

Research Article

Effect of Various Nitrogen Fertilizers and Their Levels on Big-Arch Shelter Cucumber Yield and Water Use Efficiency

¹Zhaopeng Ou Yang, ²Xurong Mei, ²Yuzhong Li and ¹Jiaxuan Guo

¹Beijing Key Laboratory of New Technology in Agricultural Application, College of Plant and Technology, Beijing University of Agriculture, Beijing 102206, P.R. China

²Water Resources and Dryland Farming Laboratory, Institute of Agricultural Environment and Sustainable Development, Chinese Academy of Agricultural Sciences, Beijing 100081, P.R. China

Abstract: Vegetables are mainly cultivated through facility in early spring and late autumn in Northern of China. In the case of a serious shortage of water resources, water use efficiency of greenhouse vegetable is of an important scientific significance in both water and fertilizer management. On the basis of pan Evaporation (Ep) and real-time monitoring of soil moisture content, the amount of water irrigation adequate to big-arch shelter cucumber growth, water dissipation, yield and water use efficiency were determined through the combination of three nitrogen fertilizers including urea, urea containing nitrification inhibitors (5:1 with urea and nitrification inhibitor) and coated urea (slow fertilizer) and their various levels with 0 kg/ha, 350 kg/ha, 550 kg/ha, 750 kg/ha. The results showed that the most 10,9000 kg/ha production was gained by the treatment of 550 kg/ha urea containing inhibitors, which could increase 41.5% of a yield, 15.2% of a cumulative water consumption that was at 462.0mm and 44.7% of a water use efficiency that is at 14.11kg (dry matter)/(mm• ha), compared with that of control, respectively. In conclusion, the present study demonstrates that the application of moderate levels of urea containing nitrification inhibitor in greenhouse cucumber can gain higher yields and water use efficiency.

Keywords: Big-arch cucumber, nitrogen fertilizers, pan evaporation, water use efficiency

INTRODUCTION

In the production of vegetable with shallow root, high fertilizer application and inefficient irrigation is the pattern in current farming practice, but can cause high environmental risk (Guo *et al.*, 2008). Therefore, water and fertilizer management in vegetable production is vital to the protection of the agricultural environment. Currently, the absolute amount of horticultural facilities area in China is the largest in the world (Zhou and Wang, 2010), horticultural facilities is mainly for vegetable cultivation, throughout China, there are 3.347 million hectares of facilities vegetables, 57.2% of facilities vegetables are cultivated in northern China (in the Bohai and the Huang-Huai-Hai area) with growing shortage of water resources (Zhang *et al.*, 2010a), cucumber is a favorite of facilities vegetables. However, the current problem with large scale cultivation of cucumber is that unreasonable water and fertilizer management system (high fertilizer application and inefficient irrigation) not only caused unnecessary waste of water and fertilizer resources, but also led to shallow groundwater nitrate pollution and other environmental problems (Zhang *et al.*, 2010b).

Development of water and fertilizer management technology that improve water use efficiency is the key to guarantee sustainable cultivation of facilities vegetable. In the field of water and fertilizer management, based on the concept of "fertilizer coupled irrigation", domestic and foreign researchers studied the effect of different irrigation volume (Wang and Zhang, 2002; Chang and Zhou, 2007; Wei *et al.*, 2010; Song *et al.*, 2010; Mao *et al.*, 2003; Sun *et al.*, 2008), different fertilization level (Cao *et al.*, 2010) and fertilizer coupled irrigation (Li *et al.*, 2010; Zhang *et al.*, 2011; Harsharn *et al.*, 2011; Ahmet *et al.*, 2006) on cucumber physiological, yield and water uses efficiency, based on these studies, they proposed water management scheme for cucumber cultivation (Wang *et al.*, 2009; Mehmet *et al.*, 2005). Research indicates that, single factor of either fertilizer application or irrigation has significant effect on water uses efficiency, of which, nitrogen fertilizer application has positive effect on water use efficiency. However, there are relatively few studies of different fertilizer types on the yield and water use efficiency of cucumber. Therefore, in this study of greenhouse cucumber cultivation, under adequate water supply, we explore the effect of

Corresponding Author: Jiaxuan Guo, Beijing Key Laboratory of New Technology in Agricultural Application, College of Plant and Technology, Beijing University of Agriculture, Beijing 102206, P.R. China

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different nitrogen fertilizer types and different nitrogen amount on water dissipation and water use efficiency, our purpose is to provide a theoretical basis for water and fertilizer management in greenhouse cucumber cultivation.

