Effects of Regulated Deficit Irrigation on soil nutrient, microorganism and enzyme activity of Isatis indigotica

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Abstract. The changes of soil ecological environment caused by different degrees of water deficit will affect the sustainable planting of soil, so it is of great significance to explore moderate water deficit and maintain a good ecological environment with sustainable soil. In this study, the effects of water stress on soil nutrients, microorganisms and enzyme activities of Isatis indigotica in Hexi corridor were studied by Mulched Drip Irrigation. The results showed that it was beneficial to the absorption and utilization of available phosphorus and available potassium in the soil of the root of Isatis indigotica by mild water deficit, increased the number of fungi and actinomycetes in the soil, and did not affect the activity of urease in the soil from 0 to 20cm. It was resulted in slow absorption of available phosphorus and available potassium in the soil and significantly decreased soil urease activity by severe water deficit, but it did not affect the number of fungi and actinomycetes. Therefore, mild water deficit is helpful to improve the utilization of soil nutrients and soil enzyme activity. This study provided a theoretical basis for the standardized planting of Isatis indigotica in northwest arid region on the basis of efficient water saving.

Keywords: Regulated Deficit Irrigation, Soil nutrients, Microbes, Enzyme activity, Isatis indigotica.

1. Introduction

One of the main components of eco-agriculture is the good ecological environment of soil, Soil ecological environment includes soil nutrient, soil microorganism, soil enzyme activity and soil PH value. The number of microorganisms in soil is the most basic index to study the microorganisms in soil. As the second largest group of soil microorganisms, soil actinomycetes can secrete many active substances. The ratio of soil actinomycetes to beneficial antagonistic actinomycetes is very important to the ecological balance of soil microorganisms[1]. As an important part of soil microbial ecosystem, soil fungi contain both beneficial and pathogenic fungi, which together constitute the diversity of soil fungi[2]. The proportion of bacteria and fungi is an important index for the stability of microbial community structure and the self-regulation of ecosystem[3], and the higher fungal bacterial ratios were considered to represent more stable host soil ecosystems[4]. Seasonal climate change, tillage methods, vegetation types, soil physical and chemical properties, irrigation methods and so on will directly or indirectly affect the number of soil microorganisms[5]. Soil enzymes are one of the most
active organic components in soil, the main factor of soil metabolism, and the driving force of soil ecosystem metabolism, and it is closely related to soil microorganisms [6]. Soil enzyme activity reflects the condition of soil to some extent, and is sensitive to the changes caused by the environment and other external factors [7], and it has been widely studied as a biological activity indicator of agricultural soil quality and ecosystem function.

The cultivation area of Isatis indigotica Fort in hexi corridor expanded rapidly and has become the main cultivation area of Isatis indigotica Fort in China. Reasonable irrigation methods become one of the major agricultural management measures, in the normal growth and development to meet crop, at the same time, it also can change [8] of soil structure and physical and chemical properties, soil microorganism, enzyme activity [9] and other changes, which by influencing crop physiological process itself, improved the yield, water use efficiency and crop quality. Compared with non-drip irrigation area, drip irrigation system has better coupling of water and fertilizer, which was more beneficial for tea tree to absorb and utilize nutrients[10]. Tan yong et al. [11]studied the effects of different water contents on the growth and development of Isatis indigotica and its main active components, and showed that when the maximum water capacity in the field was 45% ~ 70%, the yield and quality of Isatis indigotica could be better. At present, there are few studies on the effect of deficit irrigation by drip irrigation under membrane on the soil environment of Isatis indigotica. Therefore, it is very important to investigate the effects of water stress under membrane drip irrigation on soil nutrient, microorganism and enzyme activity of isatis.

The changes of soil ecological environment caused by different degrees of water deficit will affect the sustainable planting of soil. By studying the change characteristics of soil ecological environment, we seek moderate water deficit and keep the good ecological environment of soil sustainable. In this study, membrane under drip irrigation technology was adopted, Isatis indigotica in hexi corridor area as the research object, and explored the water stress of Isatis indigotica soil nutrient, and researched the influence law of microorganism and enzyme activity. In order to provide the theoretical basis of irrigation for the standardized planting of Isatis indigotica in the northwest arid region on the basis of high efficiency water saving and achieve the purpose of soil improvement.

