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EFFECTS OF ALTERNATING DRYING AND WETTING ON SOIL NITROGEN AND PHOSPHORUS LOSS IN ROOT ZONE OF DOMINANT PLANTS IN PHOSPHORUS-RICH MOUNTAINOUS AREAS

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Abstract

In the mountainous area of Yunnan-Guizhou Plateau, phosphorus and nitrogen are important factors that limit primary productivity and affect the distribution of plant communities. Alternation of wet and dry has a significant effect on the migration of various elements such as C, N, and P in soil. Taking the rhizosphere soil of the dominant plants in the phosphorus-rich mountainous area in the Dianchi Lake Basin as the research object. Six sets of different humidity treatment methods: blank constant humidity, blank dry and wet alternation, nitrogen constant humidity, nitrogen addition dry and wet alternation, carbon constant humidity, and carbon add dry and wet alternation were assessed. Responses of soluble total nitrogen and soluble total phosphorus to six treatments in plant root zone were investigated. The results showed that the contents of dissolved total nitrogen (DTN) and dissolved total phosphorus (DTP) in soil leachate and their changes of *Erianthus rufipilus* and *Eupatorium adenophorum* under different treatment conditions increased first and then decreased. In the carbon addition group, the DTN content of the soil leachate in the alternating dry and wet treatment was significantly higher than that in the constant humidity treatment, but there was no significant difference in the nitrogen addition group. The three factors of water treatment and sampling time have significant effects on the DTN content of soil leachate, and the interaction between the three also has a significant effect on it.

Introduction

The Dianchi Lake Basin is one of the important phosphate rock industrial bases and agricultural areas in China. Phosphorus-rich areas account for about ten percent of the Dianchi Lake basin area (Zhang *et al.* 2007, Xue 2008). On the basis of this rich phosphorus, agricultural production still needs to apply a large amount of phosphorus fertilizer to the land for the growth of crops. The excess phosphorus that is not used by plants will enter surface water and groundwater through surface runoff, intrusion and leaching (leakage or underground runoff (Heskethn 2000). Coupled with the mining of phosphate rock in this area, this area has become the main source of non-point source pollution output in the Dianchi Lake Basin, resulting in eutrophication of the Dianchi Lake water body.

There is also a phosphorus-rich large area in the small watershed of Chaihe River in the south of Dianchi Lake Basin. However, due to the influence of human production and life, a large amount of phosphorus is exported from the terrestrial ecosystem in the phosphorus-rich areas in the soil of Dianchi Lake Basin, which poses a serious threat to the water security of Dianchi Lake. Restore the ecological environment of the mining area by establishing dominant plant communities and introducing species supplement (Hupfer *et al.* 2008, Thanh *et al.* 2005, Zhang *et al*. 2012). Forming a sustainable ecosystem requires not only achieving vegetation cover, but also restoring soil quality and function (Schnbrunneri *et al.* 2012). Climate change in the world is an indisputable fact in the scientific community. More and more regions experience long-term