MATERIALS AND METHODS

Overview of test site. The field study was carried out in the onsite base of North Agricultural Science and Technology Park in Beijing Agricultural University. The station is located at the northern edge of the North China Plain (116°18'12 .5 "E, 40°05'28 .1" N; average altitude of 31.3 m), belongs to the continental monsoon warm temperate semi-humid climate, average annual rainfall of 616 mm, rich in light and temperature resources, the average temperature for many years is 11.9°C, total of annual sunshine hours is 2714 h, the frost-free period is 200~203 d. Soil texture is moist soil, composition as follows: soil organic matter 17.55 g/kg, total nitrogen 1.08 g/kg, alkaline hydrolysis nitrogen 100.18 mg/kg and available phosphorus 27.33 mg/kg, available potassium 150.88 mg/kg.

Test materials and design. Test was conducted during cucumber whole growth period from May 2, 2010 to July 28, 2010 (DOY122-208). The tested cucumber variety is Zhongnong 16, the planting density is 42,000 plants/ha, seedlings were grown on March 16, 2010 (DOY88) and transplanted on May 2. Test design set up three fertilizer types: urea, urea+nitrification inhibitor, slow-release fertilizer, of which, the ratio of urea and nitrification inhibitor is 5:1; three nitrogen levels are set up for each fertilizer type: 350 kg/hm², 550 kg/hm², 750 kg/hm², there is a blank control plot; each treatment has three replicate plots, there are a total of 30 plots arranged in accordance with the orthogonal design. Except for the blank control plot, the test plots are treated with organic fertilizer 7500 kg/hm², phosphate fertilizer (P2O5) 100 kg/hm², potash (K2O) 270 kg/hm²; the method of fertilizer application is as follows: base fertilizer consist of 170 kg (K2O)/hm² potash, all organic fertilizer and phosphate fertilizer, 150 kg/hm² nitrogen fertilizer (in the case of slow-release nitrogen fertilizer, no matter what the treatment levels are, the fertilizer was applied as base fertilizer); top dressing consist of the remaining nitrogen and potash fertilizer. Based on the daily cumulative evaporation data measured by 20 cm diameter water evaporating dish and real-time monitoring of soil moisture content, the amount of full complement irrigation throughout the growing period is determined to be 275 mm of irrigation water.

Methodology: Greenhouse cucumber evapotranspiration. Greenhouse cucumber evapotranspiration estimation is based on soil water balance principle Eq. (1):

$$ET = I + \Delta W - R \quad (1)$$

In the Equation, during a certain time period, ET is the total amount of evapotranspiration (mm), I is the total amount of irrigation (mm), R is the total amount of surface runoff (mm), ΔW is soil moisture variation (mm), that is, the difference of soil moisture content from the start to the end of a certain time period. In greenhouse fertility, during cucumber growth period, there is no surface irrigation water runoff problem, thus that part of the effect is ignored in the estimation of cucumber water consumption.