2. Materials and methods

2.1. General Description of Experimental Zone

The experiment was carried out at Yimin Irrigation Pilot Station (100°43’E, 38°39’N) in the middle reaches of Flood River Irrigation District, Minle County, Zhangye, Gansu Province from May to October in 2016 and 2017. The experimental zone has the continental desert steppe climate, with dry climate, abundant heat, abundant light energy and little rain; the altitude is about 1,970 m, the annual average temperature is 6.0℃, ≥0℃ cumulative temperature is 3500℃, ≥10℃ effective cumulative temperature is 2,985℃, the extreme maximum temperature is 37.8℃, the extreme minimum temperature is - 33.3℃, the average sunshine hours is 3,000 hours for years, and the frost-free period is 125 days. According to the data of precipitation for years, the average annual precipitation in this area is 215 mm with little precipitation and large variation rate. The contradiction between supply and demand is prominent, and the drought is frequent. The soil is light loam with pH value of 7.22, field water holding capacity of tillage layer soil is 24%, soil bulk density is 1.4 gꞏcm⁻³, groundwater level is low, and the area does not show salinization and alkalization.

2.2. Test Materials and Cultivation Methods

The large, full and even Isatis indigotica seeds, independently planted in the Department of Chinese herbal medicine in the Gansu Agricultural University, of which the seed purity was 96%, the weight per 1,000 seeds was 9.873 g, the germination rate was 87.6%, and the germination potential was 46.4%. Sowed on May 3 and harvested on October 13, the seeds have the sowing amount of 30.0 kgꞏhm⁻² and the planting density was 700,350 plantsꞏhm⁻². Before sowing, the experimental zone was ploughed for 30 cm to remove weeds manually. At the same time, 210 kgꞏhm⁻² urea (46% of N) was
applied, 340 kg·hm⁻² calcium superphosphate (12% of P₂O₅, 10% of S, 16% of Ca) was applied, and 270 kg·hm⁻² source potassium (25% of K₂O) was applied. All fertilizers were applied as base fertilizer at the time of sowing. Before *Isatis indigotica* were planted, three drip irrigation belts were laid manually in each plot with a distance of 1 m, a distance of 30 cm among drip emitters, and an average flow rate of 2.5 L/h. A branch control valve was installed in each plot to control the irrigation quantity, pressure gauge and water meter were located at the drip irrigation hub, and the working pressure of the system was 0.1 MPa. After drip irrigation system was installed, the soil was covered with colorless plastic film with a width of 120 cm. Each experimental plot is separated by a film with a width of 60 cm to prevent water from seepage underground.

2.3. Experiment Design

The growth stage of *Isatis indigotica* is divided into four growth stages according to its growth characteristics: seedling stage (May 3–June 7), vegetative stage (June 8–July 18), fleshy root growth stage (July 19–August 28) and fleshy root maturity (August 29–October 13). Soil moisture is divided into four levels: adequate irrigation (F, soil water content is 75%–85% of field water holding capacity), mild water deficit (L, soil water content is 65%–75% of field water holding capacity), moderate water deficit (M, soil water content is 55%–65% of field water holding capacity), and severe water deficit (H, soil water content is 45%–55% of field water holding capacity). There are 10 water control treatments, of which CK is the control treatment. Each treatment is repeated three times, totaling 30 districts. The area of each district is 36 m² (9 m x 4 m) and random block design is adopted. The effective experimental planting area is 1080 m². The method of irrigation is drip irrigation under mulch. The depth of soil layer for soil moisture control is 100 cm during the whole growth stage of irrigation. The upper and lower limits of water control coincide with the regional reality. The specific experimental design is shown in Table 1.

**Table 1.** Soil Moisture Contents under Different Treatments (Percentage of field water-holding capacity)

| Treatments | Seedling stage | Vegetative stage | Fleshy root growth stage | Fleshy root maturity |
|------------|----------------|------------------|-------------------------|---------------------|
| CK         | 75–85          | 75–85            | 75–85                   | 75–85               |
| WD1        | 75–85          | 65–75            | 75–85                   | 75–85               |
| WD2        | 75–85          | 55–65            | 75–85                   | 75–85               |
| WD3        | 75–85          | 45–55            | 75–85                   | 75–85               |
| WD4        | 75–85          | 65–75            | 65–75                   | 75–85               |
| WD5        | 75–85          | 65–75            | 55–65                   | 75–85               |
| WD6        | 75–85          | 55–65            | 65–75                   | 75–85               |
| WD7        | 75–85          | 55–65            | 55–65                   | 75–85               |
| WD8        | 75–85          | 45–55            | 65–75                   | 75–85               |
| WD9        | 75–85          | 45–55            | 55–65                   | 75–85               |

