantly reduced, which is conducive to the improvement of potato quality. Tuber growth period is a period with large water demand for crops, so that enough moisture should be guaranteed during this period. Finally, the current problems in potato planting were analysed, and the future research directions were prospected.

1. Introduction

The potato is widely planted in China and is the fourth most important food crop in the world, followed by wheat, rice and maize. Potato has high nutritional value, strong adaptability to the environment, high production and short growth cycle [1]. China's potato planting area ranks first in the world, and its output accounts for about 25% of total potato production [2]. But the agricultural water resources of China are very limited, and the water use efficiency is poor. So under the premise of ensuring crop yield and quality, regulated deficit irrigation under-mulched drip irrigation was put forward to improve the agricultural water use efficiency.

Drip irrigation can deliver water to the roots of plants accurately and efficiently, and can combine with fertilizers for integrated irrigation of water and fertilizer, thus improving the water use efficiency [3]. Regulated deficit irrigation under-mulched drip irrigation combines the mulching technique with drip irrigation effectively to conduct multiple small-flow irrigations on plants, which reduces the evaporation of soil water, saves irrigation water, increases crop yield and improves water use efficiency [4]. Crops are sensitive to water, and require different amounts of water at different times. According to the principle of regulated deficit irrigation, certain water deficit should be carried out in proper periods of crops, and then re-watering in a stage, which is positive to the redistribution of nutrients within crops to various organs, so as to achieve water-saving and yield-increasing.
2. Effect of regulated deficit irrigation under-mulched drip irrigation on potato growth, yield, quality and water use

2.1. Influence of regulated deficit irrigation under-mulched drip irrigation on potato growth

Potatoes are divided into five stages from sowing to harvesting, namely germination stage, seedling stage, tuber forming stage, tuber growth stage and starch accumulation stage. Generally speaking, the germination stage without irrigation treatment, the tuber needs the most water, followed by tuber formation period and starch accumulation stage.

Studies have shown that plant height and leaf area are important indicators to evaluate plant growth status, which play a crucial role in crop growth and yield [5]. Xue et al. (2018) revealed that certain water deficit treatment of potatoes had a significant impact on the main stem diameter during the early stage of growth, while it had a small effect in the middle and late stage [6]. Liu et al. (2018) indicated that slight water shortage during tuber formation stage had no distinct influence on potato plant height, but it had a big effect during tuber growth stage [7]. Li et al. (2015) suggested that in the case of a small amount of water shortage in tuber formation stage, there wasn’t produce a remarkable change on plant height, however, it would emerge an obvious effect in tuber growth stage, which is consistent with the result of Liu et al. (2018) [8].

Leaf area index (LAI) is regarded as another important indicator to assess the growth condition of potato. Zhang et al. (2019) revealed that in the whole growth period, LAI increased at first and then decreased, in addition, he pointed out that in seedling stage grew slowly, tuber formation grew rapidly, tuber growth reached maximum, and then LAI began to gradually decline [9]. In seedling stage and tuber formation with appropriate water deficit, LAI wasn’t influenced obviously, and when irrigated again would have a certain compensation result. Tuber growth period is sensitive to potato growth, and too much or too little water both would affect potato. Therefore, appropriate water should be guaranteed in this period to ensure the yield and quality.

2.2. Influence of regulated deficit irrigation under-mulched drip irrigation on potato yield

The yield of potato is directly related to the economic benefits of crop. Geng et al. (2019) studied different irrigation amount of potatoes in the test site, and the results implied that different irrigation amount resulted in different crop yield and under certain conditions, irrigation quota could improve crop yield [10]. Li et al. (2015) reflected that when potato was irrigated with regulated deficit drip irrigation under-mulched, the crop yield presented significant difference with different irrigation water amount [11]. Within a certain range, the yield increased with the improvement of water amount. The research of Li et al. (2019) found that certain water deficit of potato at seedling stage, tuber growth and starch accumulation stage had an obvious influence on per-plant potato number, while certain water deficit regulation treatment at tuber formation stage had little influence on per-plant potato number [12]. Du et al. (2017) implied that the potato yield was enhanced with the increase of water consumption, and in the tuber formation of plants with mild water deficit had a little effect on the potato yield, but when make a moderate water deficit in this stage and tuber growth with mild or moderate water deficit would create a significant impact on potato yield [13]. Zhang et al. (2013) found that tuber forming stage is a key time to enhance potato yield, and adequate irrigation benefit to the number of tubers per plant [14]. A slight water shortage in this stage can significantly reduce the excess branches of plants, effectively reduce crop energy consumption, and do not decrease potato yield.

The tuber growth period need the greatest water. In this period, adequate water irrigation can effectively improve the quality of potato per plant, while excessive water regulation deficit significantly affects potato yield. Therefore, sufficient water should be maintained in crop soil. Xue et al. (2018) indicated that, under the condition of water shortage, water deficit treatment of potato would seriously affect crop tuber yield, and after the potato tuber forming period, regulated deficit drip irrigation under-mulched treatment would have an obvious impact on the final tuber yield [6]. Proper
water deficit treatment of potato has no big effect on the accumulation of tuber dry matter, and can improve the water use efficiency of crops.

