Effects of Different Fertilization Modes on Soil Nutrients, Yield and Quality of Cucumber Under Moistube Irrigation

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Abstract [**Objectives**] This study was conducted to reveal the migration and distribution law of soil available nutrients in soil layer under moistube irrigation and screen out suitable fertilization modes for facility cucumber planting. [**Methods**] The experiment adopted the moistube irrigation mode and randomized block design. Seven treatments were set up as following: inorganic fertilizer (T_1), medium-concentration inorganic fertilizer (T_2), high-concentration inorganic fertilizer (T_3), low-concentration inorganic fertilizer + low-concentration biological organic fertilizer (T_4), low-concentration inorganic fertilizer + medium-concentration biological organic fertilizer (T_5), low-concentration inorganic fertilizer + high-concentration biological organic fertilizer (T_6) and no fertilizer control (CK). Nitrate nitrogen, available phosphorus and available potassium in soil and fruit yield and quality were determined. [**Results**] Under the moistube irrigation mode, the application of soluble bio-organic fertilizer combined with inorganic fertilizer could significantly increase the contents of available nutrients in the 0 – 40 cm soil layer available for cucumber utilization, and promote the absorption of available nutrients by cucumber plants. It reduced the contents of nitrate nitrogen and available potassium in the soil layer of 40 – 60 cm, but had no significant effect on the content of available phosphorus in the soil layer of 40 – 60 cm. Compared with the CK treatment, the cucumber yield, vitamin C content, soluble sugar content and soluble protein content of treatment T_6 increased by 69.27%, 29.68%, 55.91% and 32.5%, respectively. Compared with treatment T_3 (high-concentration inorganic fertilizer), treatment T_6 showed no significant difference in yield, but its nitrate content decreased by 15.97%. Soluble bio-organic fertilizer combined with inorganic fertilizer could be well combined with moistube irrigation, which could not only achieve high yield, but also reduce the risk of environmental pollution caused by fertilization, thus achieving the purpose of saving water and fertilizers and protecting the ecological environment. Considering the yield and quality of cucumber fruit, treatment T_6 was a more suitable fertilization model for cucumber planting in moistube irrigation facilities. [**Conclusions**] This study provides a scientific basis for the popularization of moistube irrigation techniques and efficient utilization of fertilizers.

Key words Fertilization mode; Fertilizer type; Moistube irrigation; Inorganic fertilizer reduction; Combined application of bio-organic fertilizer; Available nutrient; Soil nutrient; Fertilizer partial factor productivity; Agronomy fertilizer use efficiency

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Cucumber (*Cucumis sativus* L.) is a creeping or climbing herbaceous plant of Cucurbitaceae, which is widely cultivated all over China. Cucumbers are crisp and delicious, and rich in vitamin C, vitamin E, cellulose, propanol diacid and other nutrients. The plant is one of the important vegetable crops in China. With the people's growing material needs, the demand for cucumbers is increasing. In the production of cucumbers, the phenomenon of excessive water and fertilizers is more serious, which not only leads to the increase of planting cost and waste of water resources, but also to serious pollution of the ecological environment due to the large use of inorganic fertilizers[1].

As a new type of water-saving irrigation technique, moistube irrigation uses moistubes buried underground and utilizes the water potential difference inside and outside the semi-permeable membrane pipes as the driving force to transport irrigation water to the root zone of crops in a sweat-like form, achieving a slow and long-lasting soil moistening effect, which is conducive to maintaining the same soil moisture state at crop roots. It can meet the water requirement of crops, and plays a continuous irrigation role throughout their entire growth cycle[2]. Moistube irrigation technique can be well combined with water and fertilizer integration techniques to achieve the effects of saving water, reducing fertilizers and increasing production[3–5]. There have been many studies on soil moisture movement under moistube irrigation. However, few studies have been conducted on the migration law of soil fertilizers under the condition of combining with fertilization (especially the integrated application of reduced inorganic fertilizer and water-soluble bio-organic fertilizer).

Bio-organic fertilizer is a new type of fertilizer with the properties of both organic fertilizer and microbial fertilizer, which can improve soil fertility, regulate soil microecological balance, improve the quality of agricultural products and control the effectiveness of heavy metals in soil[6]. Liang *et al.*[7] reported that bio-organic fertilizer can enhance soil fertility, improve soil environment and increase the yield of *Cucurbita pepo*. Ru *et al.*[8] found that combined application of bio-organic fertilizer can improve the yield and quality of Chinese cabbage. At present, bio-organic fertilizer is generally used as base fertilizer in production research, and it is rarely applied in combination with inorganic fertilizer as topdressing relatively.