Note: WD1: mild water deficit in vegetative stage; WD2: moderate water deficit in vegetative stage; WD3: severe water deficit in vegetative stage; WD4: mild water deficit in vegetative stage and fleshy root growth stage; WD5: mild water deficit in vegetative stage and moderate water deficit in fleshy root growth stage; WD6: moderate water deficit in vegetative stage and mild water deficit in fleshy root growth stage; WD7: moderate water deficit in vegetative and fleshy root growth stage; WD8: severe water deficit in vegetative and mild water deficit in fleshy root growth stage; WD9: severe water deficit in vegetative and moderate water deficit in fleshy root growth stage; CK: normal water supply in all growth stages.
2.4. **Indicators and Methods for Measurement**

2.4.1. **Soil nutrient determination.** The sampling depth was 60cm and the gradient was measured every 20cm. Sampling was performed at each growth stage. For each soil sample, two plants with similar potential were selected in the plot, and soil samples were collected between the two plants. Then the soil samples were bagged and marked with envelopes and placed in the atmosphere to dry naturally. Determination of nitrogen by alkaline hydrolysis: The method of substitution of glycerol for alkaline adhesive solution was used; Rapid potassium determination: NH₄OAc was used for extraction, Flame photometry; Determination of available phosphorus: Sodium bicarbonate method was used for determination.

2.4.2. **Soil microbiological assay.** The sampling depth was 60cm and the gradient was measured every 20cm. Sampling was performed at each growth stage. For each soil sample, two plants with similar potential were selected in the plot, and soil samples were collected between the two plants. Soil microorganism quantity was determined by plate counting method. Fungi: marding's medium; Bacteria: beef extract peptone medium; Actinomycetes: High - I medium.

2.4.3. **Determination of soil enzyme activity.** Urease was determined by phenol sodium - sodium hypochlorite colorimetry. Sucrase was determined by colorimetric method.

2.5. **Statistical analysis of data**
Duncan's multiple comparison method in SPSS 19.0 software was used to compare the significance of the differences in the relevant data of each process. GraphPad Prism 5 was plotted, and the data in each table were averages.

3. **Results and analysis**

3.1. **Effects of different deficient water treatments on soil nutrients**
The changes of available N, available P and available K in the soil before and after seeding were studied to explore the change rule between soil nutrients and water at the root of *Isatis indigotica*. Table 2 shows the changes of available nitrogen, available phosphorus and available potassium in soil from 0 to 40 cm before and after sowing. The results of soil nutrient determination showed that there was no significant difference in the contents of available nitrogen, available phosphorus, available potassium and other soil nutrients between treatments in the 0-40 cm soil layer before the planting of *Isatis indigotica*, indicating that the soil was fertilized uniformly and the farmland leveling effect was good before the planting (table 2). There were significant differences in available nitrogen, available phosphorus and available potassium among different treatments of water deficit in soil after harvest ($p<0.05$). The available nitrogen content of WD3, WD8 and WD9 with severe water deficit was similar to that before sowing, while that of WD1, WD2, WD4, WD5 and WD7 with mild and moderate water deficit was lower. The content of available P, available K in all treated *Isatis indigotica* decreased after harvest compared with that before sowing. This was mainly due to the transport of nutrients and minerals by water in the soil around the root system, which resulted in better absorption of nitrogen and higher utilization of nitrogen by the root system.
Table 2. Changes of N, P and K contents in different treatments of Isatis indigotica field

| Treatments | available N /mg·kg⁻¹ | available P/mg·kg⁻¹ | available K/mg·kg⁻¹ |
|------------|-----------------------|----------------------|---------------------|
|            | Before sowing After harvest | Before sowing After harvest | Before sowing After harvest |
| CK         | 59.84a 51.15cd | 27.56a 22.93a | 88.22a 75.87a |
| WD1        | 58.11a 46.17d | 27.23a 21.89ab | 89.67a 59.29c |
| WD2        | 60.61a 52.67cd | 26.90a 20.35abc | 89.57a 69.03ab |
| WD3        | 59.02a 62.89ab | 25.66a 17.43c | 88.84a 71.78a |
| WD4        | 60.13a 53.58cd | 26.31a 18.94bc | 88.34a 62.39bc |
| WD5        | 59.30a 47.26d | 25.57a 18.64bc | 86.99a 71.66a |
| WD6        | 61.40a 57.50bc | 24.71a 19.12bc | 90.59a 59.75c |
| WD7        | 60.76a 52.26cd | 26.84a 20.65abc | 87.30a 71.32a |
| WD8        | 60.09a 65.84a | 26.87a 22.91a | 87.27a 72.34a |
| WD9        | 58.36a 63.53ab | 26.12a 24.01a | 85.38a 75.23a |