Measurement of indicators: In greenhouses cucumber vegetable plot, every 5 days, TDR Time Domain Reflectometer (TRIME-FM3, IMKO) was used to measure soil moisture content in different depth of soil layers: 10 cm, 20 cm, 40 cm, 60 cm, 80 cm, 100 cm, 120 cm, 140 cm, 160 cm and the time domain reflectometry measurements were calibrated by drying method; at the same time, soil moisture tester (EM50, Decon) was used to automatically records 30 min average of soil volumetric water content in different depth of soil layers: 5 cm, 10 cm, 20 cm, 40 cm, 60 cm. ADM7A type evaporator and evaporating dish was placed at position of 70 cm height, water surface evaporation is measured daily at 20:00; dry bulb thermometer was used daily at 14:00 for the determination of air temperature at 1.5 m height, central of the greenhouses; curved pipe geo temperature table was used daily at 8:00,14:00 20:00 for the determination of ground temperature in the soil depth of 10 cm, 15 cm and 20 cm; cucumber yield indicators were measured, sampling method according to reference "agricultural meteorological observation method" (Yao *et al*, 1995).

RESULTS AND DISCUSSION

Water surface evaporation and temperature variations in the greenhouse. In greenhouse fertility, for spring crop of cucumber, during growth period, soil water evaporation is significantly influenced by the external environment changes (Fig. 1b). The trend of daily evaporation variation is that of gradual increase and is consistent with the trend of daily 14:00 air temperature variation inside the greenhouse (Fig. 1a), during cucumber growth period, average daily water surface evaporation is 4.5±1.3 mm, variation is in the range of 1.6~6.8 mm, the cumulative evaporation is 370.7 mm (1-c). During cucumber growth period, at the height of 1.5 m in central of the greenhouses air greenhouses, average air temperature at 14:00 is 32.8 ± 5.5°C, variation is in the range of 20.4~42.6°C; for soil temperature at the depth of 5 cm, 10 cm, 15 cm, 20 cm, during the whole growth period, the trend of temperature variation is that of gradual increase, from

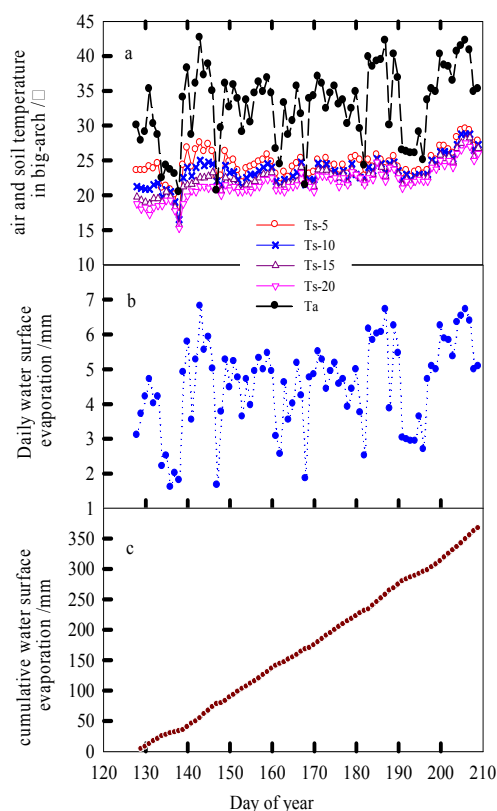


Fig. 1: Diurnal variation of pan evaporation and air temperature in big-arch shelter during cucumber growth period

seedling transplantation to early fruit, the temperature difference of different soil depth is more significant, from early fruit period onwards, with the rapid growth of cucumber, as the canopy cover increases, the temperature difference of different soil depth is less significant, maximum variation (17.3~29.5°C) is for soil temperature at the depth of 5 cm, minimum variation (15.3~27.5°C) is for soil temperature at the depth of 20 cm; at the two depth of soil layers, both the average daily minimum temperature and average daily maximum temperature differ about 2°C (Fig. 1a).