In this study, directing at the combined application of inorganic fertilizer and water-soluble bio-organic fertilizer as topdressing, the migration and distribution law of various available nutrients in the soil layer under moistube irrigation mode was investigated, and the yield and quality of cucumber were analyzed to screen out fertilization modes suitable for facility cucumber planting. This study provides a scientific basis for the popularization of moistube irrigation technique and efficient utilization of fertilizers.

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Jiahao XU (1997 –), male, P. R. China, master, devoted to research about efficient utilization of water and fertilizer resources.

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Materials and Methods

General situation of experimental area

This experiment was conducted in a solar greenhouse in Liujiabao Township, Xiaodian District, Taiyuan City, Shanxi Province from June to September, 2022. The experimental area has a temperate continental monsoon arid climate with four distinct seasons. The average annual temperature is 11 ℃. The annual rainfall is about 520 mm. The frost-free period is 170 d. Before the experiment, the physical and chemical properties of the 0 – 20 cm soil layer were as follows: pH 7.36, nitrate nitrogen 16.87 mg/kg, available phosphorus 7.13 mg/kg, available potassium 193.41 mg/kg, organic matter 25.8 g/kg, field water-holding capacity 26.1%, and soil bulk density 1.52 g/cm^3.

Experimental design

The experiment adopted randomized block design, including seven treatments: low-concentration inorganic fertilizer (T_1), medium-concentration inorganic fertilizer (T_2), high-concentration inorganic fertilizer (T_3), low-concentration inorganic fertilizer + low-concentration bio-organic fertilizer (T_4), low-concentration inorganic fertilizer + medium-concentration bio-organic fertilizer (T_5), low-concentration inorganic fertilizer + high-concentration bio-organic fertilizer (T_6) and no fertilization (CK). Table 1 shows the fertilizing amounts of various treatments. All fertilizers were applied in a mode of topdressing with water throughout the entire growth period, once every 15, for a total of five times. Each treatment was set with three replicates, and the plot area was 36 m^2. The seedlings were planted in double rows with a plant spacing of 30 cm and a row spacing of 40 cm in one ridge. Two moistubes were arranged in a ridge, with a buried depth of 15 cm, and the pressure head was 1.5 – 1.8 m. During the growth period of cucumber, other field management was carried out by special personnel, and controlled strictly to ensure the accuracy and effectiveness of the experimental data.

Table 1 Fertilization amounts for different fertilization treatments

kg/hm^2

Treatment	N	P_2O_5	K_2O	Bio-organic fertilizer
CK	0	0	0	0
T_1	180	90	270	0
T_2	360	180	540	0
T_3	540	270	810	0
T_4	180	90	270	400
T_5	180	90	270	650
T_6	180	90	270	900

Experimental materials

The used bio-organic fertilizer was Shidijia water-soluble bio-organic fertilizer (effective living bacteria count ≥ 200 million/g, organic matter ≥40%, amino acid ≥10%, fulvic acid ≥5%). The used inorganic fertilizer was Guoguang potassium dihydrogen phosphate (water-soluble phosphorus pentoxide ≥51%, potassium oxide ≥33.8%), fully water-soluble agricultural potassium sulfate (potassium oxide ≥52%) and urea (N≥46%). Guoguang potassium dihydrogen phosphate and fully water-soluble agricultural potassium sulfate both contain potassium oxide. The application amount of Guoguang potassium dihydrogen phosphate was calculated by the amount of phosphorus pentoxide, and then the content of potassium oxide in Guoguang potassium dihydrogen phosphate was subtracted from the amount of potassium oxide, so as to calculate the amount of fully water-soluble agricultural potassium sulfate.

Experimental indexed and determination methods

The mixed soil samples of the 0 – 20, 20 – 40 and 40 – 60 cm soil layers were taken every 15 d according to the "S" curve. The collected soil was reduced to 2 kg according to the "quartering method", and the contents of available phosphorus, available potassium and nitrate nitrogen in each soil layer were determined after air drying, grinding and sieving. Available phosphorus was determined by the sodium bicarbonate leaching-molybdenum antimony colorimetric method. Available potassium was determined by the flame photometer method. Nitrate nitrogen was determined by the ultraviolet spectrophotometer method[9].