Note: Within each column different small letters mean significant difference at $p<0.05$

3.2. Effects of different water treatments on soil microorganisms

Figure 1 shows the changes of bacterial quantity in the soil during each growth period of *Isatis indigotica* in different soil layers in 2017. The number of bacteria in soil gradually decreased with the increase of soil depth. From the point of view of the whole growth period of song LAN, there were more bacteria in the soil during the vegetative growth period, and the number of bacteria in the soil during the other three growth periods was basically the same. Different water deficits affect the number of bacteria in the soil. The bacteria of CK, WD1, WD2 and WD4 in the soil layer of 0–20cm were more abundant in vegetative growth period. The bacteria of WD2, WD3 and WD4 in the soil layer of 0–20cm were more abundant in fleshy root growth period. The number of soil bacteria in 20–40cm soil treated by WD5, WD8 and WD9 was significantly lower than that of other treatments. The experimental data showed that during the vegetative growth period of *Isatis indigotica*, mild to moderate water deficit did not significantly affect the number of soil bacteria in the soil layer of 0–20cm, but the amount of soil bacteria in the soil layer of 20–40cm and 40–60cm with severe water deficit was significantly reduced compared with that of full and mild water deficit. Excessive water leads to a decrease in the number of bacteria in the surface soil, but the rehydration effect caused by water deficit will increase the number of bacteria in the surface soil in the fleshy root growth period.
Figure 1. Variation in the number of bacteria of different soil layers in different growth periods

Figure 2 shows the changes in the number of fungi in the soil during each growth period of different soil layers in 2017. The number of fungi in soil decreased gradually with the increased of soil depth. From the perspective of the whole growth period, the number of soil fungi in the 0-20cm soil layer was: the growth stage of > fleshy root maturation stage of > fleshy root growth stage of > seedling stage. Different water deficit affected the number of fungi in soil. The fungi of CK, WD1, WD4 and WD5 were more abundant in the soil layer of 0~20cm in vegetative growth period, and were significantly higher than those of other treatments. The fungi of CK, WD1 and WD4 were more abundant in the soil layer of 0~20cm in fleshy root growth period. The experimental data showed that water deficit did not significantly affect the number of soil fungi in the 0-20cm soil layer, and mild water deficit increased the number of fungi in the soil.
Figure 2. Variation in the number of fungi of different soil layers in different growth periods

Figure 3 shows the changes of actinomycetes in the soil at different growth stages of *Isatis indigotica* in different soil layers in 2017. The number of actinomycetes in soil gradually decreased with the increase of soil depth. From the perspective of the whole growth period of *Isatis indigotica*, the number of soil actinomycetes in the soil layer of 0-20cm was: the vegetative growth period > seedling stage > fleshy root maturation period > fleshy root growth period. Different water deficit affected the amount of actinomycetes in soil. The Numbers of actinomycetes of CK, WD1, WD2, WD3 and WD5 were more in the soil layer of 0-20cm, and were significantly higher than other treatment. The amount of actinomycetes of CK, WD1, WD2, WD4, WD5 and WD6 were more in the soil layer of 20-40cm, while the amount of actinomycetes of 40-60cm treated by WD8 and WD9 with severe water deficit was lower in fleshy root growth period. This study showed that mild to moderate water deficit did not significantly affect the amount of actinomycetes in soil from 0 to 20cm, and mild water deficit increased the amount of actinomycetes in soil.
3.3. Effects of different deficient water treatment on soil enzyme activity

FIG. 4 shows the changes of urease activity in soil at different growth stages of *Isatis indigotica* in different soil layers in 2017. With the increase of soil depth, the activity of urease in soil gradually decreased. Different water deficit affected urease activity in soil. Urease activities of CK, WD1, WD2 and WD4 in the soil layer of 0~20cm were higher in vegetative growth period. The urease activity of WD3 and WD9 was lower in the soil layer of 0~20cm in fleshy root growth period. The experimental data showed that full irrigation and mild water deficit did not significantly affect the urease activity in the 0-20cm soil layer, but the urease activity in the soil with severe water deficit was significantly lower than that under the treatment of full and mild water deficit in the vegetative growth period of *Isatis indigotica*. Mild to moderate water deficit was associated with increased urease activity in topsoil during the fleshy root growth period.