2.3. Influence of regulated deficit irrigation under-mulched drip irrigation on potato quality
With the continuous improvement of people's living standard, people ask higher and higher requirements on the quality of potatoes. Potato quality index mainly includes total sugar content, starch content, protein content, organic acid content, reducing sugar content and so on. Liu et al. (2018) implied that regulated deficit drip irrigation under-mulched treatment at different growth stages of potatoes had a clear impact on crop quality, and mild water deficit treatment in tuber formation stage could increase the total sugar content, protein content and starch content of crops, and positively reduce the organic acid content [7]. Mild water deficit treatment during tuber growth period had no remarkable effect on total sugar content and starch content, but heavily reduced protein content and organic acid content. The content of total sugar and starch could be increased effectively, but the content of protein and organic acid could be decreased significantly.

Therefore, moderate water shortage treatment of potatoes during tuber forming period can effectively improve the total sugar content, protein content and starch content of crops, and significantly reduce the content of organic acids, so as to improve the quality of potato.

2.4. Influence of regulated deficit irrigation under-mulched drip irrigation on water use of potato
Water is not only the main raw material for plants to carry out photosynthesis and make organic matter, but also plays a role in transporting nutrients inside plants. Potato is a kind of crop which needs much water, and its dependence on water is different at different growth stages. When the photosynthesis of plants is most vigorous, it will not increase with the improvement of soil water content, but the transpiration rate of plants will continue to increase, so that the water is not fully and effectively utilized.

Li et al. (2015) reflected that the water demand of potato during the whole growth period showed a trend of first increasing and then decreasing [15]. In the seedling period, the water consumption was small, and during tuber formation period gradually increased, in the tuber growth period, it reached the maximum, and then the starch accumulation period gradually decreased. Cao et al. (2019) found that the water use efficiency of potatoes showed a rule of first increasing, then decreasing and later increasing [16]. Xue et al. (2017) revealed that excessive irrigation water on plants would not only result in water waste, but also lead to crop rot, unsuitable for storage and other disadvantages [17].

Therefore, mild water deficit regulation treatment on potatoes during tuber formation would significantly improve water use efficiency. Drip irrigation under-mulched makes use of crop growth characteristics to conduct timely and appropriate regulated deficit irrigation on potato, which effectively improves water utilization status and plays an important role in potato growth and water effective utilization.

3. Discussion
The treatment of different irrigation water amount at different growth stages of crops will affect the growth, yield, quality and water use efficiency. In arid farming areas of northwest China, water scarcity is the main factor limiting crop growth [18]. As one of the main food crops in China, potato plays an irreplaceable role [19]. A large number of studies at home and abroad have proved that under-mulched drip irrigation can effectively improve the water use efficiency of potato and significantly increase the crop yield [20][21]. Therefore, under-mulched drip irrigation has become the main research direction in potato cultivation in the future.

The present study implied that tuber formation period and tuber growth period were the key periods for crop water requirement, and also the important stages for potato yield [10]-[13]. Mild water deficit during potato tuber formation can effectively reduce excessive branching and thus increase yield [14]. Therefore, mild water deficit irrigation at this stage can improve both crop yield and water use efficiency. Wang et al. (2019) reflected that water shortage would reduce the rate of plant
photosynthesis and lead to the imbalance of crop metabolism, thus affecting the yield and quality of crops [22]. The research of Wang et al. (2017 ) revealed that soil water is the basic condition to ensure potato yield, and irrigation method is an important factor for water saving, high yield, time saving and labor saving[23].

Faced with the current food crisis and limited water resources, potato planting must find a way to save water and increase yield. Regulated deficit irrigation under-mulched drip irrigation, on the premise of ensuring potato yield and quality, improving the soil water use efficiency, achieving the purpose of water-saving and high-yield, which is an important condition for sustainable development of China's agriculture [24]. In the future agricultural planting, the growth characteristics of crops should be effectively combined with water-saving irrigation to further realize the construction of high-standard farmland in China [25].

4. Conclusions
Certain water deficit treatment in potato tuber formation stage will not have obvious influence on plant growth, but it will inhibit crop growth significantly in tuber growth stage, and rehydration treatment cannot recover, so sufficient water irrigation should be carried out in potato tuber growth stage. Mild water deficit treatment in potato tuber forming period can effectively reduce excessive plant branches and contribute to the increase of crop yield. Tuber growth period is a period with large water demand for crops, and sufficient irrigation requirements should be ensured during this period. Proper water shortage treatment during potato tuber formation can improve the total sugar content, protein content and starch content, and the content of organic acids would be significantly reduced, which is conducive to the improvement of potato quality. Meanwhile, moderate water shortage during potato tuber formation is conducive to crop storage and transportation, and can significantly improve soil water use efficiency.

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