From the beginning to the end of the melon period, six representative cucumber plants were selected as markers in the plots of various cucumber treatments for the determination of cumulative weight of fresh cucumbers. The yield was converted according to the planting area.

During the peak melon season, 5 – 6 pieces of fruit with similar maturity were randomly selected from the plants marked in each plot to determine fruit quality. The content of vitamin C was determined by 2,6-dichloroindophenol method. Soluble sugar content was determined by anthrone colorimetry. Soluble protein content was determined by Coomassie brilliant blue method. Nitrate content was determined by ultraviolet spectrophotometry[10].

The partial factor productivity (PFP, kg/kg) of nitrogen (phosphorus, potassium) fertilizer was calculated according to following formula:

$$PFP = Y/F_T \quad (1)$$

In the formula, Y is crop yield, kg/hm^2; and F_T is the total input of N, P_2O_5 and K_2O, kg/hm^2.

The agronomy fertilizer use efficiency (AFUE, kg/kg) of nitrogen (phosphorus, potassium) fertilizer was calculated according to following formula:

$$AFUE = (Y - Y_0)/F_T \quad (2)$$

In the formula, Y_0 is the yield of the non-fertilization treatment, kg/hm^2.

Data processing

Microsoft Excel 2019 was employed to process the data. Origin2021 was adopted to draw relevant charts. SPSS 27.0 software (*LSD*) was used to test the significance, and the significance level was 0.05.

Results and Analysis

Effects of different fertilization modes on temporal and spatial distribution of nitrate nitrogen in root zone soil of cucumber

Fig. 1 shows the dynamic change curve of nitrate nitrogen content with time in different soil layers under different fertilization modes. Nitrate nitrogen is a kind of soil available nutrient, which can be directly absorbed and utilized by cucumber plants. As shown in Fig. 1(a) and Fig. 1(b), the content of nitrate nitrogen showed a trend of increasing first and then decreasing with the passage of time in the 0 – 20 and 20 – 40 cm soil layers. The dynamic changes of nitrate nitrogen content in the 0 – 20 and 20 – 40 cm soil layers were closely related to the growth and development of cucumber plants. Cucumber plants grew slowly in the early stage of growth, and the demand for nitrate nitrogen was less, so nitrate nitrogen gradually accumulated in the soil. The peak values of nitrate nitrogen content in the 0 – 20 and 20 – 40 cm soil layers both appeared at day 45. The content of nitrate nitrogen in the soil layer of 0 – 20 cm showed an order of T_3, T_6, T_2, T_5, T_4 and T_1 from large to small on day 45. There was no significant difference between treatments T_2 and T_5. Compared with treatment T_1, the values of treatments T_4, T_5 and T_6 with combined application of bio-organic fertilizer and low-concentration inorganic fertilizer increased by 9.6%, 22.92% and 35.97% respectively. The content of nitrate nitrogen in the soil layer of 20 – 40 cm showed an order of T_3, T_2, T_6, T_5, T_4 and T_1 from large to small on day 45, and the values of treatments T_4, T_5 and T_6 with combined application of bio-organic fertilizer and low-concentration inorganic fertilizer increased by 4.3%, 13.32% and 20.62% respectively, compared with treatment T_1. The contents of nitrate nitrogen in the 0 – 20 and 20 – 40 cm soil layers on day 90 were lower than those on day 15 except treatment T_3. From Fig. 1(c), it can be seen that the nitrate content in the 40 – 60 cm soil layer was less affected by the growth and development of cucumber plants, and the nitrate content in treatment T_3 showed a cumulative trend, while the nitrate contents in T_1, T_2, T_4, T_5 and T_6 showed a downward trend.

Effects of different fertilization modes on temporal and spatial distribution of soil available phosphorus in root zone soil of cucumber