**Figure 3.** Variation in the number of actinomyces of different soil layers in different growth periods
Figure 4. Urease activity of different soil layers in different growth periods

Figure 5 shows the changes of sucrase activity in different soil layers in each growth period in 2017. The activity of sucrase in soil decreased gradually with the increase of soil depth. With its growth and development, the activity of sucrase in soil increased gradually. Full irrigation and mild water deficit improved the sucrase activity in the 0-20cm soil layer, but the sucrase activity in the soil with severe water deficit was significantly lower than that under the treatment of full and mild water deficit in vegetative growth period. The sucrase activity in 0~20cm topsoil was significantly higher than that in 40~60cm topsoil in fleshy root growth period. Mild to moderate water deficit was associated with increased sucrase activity in topsoil.
Figure 5. Sucrase activity of different soil layers in different growth periods

4. Discussion

Soil nutrients are the basis of agricultural production and the core element of soil fertility. The moderate water deficit irrigation can reduce the loss of available nutrients in the soil, promote the absorption and utilization of nutrients such as N and K, and thus promote the formation of final yield [12][13]. It is necessary to pay attention to the sustainable use of soil nutrients and other factors such as water and soil microorganisms in crop cultivation. A comprehensive understanding of the relationship between soil nutrients and crop growth and development and the full use of soil fertility can effectively improve crop productivity [14]. Estimates of nutrients in microbial biomass suggested greater N, P and S immobilization during the wet season than the dry season and greater nutrient immobilization in irrigated than in control plots [15].

Zhang xiaoying et al. found that [16], moderate water deficit significantly increased the yield of grafted cucumber from different roots and promoted the absorption and utilization of soil nutrients N, P and K. Thus alternate partial root-zone irrigation at the jointing-tasselling stage could increase total dry mass and N uptakes under mild water deficit and combined application of organic and inorganic N fertilizer [17].

This experimental study reached a similar conclusion. The differences of available nitrogen, available phosphorus and available potassium in different treatments of water deficit in soil after harvest were significant ($p<0.05$). The content of available N after harvest was lower in all treatments than before sowing. The available nitrogen of WD3, WD8 and WD9 treated with severe water deficit was similar to that before sowing, but the content of available nitrogen in WD1, WD2, WD4, WD5 and WD7 in mild and moderate water deficit treatment was significantly reduced. This was mainly due
to the transport of nutrients and minerals by water in the soil around the root system, which resulted in better absorption of nitrogen and higher utilization of nitrogen by the root system. The content of available P and available K in all treated *Isatis indigotica* decreased after harvest compared with that before sowing. The main reason is that light to moderate water deficit is beneficial to the absorption and utilization of available P and available K in the soil.

Wang lide et al. [18] found that the number of bacteria, actinomycetes and fungi in the soil of abandoned farmland in the lower reaches of Shiyang river decreased successively, and the number of soil microorganisms, biomass and soil enzyme activities showed a trend of gradual decline with the depth of soil, and the number of surface soil microorganisms and soil enzyme activities accounted for a large proportion. Wang jinfeng et al. [19] showed that mild water deficit can effectively improve the soil’s gas-heat-water environment, so as to facilitate the growth and reproduction of soil microorganisms and increase their number. There are studies that show that irrigation significantly increased soil microbial biomass and activity [20]. The results of this experiment showed that among the soil microbial composition of *Isatis indigotica*, the number of bacteria was the largest, followed by actinomycetes, and fungi was the least. The number of bacteria, fungi and actinomycetes in soil gradually decreased with the increase of soil depth. Mild to moderate water deficit did not significantly affect the amount of soil bacteria in the soil layer between 0 and 20cm in vegetative growth period. However, the amount of soil bacteria in the 20-40cm and 40-60cm soil layers with severe water deficit was lower than that of those with sufficient and mild water deficit. Too much water will lead to the reduction of the number of bacteria in the surface soil, but the rehydration effect caused by water deficit will increase the number of bacteria in the surface soil in fleshy root growth period. Water deficit did not significantly affect the number of soil fungi and actinomycetes in the soil layer between 0-20cm soil layer, and mild water deficit increased the number of fungi and actinomycetes in the soil.