Effect of different nitrogen fertilizer type and nitrogen application levels on cucumber yield. Nitrogen fertilizer can significantly increase the yield of cucumber, but different nitrogen fertilizer types and nitrogen application levels have different effect on yield of cucumber. At low nitrogen application level (350 kg/hm²), the rapid release fertilizer type caused the highest yield of cucumber (9.8×10⁵ kg/hm²), increased 27.3% as compared with the blank control plot; the slow release fertilizer type caused the lowest yield of cucumber (8.3×10⁵ kg/hm²), increased 7.8% as compared with the blank control plot. At higher

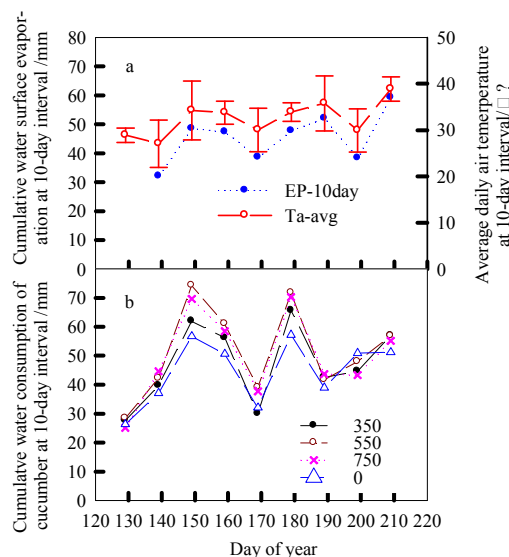


Fig. 2: Variation of water consumption of cucumber under different nitrate level and pan evaporation and air temperature at 10 days period in big-arch shelter

nitrogen application level (550 kg/hm²), the fertilizer type with nitrification inhibitors caused the highest yield of cucumber (10.9×10⁵ kg/hm²), increased 41.5% as compared with the blank control plot, the slow release fertilizer type caused lowest yield of cucumber. At the highest nitrogen application level (750 kg/hm²), as compared with the lower nitrogen application levels (350 kg/hm², 550 kg/hm²), the slow release fertilizer type caused increased yield of cucumber, whereas the other two fertilizer types (urea and urea with nitrification inhibitors) caused decreased yield of cucumber.

Effect of nitrogen fertilizer types and nitrogen application levels on cucumber water dissipation and water use efficiency. In greenhouse fertility, during growth period, under adequate water supply (non-stress condition), the dynamic trends of cucumber water dissipation is affected by cucumber growth status combined with environmental factors inside the greenhouse. As shown in Fig. 2, at the time scale of ten days, under different nitrogen application levels, the dynamic trends of cucumber water dissipation is consistent with the trends of average air temperature variation and cumulative surface water evaporation within the same ten days; in the first 20 days after seedling transplantation, the canopy cover is low, soil evaporation account for the majority of water dissipation, there is no significant difference in total water dissipation among the three different nitrogen application levels; from 20-30 days after seedling transplantation to early July, cucumber grow rapidly, plant transpiration account for the majority of water dissipation, there is significant difference in total water

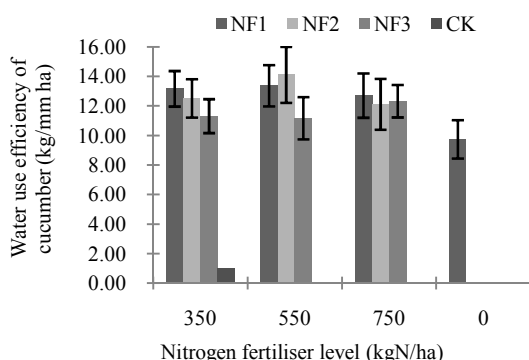


Fig. 3: Different effects of nitrogen fertilizer and fertilization effectson water use efficiency of greenhouse cucumber system

dissipation among the three different nitrogen application levels, water dissipation is the highest at the 550 kg/hm² nitrogen application level, water dissipation is the second highest at the 750 kg/hm² nitrogen application levels; from mid-July to harvest, cucumber grow slowly, and senescence of cucumber leaf result in decreased transpiration, there is no significant difference in total water dissipation among the three different nitrogen application levels. In greenhouse fertility, for spring crop of cucumber, during the whole growth period, at the 350 kg/hm², 550 kg/hm², 750 kg/hm² nitrogen application level, cucumber water consumption is 441 mm, 448 mm, 401 mm respectively. Generally speaking, the air temperature is the major environmental factors affecting the trend of water consumption during cucumber growth period, whereas both low (350 kg/hm²) and high (750 kg/hm²) nitrogen application level can only cause relatively low improvement in cucumber yield and total biomass, resulting in decreased plant transpiration at the two nitrogen application levels.