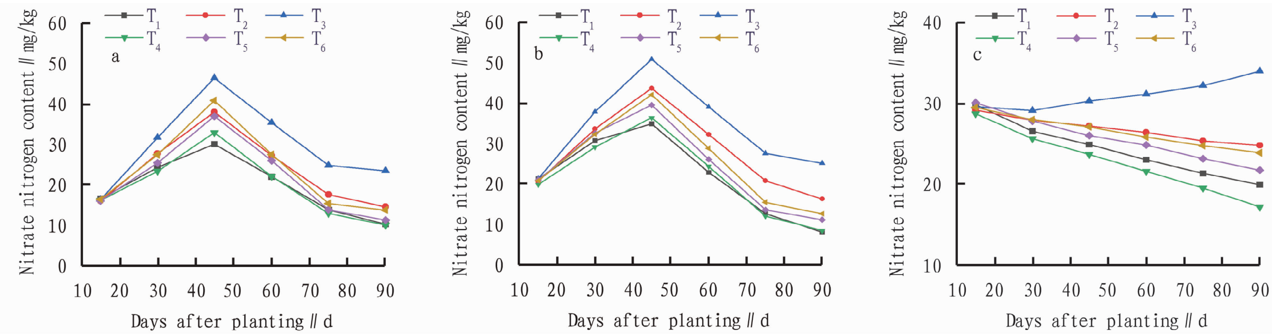
Fig. 2 shows the dynamic change curve of available phosphorus content with time in different soil layers under different fertilization modes. Available phosphorus is easily fixed by soil, and cannot move with water easily. It can be seen from Fig. 2 that available phosphorus in the soil was mainly distributed in the 0 – 40 cm soil layer, and the content of available phosphorus in the 40 – 60 cm soil layer was less affected by the growth and development of cucumber plants and fertilization patterns. It can be seen from Fig. 2(a) and Fig. 2(b) that the content of available phosphorus showed a trend of decreasing first and then increasing with time in the soil layers of 0 – 20 and 20 – 40 cm. Compared with the available phosphorus content in the soil layer of 0 – 20 cm on day 15, the available phosphorus content on day 45 decreased by 12.42% in treatment T_1 and 7.3% in treatment T_2, increased by 4.2% in treatment T_3, and decreased by 19.94% in treatment T_4, 22.09% in treatment T_5 and 13.27% in treatment T_6. Compared with the available phosphorus content in the soil layer of 0 – 20 cm on day 45, the available phosphorus content on day 90 increased by 31.56% in treatment T_1, 58.03% in treatment T_2, 50.08% in treatment T_3, 40.78% in treatment T_4, 48.51% in treatment T_5 and 60.8% in treatment T_6. The available phosphorus content in the soil layer of 20 – 40 cm on day 45 showed an order of T_3, T_2, T_6, T_1, T_5 and T_4 from large to small, and that on day 75 exhibited an order of T_3, T_6, T_2, T_5, T_1 and T_4 from large to small.

Effects of different fertilization modes on temporal and spatial distribution of soil available potassium in root zone soil of cucumber

Fig. 3 shows the dynamic change curve of available potassium content with time under different fertilization modes in different soil layers. Available potassium moves easily with water in soil, and the demand of cucumber for available potassium is relatively large, and it needs to absorb a lot of available potassium throughout the growth period. From Fig. 3(a) and Fig. 3(b), it can be seen that the available potassium contents in the 0 – 20 and 20 – 40 cm soil layers on day 90 were lower than those on day 15. The available potassium content in the 0 – 20 soil layer on day 90 showed an order of T_3, T_6, T_2, T_5, T_4 and T_1 from large to small. The available potassium content in the 20 – 40 soil layer on day 90 exhibited an order of T_3, T_2, T_6, T_1, T_5 and T_4 from large to small. From Fig. 3(c), it can be seen that the content of available potassium in the 40 – 60 cm soil layer first decreased and then increased, and available potassium gradually accumulated in the soil after 30 d. Compared with the content of available potassium on day 15, the content of available potassium on day 90 was basically unchanged in treatment T_1, and showed an increase of 32.73% in treatment T_2, an increase of 61.47% in treatment T_3, a decreased of 16.22% in treatment T_4, an increase of 8.3% in treatment T_5 and an increase of 20.56% in treatment T_6.