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droughts after heavy rains, or areas with high precipitation are getting more and more arid, and they have to irrigate to maintain agricultural production. So the soil is more likely to experience multiple wet and dry alternations. Wet and dry alternation is one of the most extensive forms of stress experienced by soils (Gerstengarbe *et al.* 2008, Katterer *et al.* 1998, Kruse *et al.* 2004, Torbert *et al.*1992, Schjonning *et al.* 1999), and it is a common phenomenon in nature. Low and random rainfall, warm and dry climate, etc. can cause dry and wet alternation, which will cause the soil to experience dry and wet alternation many times. Under the conditions of alternating dry and wet, the soil has undergone physical, chemical, and biological changes (Gordillo *et al.* 1997, Li *et al.* 2022, Hao *et al.* 2022) Which are mainly manifested in the formation of soil structure, the decomposition and mineralization of organic matter, and the number and structure of soil (Tran *et al.* 2022). The content of mineral elements in soil varies from place to place. In the mountainous region of the Yunnan-Guizhou Plateau, phosphorus and nitrogen are considered to be important factors that limit primary productivity and affect the distribution of plant communities (Ullah *et al.* 2022, Ananna *et al.* 2022, Weber *et al.* 2021, Zhang *et al.* 2021). In recent years, by studying the effect of soil phosphorus migration and transformation under the condition of dry-wet alternation, the migration and transformation process of soil phosphorus under the condition of dry-wet alternation has been explored, and the biochemical cycle process of soil phosphorus has been recognized in the process of dry-wet alternation (Arruda *et al*. 2021, James *et al.* 2021, Albadri *et al*. 2021). The change of telecommunication has become a hot issue studied by many scholars at home and abroad (Thyagaraj *et al.* 2021). As core indicators of soil fertility, soil organic matter and soil nitrogen respond to major changes in soil. In recent years, with the further development of microbial denitrification theory and organic matter mineralization theory, many scholars have turned their attention to the impact of climate change on soil nitrogen and carbon cycle transformation (Dash *et al.* 2021, Watanabe *et al.* 2021, Zhou *et al.* 2020, Malumpong *et al*. 2021, Jin *et al.* 2021), making the dynamic change of soil organic carbon. Great progress has been made in research and the theory of soil nitrogen transformation. These research results have a very profound effect on reducing soil erosion, maintaining soil nutrients, reducing the impact of global climate change, rational fertilization management of farmland, and sustainable development of agriculture.

Materials and Methods

The study area is located in Jinning County, Kunming City. The geographical position is 24°36'-37'N, 102°41'-42'E, and the altitude is 1936-2256 m. The landform is mountainous and semi-mountainous, and it is located from southeast to northwest. Chaihe is the small watershed of Dianchi Lake. This area belongs to the subtropical humid monsoon climate. The dry and wet seasons are distinct. The average annual temperature is 14.6°C and the average annual rainfall is 925.4 mm. The types of soil are mostly mountain yellow-red soil and brown-red soil. The moisture content of the soil is 14.29%, the pH is 6.23, the total nitrogen of the soil is 0.78 mg/g^-, and the total phosphorus of the soil is 6.57 mg/g^-. The total potassium of the soil is 3.36 mg/g, and the organic matter is 3.21%. Details are shown in Table 1.

There are many early phosphate mining in this area, most of which are located in the 1/3 to 2/3 mountainside area. The soil in the area is very rich in phosphorus. With the early phosphate mining and other human production activities, the vegetation in the area has been severely destroyed, and a large amount of phosphorus has entered the lake with severe soil erosion. The plants selected in this experiment are the two most common dominant plants in the phosphorus-rich mountain areas of the Dianchi Lake Basin, *Erianthus rufipilus* and *Eupatorium adenophorum*. Soil sample collection: During the collection, three plants of uniform size are randomly selected for each plant, and the stripping method is used for collection. First, the dead branches and deciduous layers are removed to expose the base of the trunk of the dominant plants. Then, the soil in the area required for the experiment is taken with a soil knife. Then, the part of fibrous roots along the lateral roots is found, and the branch part is cut. Carefully take out the soil with fibrous roots and divide the samples. The soil falling after gently shaking is root zone soil (non rhizosphere soil), However, the soil still sticking to the root surface is rhizosphere soil, which is put into a self sealing bag together with the root and peeled off immediately after being taken back. The soil that sticks tightly can be gently knocked or carefully peeled off with a blade and taken back to the laboratory for enzyme activity analysis

Table 1. Properties of soil and water.