The results of this experiment showed that the activities of urease and sucrase in soil gradually decreased with the increase of soil depth. Urease activity decreased with soil depth in each growth period of *Isatis indigotica*.

Fan hailan [21] found that under different water conditions, urease activity in rhizosphere soil showed a trend of decreasing first and then increasing, urease activity was higher in rhizosphere soil under moderate water stress, and soil sucrase activity was decreased after severe water stress. The research results of Chen nana et al. [22] showed that water deficit treatment in the growing period of grape shoots could significantly improve the soil sucrase activity. The results of this experiment show that full irrigation and mild water deficit did not significantly affect the urease activity in the 0-20cm soil layer, but the urease activity in the soil with severe water deficit was significantly lower than that under the treatment of full and mild water deficit in vegetative growth period. Full irrigation and mild to moderate water deficit was beneficial to the improvement of urease activity and sucrase activity in topsoil in fleshy root growth period.

5. Conclusion

The following conclusions were drawn by analyzing and studying the soil nutrient, microorganism and enzyme activity of *Isatis indigotica* under the condition of water deficit.

1. There were significant differences in alkali-hydrolyzed nitrogen, available phosphorus and available potassium among different water deficit treatments in the soil after harvest. The alkali-hydrolyzed nitrogen content of mild and moderate water deficit treatment was significantly lower than that of CK. This was mainly due to the transport of nutrients and minerals by water in the soil around the root system, which resulted in better absorption of alkali-hydrolyzed nitrogen and higher utilization of alkali-hydrolyzed nitrogen. Severe water deficit leads to slow absorption of available phosphorus and available potassium in the soil, while mild to moderate water deficit is beneficial to the absorption and utilization of available phosphorus and available potassium in the soil by the root of *Isatis indigotica*.

2. The number of bacteria, fungi and actinomycetes in *Isatis indigotica*’s soil gradually decreased with the increase of soil depth. Water deficit did not significantly affect the number of soil fungi and...
actinomycetes in the 0-20cm soil layer, and mild water deficit increased the number of fungi and actinomycetes in the soil.

(3) Full irrigation and mild water deficit did not significantly affect the urease activity in the 0-20cm soil layer, while the urease activity in the soil with severe water deficit significantly decreased. Mild water deficit can increase the sucrase activity in the 0~20cm soil layer, while severe water deficit can significantly reduce the sucrase activity in the soil.