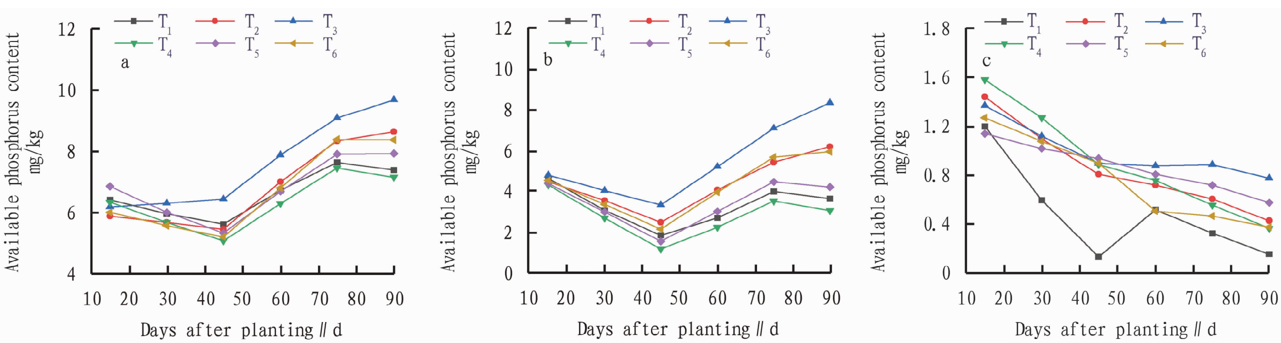
Effects of different fertilization modes on cucumber yield

Table 2 shows the effects of different fertilization modes on cucumber yield, and fertilizer partial factor productivity and agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) fertilizer. Fertilization modes had a significant effect on the yield of facility cucumber. Compared with the yield of CK without fertilization, the yields of T_1, T_2, T_3, T_4, T_5 and T_6 increased by 27.51%, 66.78%, 71.06%, 41.94%, 60.35% and 69.27% respectively. Compared with treatment T_1, the yields of treatments T_4, T_5 and T_6 increased by 11.31%, 25.75% and 32.75% respectively. It can be seen from Table 2 that the partial factor productivity of nitrogen (phosphorus, potassium) fertilizer in treatments T_1, T_2 and T_3 with only inorganic fertilizer decreased with the increase of fertilizing amount. There was no significant difference in partial factor productivity of nitrogen between treatments T_5 and T_6, and between treatments T_1 and T_4, and the nitrogen partial factor productivity of treatment T_5 was the highest, at 309.38 kg/kg. There was no significant difference in partial factor productivity of phosphorus fertilizer between treatments T_4 and T_5, and the partial factor productivity of phosphorus fertilizer in various treatments ranked as T_1, T_5, T_4, T_6, T_2 and T_3 from large to small. Treatment T_5 and T_6 had no significant difference in partial factor productivity of potassium fertilizer, and treatment T_6 showed that highest value of 220.33 kg/kg. It can be seen from Table 2 that the agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) fertilizer in treatments T_4, T_5 and T_6 combining inorganic fertilizer and bio-organic fertilizer was significantly higher than that in T_1, treatments T_2 and T_3 applying inorganic fertilizer alone.



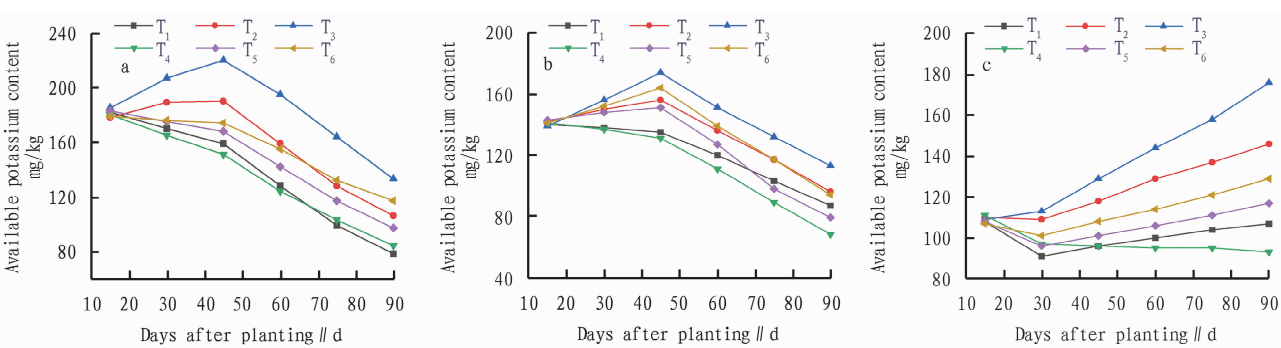
a. Nitrate nitrogen content of the 0 – 20 cm soil layer; b. Nitrate nitrogen content of the 20 – 40 cm soil layer; c. Nitrate nitrogen content of the 40 – 60 cm soil layer.

Fig. 1 Nitrate nitrogen content in soil under different fertilization modes



a. Available phosphorus content of the 0 – 20 cm soil layer; b. Available phosphorus content of the 20 – 40 cm soil layer; c. Available phosphorus content of the 40 – 60 cm soil layer.