Indicator	soil	water
pH	6.23±1.21	7.21±1.34
Bulk density (g/cm)	96.41±3.27	-
Conductivity (mS/cm)	100.12±12.4	0.62±0.13
Organic matter content (%)	3.21	0.17
Soil moisture content (%)	14.29	-
Total potassiumcontent (mg/g) /(mg/l)	6.57±1.25	0.02
Total nitrogencontent (mg/g)/(mg/l)	0.78±0.12	0.24±0.02
Total potassiumcontent (mg/g)/(mg/l)	3.36±1.31	0.35±0.11
δ13c (‰)	-26.12	-
Sal (‰)	-	0.31±0.12

In this study, we used the alternate dry and wet condition to simulate the cultivation methods of the dry and rainy seasons in nature. The sieved soil was kept into a PVC tube with a diameter of 5 cm in the culture device, deionized water was added and covered with aluminum foil, and the silica gel was allowed to dry out at certain intervals. Six experimental groups were set up with different water treatment methods, namely blank with constant humidity (KA), blank with dry and wet alternate (KB), nitrogen added with constant humidity (NA), nitrogen added with alternate dry and wet (NB), carbon with constant humidity (CA), carbon with dry and wet alternately (CB). The six sets of experimental devices were all cultured in an artificial climate chamber (BIC-300 type) with constant temperature and humidity. The temperature was set to 25 °C, the humidity was 50%, and the light time was 6:00 to 18:00. At the same time, the different experimental groups exchange positions were noted every day to ensure that the error caused by the artificial climate chamber interferes with the experimental data. The cultivation time was 60 days, which were divided into six batches of 2, 16, 29, 31, 46 and 60 days.

Using alkaline potassium persulfate digestion ultraviolet spectrophotometry, according to the national standard (GB 11894-89), the total nitrogen for water quality analysis was determined. Using ammonium molybdate spectrophotometric method, according to the national standard (GB 11893-89), the total phosphorus was determined. R software was used to carry out multivariate analysis of variance. OriginPro2021 software was used for drawing.

Results and Discussion

The content and change of total soluble nitrogen in the soil leachate of sugarcane under different treatment conditions are shown in Fig. 1a. It can be seen that the content change trend before 30 days roughly increased first and then decreased, and appeared after 30 days. The trend was basically to increase first and then decrease, and the changes in the carbon addition group were different.

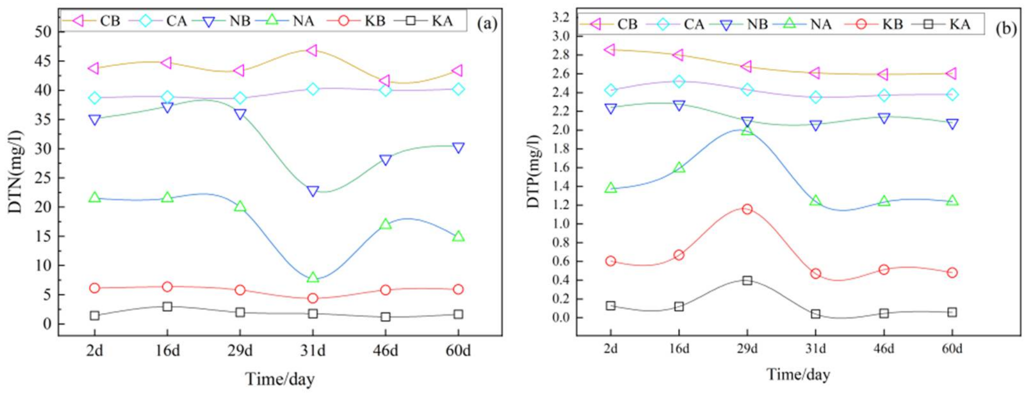

Fig. 1. The content and changes of DTN and DTP in soil leachate of *Erianthusrufipilus* under different treatment conditions.

The content and change of soluble total phosphorus in the soil leachate of sugarcane under different treatment conditions are shown in Fig. 1b. It can be seen that the content change showed an opposite trend, roughly increased first and then decrease before 30 days, and then regain the initial values after 30 days. The trend is also to increase first and then decrease.

The content and change of soluble total nitrogen in soil leachate of *B. adenophora* under different treatment conditions are shown in Fig. 2a. There were a fluctuating tendency, where the general direction of the content change before 30 days was to increase first and then decrease, after 30 days. The changes of nitrogen addition group were different.