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References
[1] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2000) 51-59.
[2] W. Strunk Jr., E.B. White, The Elements of Style, third ed., Macmillan, New York, 1979. Reference to a chapter in an edited book:
[3] G.R. Mettam, How to prepare an electronic version of your article, in: B.S. Jones, R.Z. Smith (Eds.), Introduction to the Electronic Age, E-Publishing Inc., New York, 1999, pp. 281-304.
[4] R.J. Ong, J.T. Dawley and P.G. Clem: submitted to Journal of Materials Research (2003)
[5] P.G. Clem, M. Rodriguez, J.A. Voigt and C.S. Ashley, U.S. Patent 6,231,666. (2001)
[6] Information on http://www.weld.labs.gov.cn
[7] Zhang H, Xue Q, Tang M, Wang L, Duan C. Study on actinomycetic ecology in soil with the different cultivating years of ginseng [J]. Journal of northwest a & f university (natural science edition), 2010, 38(8):151-159.
[8] Wang F, Bau T. Research advances in the diversity of soil fungi [J]. Journal of Fungal Research, 2014, 12 (03):178-186.
[9] Antizar-Ladislao B, Spanova K, Beck A J, Nicholas J. R. Microbial community structure changes during bioremediation of PAHs in an aged coal-tar contaminated soil by in-vessel composting [J]. International Biodeterioration & Biodegradation, 2008, 61(4):357-364.
[10] Vries F T D, Hoffland E, Eekeren N V, Brussaard L, Bloem J. Fungal/bacterial ratios in grasslands with contrasting nitrogen management [J]. Soil Biology & Biochemistry, 2006, 38 (8):2092-2103.
[11] Cao H, Sun H, Yang H, Sun B, Zhao Q. A review of Soil enzyme activity and its indication for soil quality [J]. Chinese Journal of Applied & Environmental Biology, 2003, 9 (01):105-109.
[12] Li C, Jia Z, Tang L, Wu Y, Li Y. Effect of model of fertilization on microbial abundance and enzyme activity in oasis farmland soil [J]. Acta Pedologica Sinica, 2012, 49 (03):567-574.
[13] Badiane N N Y, Chotte J L, Pate E, Masse D, Rouland C. Use of soil enzyme activities to monitor soil quality in natural and improved fallows in semiarid tropical regions [J]. Applied Soil Ecology, 2001, 18 (03): 229-238.
[14] Chai Z, Liang Z, Wang X, Jia H. The influence of the different methods of irrigation on the soil physical properties in cotton field [J]. Journal of Xinjiang Agricultural University, 2008, 31 (05): 57-59.
[15] Zhang L, Zeng F, Yuan N, Liu B, Luo W, Song C, Peng S. Root Growth and ramets architecture characteristics of Alhagisparifolia under different water treatments[J]. Journal of Desert Research, 2013, 33 (03): 717-723.
[16] Chen Y, Tian Y. The influence trogen and phosphorus contents of soil and tea in tea garden under drip irrigation condition [J]. Environmental Science & Technology, 2012, 35(61):49-52.
[17] Tan Y, Liang Z, Dong J, Hao H, Ye Q. Effect of water stress on growth and accumulation of active components of Isatis indigotica[J]. China journal of Chinese materia medica, 2008, 33(01):19-22.
[18] Zhang H, Gan Y, Huang G, Zhao W, Li F. Postharvest residual soil nutrients and yield of spring wheat under water deficit in arid northwest China [J]. Agricultural Water Management, 2009, 96, 1045-1051.

[19] Li W, Zhou L, Xu M. Effect of nitrogen and water stress on the relations between environment and the physiological properties of wheat plant [J]. Acta Pedologica Sinica, 2002, 39(03):397-403.

[20] Zhan A, Zou C, Ye Y, Liu Z, Cui Z, Chen X. Estimating on-farm wheat yield response to potassium and potassium uptake requirement in China [J]. Field Crops Research, 2016, 191, 13-19.

[21] Yavitt J B, Wright S J, Wieder R K. Seasonal drought and dry-season irrigation influence leaf-litter nutrients and soil enzymes in a moist lowland forest in Panama [J]. Austral Ecology, 2004, 29 (2):177-188.

[22] Zhang X, Liang X, Zhang Z, Tong R, Gao L. Influence of grafting on cucumber growth and nutrient absorption under water deficient condition [J]. Journal of China Agricultural University, 2014, 19 (03):137-144.

[23] Liu S, Li F. Effect of irrigation method on dry mass and nitrogen and potassium utilization of maize under different water and nitrogen conditions [J]. Acta Ecologica Sinica, 2014, 34(18): 5249-5256.

[24] Wang L, Yao T, Wang F, Wei L, Guo C, Wu C, Li F. Soil microbial and soil enzyme activity in a discontinued farmland by the Lower Shiyang River [J].Acta Ecologica Sinica, 2016, 36(15): 4769-4779.

[25] Wang J, Kang S, Li F, Zhang F, Li Z, Zhang J. Effects of alternate partial root-zone irrigation on soil microorganism and maize growth [J]. Plant & Soil, 2008, 302(1-2):45-52.

[26] Zhang Y, Wang L, Yuan Y, Xu J, Tu C, Fisk C, Zhang W, Chen X, Ritchie D, Hu S. Irrigation and weed control alter soil microbiology and nutrient availability in North Carolina Sandhill peach orchards [J]. Science of the Total Environment, 2018, 615:517-525.

[27] Fan H, Hong W, Wu C, Li J, Chen C, Huang J, Rong H. Effects of Water Stress on Growth and Total Saponin Content of Liriope muscari (Decne.) Bailey [J]. Chinese Journal of Applied & Environmental Biology, 2011, 17 (03): 345-349.

[28] Chen N, Jia S, Zhang R. Effects of Water Deficit on the Biological Characteristics of Grape Grown in Greenhouse [J]. Acta Agriculturae Boreali-Sinica, 2017, 32(05): 192-199.