Fig. 2 Soil available phosphorus content under different fertilization modes



a. Available potassium content of the 0 – 20 cm soil layer; b. Available potassium content of the 20 – 40 cm soil layer; c. Available potassium content of the 40 – 60 cm soil layer.

Fig. 3 Soil available potassium content under different fertilization modes

Table 2 Cucumber yield and partial factor productivity and agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) under different fertilization modes

Treatment	Yield // kg/hm^2	PFPN // kg/kg	PFPP // kg/kg	PFPK // kg/kg	AFUEN // kg/kg	AFUEP // kg/kg	AFUEK // kg/kg
CK	41 001.89 ± 716.81 f	–	–	–	–	–	–
T_1	52 282.20 ± 634.37 e	290.46 ± 3.52 b	580.91 ± 7.05 a	193.64 ± 2.35 c	62.67 ± 3.52 e	125.34 ± 7.05 c	41.78 ± 2.35 e
T_2	68 384.10 ± 676.45 b	189.96 ± 1.88 c	379.91 ± 3.76 d	126.64 ± 1.25 d	76.06 ± 1.88 d	152.12 ± 3.76 b	50.71 ± 1.25 d
T_3	70 136.87 ± 621.58 a	129.88 ± 1.15 d	259.77 ± 2.30 f	86.59 ± 0.77 e	53.95 ± 1.15 f	107.91 ± 2.30 d	35.97 ± 0.77 f
T_4	58 196.06 ± 749.46 d	290.98 ± 3.75 b	529.06 ± 6.81 b	200.67 ± 2.58 b	85.97 ± 3.75 c	156.31 ± 6.81 b	59.29 ± 2.58 c
T_5	65 746.57 ± 446.15 c	309.39 ± 2.10 a	536.71 ± 3.64 b	217.35 ± 1.48 a	116.44 ± 2.10 b	202.00 ± 3.64 a	81.80 ± 1.48 b
T_6	69 405.01 ± 716.81 ab	308.46 ± 4.10 a	514.11 ± 6.84 c	220.33 ± 2.93 a	126.23 ± 4.10 a	210.39 ± 6.84 a	90.17 ± 2.93 a

Effects of different fertilization mode on quality of cucumber

It can be seen from Table 3 that the contents of vitamin C, soluble sugar and soluble protein in cucumber fruit of treatment T_6 were higher than those of other treatments, and the values were 13.37 mg/100 g, 1.45% and 2.65 mg/g respectively. Treatment T_3 showed highest nitrate content, reaching 81.27 mg/kg.

Compared with treatment T_1, the vitamin C contents of treatments T_4, T_5 and T_6 combining bio-organic fertilizer and inorganic fertilizer increased by 4.45%, 12.47% and 19.06%, respectively, and their soluble sugar contents increased by 6.84%, 17.09% and 23.93%, respectively, and their soluble protein contents increased by 2.61%, 10% and 15.22, respectively. The nitrate contents of various treatments showed an order of T_3, T_2, T_6, T_5, T_4 and T_1 from high to low. The nitrate content increased with the fertilizing amount increasing, whether it was single application of organic fertilizer or combined application of bio-organic fertilizer and inorganic fertilizer.

Table 3 Cucumber quality under different fertilization modes

Treatment	V_C content//mg/100g	Soluble sugar//%	Soluble protein//mg/g	Nitrate//mg/kg
CK	10.31 ±0.20 f	0.93 ±0.05 d	2.00 ±0.15 d	43.38 ±2.34 f
T_1	11.23 ±0.06 e	1.17 ±0.04 c	2.30 ±0.04 c	58.69 ±2.00 d
T_2	13.16 ±0.20 a	1.41 ±0.03 ab	2.61 ±0.05 ab	73.04 ±1.44 b
T_3	12.20 ±0.14 c	1.36 ±0.07 b	2.55 ±0.03 ab	81.27 ±1.17 a
T_4	11.73 ±0.36 d	1.25 ±0.06 c	2.36 ±0.05 c	55.04 ±1.10 e
T_5	12.63 ±0.23 b	1.37 ±0.05 ab	2.53 ±0.02 b	60.01 ±0.87 d
T_6	13.37 ±0.32 a	1.45 ±0.03 a	2.65 ±0.03 a	68.29 ±0.78 c