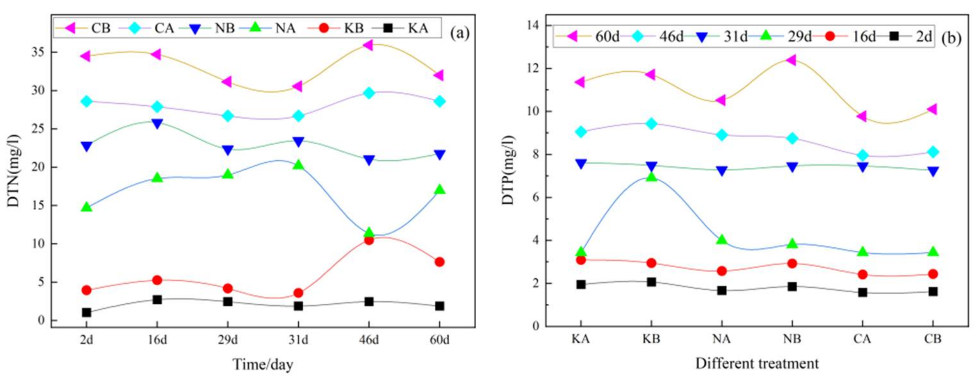

Fig. 2. The content and change of DTN/DTP in soil leachate of *Eupatorium adenophorum* under different treatment conditions.

The content and change of total soluble phosphorus in the soil leachate of *B. adenophora* under different treatment conditions are shown in Fig. 2b. It can be seen that the content change trend was roughly increased first and then decreased before 30 days, and appeared after 30 days. The basic trend was to decrease and then increase.

The effect of alternating wet and dry conditions on the total soluble nitrogen in the soil leachate of sugarcane grass under different treatment conditions is shown in Fig. 3a. It can be seen that the highest content of soluble total nitrogen in the soil leachate is the nitrogen addition treatment group, and its DTN was significantly higher than other treatments, but in the nitrogen addition group, there was no significant difference in the DTN of the soil leachate between the dry and wet treatments and the constant humidity treatment; for the control group, the soil leachate DTN of the alternate dry and wet treatments and the constant humidity treatment also had no significant differences; but for carbon, in the addition group, the DTN content of soil leachate treated with alternating wet and dry treatments was significantly higher than that of constant humidity treatment.

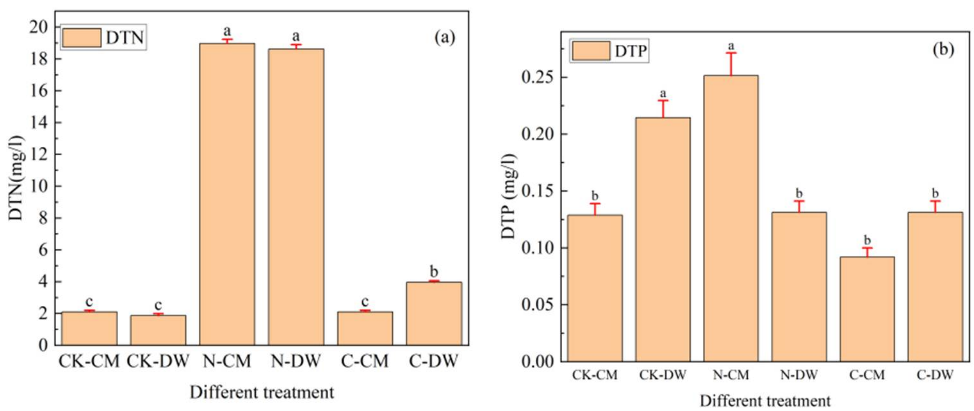

Fig. 3. The effect of alternation of drying and wetting under different treatment conditions on the DTN/DTP of the soil leachate of *Erianthus rufipilus*.