Different nitrogen fertilizer type and different nitrogen application level have different effect on cucumber water use efficiency. As shown in Fig. 3, at 550 kg/hm² nitrogen application level, the highest cucumber yield water use efficiency (14.11 kg/(mm hm²), dry weight) occurs under urea+nitrification inhibitor treatment, increased 44.7% as compared with the blank control plot, whereas the lowest water use efficiency (11.17 kg/(mm hm²)) occurs under slow release fertilizer. In general, different nitrogen application levels significantly affected cucumber yield and water consumption.

(NF1 means urea, NF2 means urea containing nitrification inhibitor, NF3 means coated urea, CK means no nitrogen fertilizer).

DISCUSSION AND CONCLUSION

Under adequate water supply (non-stress condition), we conducted field experiments to study the effect of different nitrogen fertilizer types and different nitrogen application levels on greenhouse cucumber yield and water use efficiency. Different nitrogen fertilizer types and different nitrogen application levels have different effect on cucumber yield, water dissipation, water use efficiency, our result indicate that the fertilizer type (the ratio of urea to nitrification inhibitor is 5:1) combined with the moderate nitrogen application level (550 kg/hm²) can significantly improve cucumber yield and water use efficiency.

Water and fertilizer management is important to cucumber yield and water use efficiency, facility factors such as different growth stages, irrigation method and frequency, nitrogen application levels etc, all have different effect on cucumber water use efficiency. The study showed the effect of different nitrogen levels on the greenhouse cucumber water consumption, our result indicate that the moderate nitrogen application level (550 kg/hm²) combined with the fertilizer type (the ratio of urea to nitrification inhibitor is 5:1) can significantly improve cucumber yield, water consumption and water use efficiency, the reason is that different nitrogen application levels have different effects on plant growth, cucumber yield and canopy cover, resulting in different rate of soil evaporation and plant transpiration strength. In sunlight greenhouse, from full fruit period to harvest, water use efficiency decrease as irrigation volume increase (Mao *et al.*, 2003); although high irrigation according to the Ep ratio of 1 combined with 600 kg/hm² nitrogen application level improved cucumber yields, water use efficiency is decreased, therefore, optimal program of water and fertilizer management in solar greenhouse is 0.8 Ep underground drip irrigation combined with 450–600 kg/hm² nitrogen application level (Zhang *et al.*, 2011). The best result of cultivation as well as the highest efficiency of water and nitrogen use can be achieved when the irrigation volume was 300 m³/(hm² • times), combined with 240 kg/hm² nitrogen application level for winter and spring crop, 50 kg/hm² nitrogen application level for autumn and winter crop (Gao *et al.*, 2010); In the open field, cucumber irrigation management should be 3 day irrigation cycle and supplemental irrigation volume determined according to the Ep ratio of 1, as well as timely irrigation whenever the CWSI (Crop water stress index) reached the critical value of 0.2 (Mehmet *et al.*, 2005); For Solar greenhouse located in arid and semi-arid area, irrigation should be carried out according to 0.8 Ep

combined with 4 d or 8 d irrigation cycle (Wang and Zhang, 2009), because high fertilizer application and inefficient irrigation is the norm in current farming practice, we should take the measure of reducing irrigation volume by 30%, reducing nitrogen application level by 25%~50%, we can not only maintain optimal features of cucumber growth and improve leaf water use efficiency, but also maintain cucumber yield and improve fruit quality (Li *et al.*, 2010). In cucumber cultivation, because water dissipative strength correlate not only with vegetable growth period, but also with many aspects of irrigation and fertilization management such as irrigation methods and irrigation frequency, facilities and environmental factors, we should put our effort on developing better model and method for estimation of irrigation water demand, we also should put our effort on developing system for accurate quantification of vegetable water dissipation, in order to provide theoretical basis scientific irrigation management of facilities vegetables.

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