Conclusions and Discussion

With the goal of high yield and high quality of greenhouse cucumber and based on protecting the ecological environment, in this study, we systematically analyzed the temporal and spatial distribution characteristics of soil available nutrients (nitrate nitrogen, available phosphorus and available potassium) in the whole growth period of cucumber in facilities with moistube irrigation under different fertilization modes, and cucumber yield, partial factor productivity and agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) fertilizer in facilities with moistube irrigation, as well as the response characteristics of cucumber quality to different fertilization modes. The results showed that the application of inorganic fertilizer combined with bio-organic fertilizer could not only obtain high yield of cucumber, but also reduce the accumulation and leaching of available nutrients in soil, which is similar to the research results of Liu *et al.*[11]. The contents of available nutrients in the soil of treatments T_4, T_5 and T_6 with more bio-organic fertilizer and less inorganic fertilizer increased with the concentration of bio-organic fertilizer increasing, and compared with treatment T_1 (low-concentration organic fertilizer), available nutrients in the soil increased significantly, which is basically consistent with the research results of Ma *et al.*[12]. In terms of fruit quality, compared with treatment T_1 (low-concentration inorganic fertilizer), treatments adding bio-organic fertilizer could significantly increase the content of vitamin C and soluble sugar in cucumbers, which is basically consistent with the research results of Li *et al.*[13]. In terms of fertilizer utilization, the partial factor productivity of nitrogen (phosphorus, potassium) fertilizer decreased with the fertilizer application rate increasing in treatments applying inorganic fertilizer alone, which is basically consistent with Ma Xinchao's research results[14]. Meanwhile, it was found in this study that the partial factor productivity of nitrogen (potassium) fertilizer and agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) fertilizer could be significantly improved after adding bio-organic fertilizer, but the partial factor productivity of phosphorus fertilizer significantly decreased in treatments T_4, T_5 and T_6 adding bio-organic fertilizer, compared with treatment T_1 (low-concentration inorganic fertilizer), which might be because cucumber plants have less demand for phosphorus fertilizer. Based on the spatial and temporal distribution of available nutrients and cucumber yield and quality, it was found in this study that for treatments applying inorganic fertilizer alone, the yield and quality of cucumber were significantly improved with the increase of available nutrients in the topsoil (0 – 40 cm), and nitrate content was also significantly improved. For treatments adding bio-organic fertilizer while reducing inorganic fertilizer, the yield and quality of cucumber were significantly improved with available nutrients increasing in the topsoil (0 – 40 cm), and nitrate content was also significantly improved. However, no such rule was observed when comparing treatments applying inorganic fertilizer alone with treatments adding the application of bio-organic fertilizer while decreasing the application of inorganic fertilizer. The reason might be that bio-organic fertilizer contained a large number of microorganisms, which promoted the absorption and utilization of nutrients by plants[15].

Under the moistube irrigation mode, the application of soluble bio-organic fertilizer combined with inorganic fertilizer could significantly increase the content of available nutrients in the 0 – 40 cm soil available for cucumber utilization, and promote the absorption of available nutrients by cucumber plants. It reduced the contents of nitrate nitrogen and available potassium in the soil layer of 40 – 60 cm, but had no significant effect on the content of available phosphorus in the soil layer of 40 – 60 cm.

Compared with the CK treatment, all treatments promoted the increase in cucumber yield. Considering the yield and quality of cucumber fruit, treatment T_6 (low-concentration inorganic fertilizer + high-concentration bio-organic fertilizer) was the most suitable fertilization mode for cucumber planting in facilities with moistube irrigation. Compared with the CK treatment, cucumber yield, vitamin C content, soluble sugar content and soluble protein content of treatment T_6 increased by 69.27%, 29.68%, 55.91% and 32.5%, respectively. Compared with treatment T_3 (high-concentration inorganic fertilizer), treatment T_6 showed no significant difference in yield, but its nitrate content decreased by 15.97%.

Treatment T_6 (low-concentration inorganic fertilizer + high-concentration bio-organic fertilizer) showed significantly-improved partial factor productivity and agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) fertilizer compared with treatment T_3 (high-concentration inorganic fertilizer). Compared with treatment T_1 (low-concentration inorganic fertilizer), the partial factor productivity of nitrogen and potassium fertilizers increased by 6.2% and 13.78%, respectively, while that of phosphate fertilizer decreased by 11.5%. Meanwhile, the agronomy fertilizer use efficiency of nitrogen (phosphorus, potassium) fertilizer was significantly improved.

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