The effect of alternating drying and wetting under different treatment conditions on the soluble total phosphorus in the soil leachate of *Saccharum vulgare* is shown in Fig. 3b. It can be seen that the highest soluble total phosphorus content in the soil leachate is the constant humidity treatment of the nitrogen addition treatment group and the control group. There were significant differences between the two DTP treatments and other treatments in the dry wet alternate treatment; In the control group and the nitrogen group, the DTP of soil leachate under dry wet alternate treatment and constant humidity treatment was significantly different.

The effect of alternating wet and dry conditions on the total soluble nitrogen in soil leachate of *E. adenophorum* under different treatment conditions is shown in Fig. 4a. It can be seen that the highest content of soluble total nitrogen in the soil leachate was the nitrogen addition treatment group, and the DTN is significant. It was higher than other treatments; and in the nitrogen addition group, there was a significant difference in the DTN of the soil leachate between the dry and wet treatment and the constant humidity treatment; but for the control group and the carbon addition group, the soil leachate DTN of the alternate dry and wet treatment and the constant humidity treatment also have no DTN significant differences.

The effect of alternating wet and dry conditions on the total soluble phosphorus of *E. adenophorum* soil leachate under different treatment conditions is shown in Fig. 4b. It can be seen that the content of total soluble phosphorus in the soil leachate was the highest under the constant humidity treatment in the nitrogen addition group. It was the lowest in the carbon-added group under the constant humidity treatment condition; for the nitrogen-added group, the carbon-added group and the control group, although the contents were different, there was no significant difference in the statistical significance test.

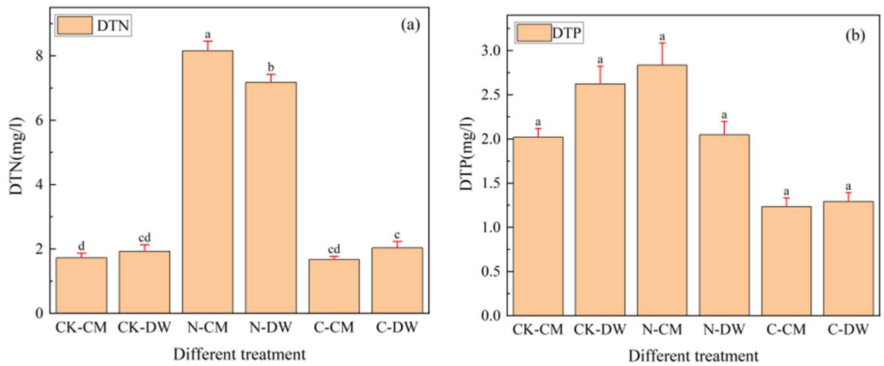

Fig. 4. The effect of alternating wet and dry conditions on the DTN/DTP of *Eupatorium adenophorum* soil leachate under different treatment conditions.

The multi-factor analysis of variance affecting DTN and DTP of soil leachate is shown in the above table. It can be seen that the three factors of species, water treatment, and sampling time have significant effects on the DTN content of soil leachate, and the interaction between the three has a significant effect on the DTN content of soil leachate. It also has a significant impact. For soil leachate DTP content, species and water treatment have significant effects on it, but sampling time has no significant effect on the content, and the interaction between species and water treatment, and the interaction between species and sampling time on the DTP The content also has no significant effect; at the same time, the interaction of water treatment and sampling time and the interaction of the three factors have a significant impact.

Table 2. Multi-factor analysis of variance affecting soil leachate DTN and DTP.

	DTN		DTP	
	F	*P*	F	*P*
Species	31.17	0.00	129.38	0.00
Moisture treatment	1087.24	0.00	3.00	0.01
Sampling time	11.93	0.00	1.76	0.13
Species * Moisture treatment	10.67	0.00	2.11	0.07
Species * sampling time	8.11	0.00	2.30	0.05
Moisture treatment * Sampling time	6.09	0.00	2.14	0.00
Species * Moisture treatment * Sampling time	8.17	0.00	2.13	0.00

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