

Study on greenhouse soil nitrogen absorption and soil layer transport of different summer catch crops with different planting density in North China

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Abstract. In order to improve the utilization rate of nitrogen fertilizer and reduce the environmental pollution risk of the nitrogen accumulation in the vegetable field, this study was carried out in the summer leisure period of the greenhouse vegetable production. This experiment designed different planting density treatments in 2017 and 2018, i.e. for catch waxy corn, 3300 plants/667m² (WCD1), 5000 plants/667m² (WCD2), 6600 plants/667m² (WCD3), for forage sweet sorghum, 4500 plants/667m² (FSS4), 7000 plants/667m² (FSS5), 9000 plants/667m² (FSS6) in 2017; and for catch waxy corn, 4500 plants/667m² (WCDI), 7000 plants/667m² (WCDII), 9000 plants/667m² (WCDIII), for forage sweet sorghum, 7000 plants/667m² (FSSIV), 10000 plants/667m² (FSSV), 14000 plants/667m² (FSSVI) in 2018. The results showed that the biomass and nitrogen absorption of the two catch crops began to improve and then decreased with the increase of planting density. The nitrogen absorption amount of the catch waxy corn and forage sweet sorghum was 22.36~28.68 kg/667m², 21.67~24.39 kg/667m², respectively. Different planting density of catch waxy corn and forage sweet sorghum could significantly reduce the total nitrogen content of 0~30cm soil layer and the nitrate nitrogen content of 0~90cm soil layer, for catch waxy corn and forage sweet sorghum, the reduction rate of total nitrogen content in 0~30cm soil layer was 9.6%~27.0%, 5.7%~23.5%, the reduction rate of nitrate nitrogen content reached 50.0%~90.8%, 80.1%~96.4%, respectively, which effectively controlled the nitrate nitrogen leaching to soil deep layer. Planting catch crops could increase soil urease activity, regulate soil nitrogen transformation. Compared with other treatments, WCDII and FSSV treatment can reduce the initial urease activity and soil nitrate nitrogen content of next crops, which is consistent with the nutrient requirements of broccoli in the early stage of growth. These catch crops planting could reduce the nitrogen environmental risk in the greenhouse soil. Finally, the study proposed that the suitable planting density of catch waxy corn and forage sweet sorghum planted was 6600~7000 plants/667m², and 9000~10000 plants/667m², respectively, in the greenhouse summer leisure period. It is more advantageous to improve soil nitrogen absorption and reduce soil nitrogen environmental risks for catch waxy corn.

1 Introduction

Nitrogen is an important necessary nutrient element for the growth and development of crops, and is also an element that causes eutrophication of water bodies in the ecological environment^[1,2], especially in the production system of intensive greenhouse. In recent years, China's intensive facilities had grown in size. In 2015, China's facility vegetable fields area reached 5.35×10^6 ha, accounting for 23.6% of total vegetable acreage^[3]. The input of nitrogen fertilizer in the greenhouse production system is several times higher than the nitrogen demand of vegetable crops. Peng et al^[4] pointed out that the nitrogen fertilizer input amount was even more than 10 times the recommended amount in the vegetable fields in the North China Plain. Among the top 10 provinces in China, the average amount of nitrogen fertilizer exceeded 300 kg/ha, and even reached 500 kg/ha^[5]. The utilization rate of nitrogen fertilizer was only 30% to 40%. Most of the nitrogen remained in the soil, and the residual amount of nitrogen in the soil increased with the

increase of nitrogen application^[7,8]. When the nitrogen application rate in the vegetable plots was 240 kg/ha and 360 kg/ha, the nitrogen residues were 24.5% and 47.5%^[9]. Nitrogen remaining in the soil easily moved deep into the soil under irrigation and precipitation conditions, and drip washing heavily into the groundwater. Groundwater contaminated by nitrogen migrated with underground runoff to surrounding water bodies, causing water pollution^[10]. In the summer season of North China from June to September, more than 60% of the facility greenhouses are in open-top leisure conditions due to high temperature and heat^[11], and the summer precipitation is concentrated. Therefore, during the summer leisure period, the vegetable fields became the peak of nitrate leaching, accounting for 22% to 44% of the total nitrogen leaching in one year^[12]. Based on this condition, the introduction of catch crop planting had become a new biological pathway to solve the nitrogen leaching of the facility soil, which could effectively absorb the nitrogen accumulated in the soil and improve the soil ecological environment quality^[13].

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Relevant literatures showed that the catch crop could effectively absorb the nitrogen in the soil leaching solution, the absorption amount could reach 190.05 kg/ha (in terms of pure nitrogen), and the nitrate leaching loss could be reduced by 75% every year^[14]. Planting sweet corn in the summer leisure period could reduce the amount of nitrate nitrogen in the 0~100cm soil layer of the vegetable field by an average of 290.4 kg/ha^[15]. In recent years, it had become the focus of researchers to solve the problem of nitrogen accumulation in the soil during the greenhouse open-top period, reducing the movement of nitrogen in the lower layer, and improving the greenhouse production efficiency. On one hand, biomass and nitrogen uptake of introduced catch crop was high, on the other, the economic benefits of introduced catch crop were obvious. Studies had shown that C4 crops are ideal for catch crops, which had the characteristics of large biomass and high temperature tolerance in the short term^[16], and could effectively reduce the loss of nitrate in soil. However, systematic studies on planting density, biomass and nitrogen uptake and soil migration between C4 crops had not been reported. Therefore, this article intended to C4 crops by planting deep root with different cultivation densities during the summer season. The objectives were to test: if (1) Relationship between different planting density and biomass and nitrogen uptake of C4 crops during greenhouse recreation; (2) The vertical variation of easily moving nitrogen in soil layers at different depths under different planting densities of C4 crops during greenhouse recreation; (3) The horizontal and horizontal changes of easily-movable nitrogen in different depths of C4 crops under different planting densities before and after planting. The study provided a reliable bio-technical approach to the control of nitrogen non-point source pollution in facility vegetable fields.

2 Materials and methods

2.1 Test area overview

The study was conducted at a greenhouse vegetable production base in the northern part of Wuqing, Tianjin, North China. The natural geographical position is E116°57'27.03"—116°57'51.87", N39°32'8.24"—39°32'51.81", which belongs to the temperate semi-humid continental monsoon climate. The greenhouse age was about 16 years old. The crops were mainly cultivated with fruits and vegetables in winter and spring, and the crops were mainly leafy vegetables in autumn and winter. In July and August, it was a leisure season. From July to August 2009 to 2016, the average precipitation in the region was above 280 mm, accounting for more than 50% of the annual average precipitation^[17]. The sampling time of the test basic soil samples was in early June 2017. The soil type of the test greenhouse was medium-altitude fluvo-aquic soil, the organic matter content and soil nitrogen and phosphorus nutrient content were high, and the soil was light salinization. The soil nutrient status was shown in Table 1.

Table 1. Test surface soil nutrient status.

Index	Contents
Organic matter g/kg	32.42
Total nitrogen g/kg	2.55
Effective phosphorus mg/kg	404.86
Nitrate nitrogen mg/kg	188.33
pH	7.42
Salt content g/kg	2.48

2.2 Test materials

Waxy corn: In 2017, the planting variety was Xuenuo No. 2, with an average growth period of 95 days, and the row spacing of conventional planting rows in farmland was 40 cm×50 cm; In 2018, the planting variety was Aozao 60, and the average growth period was 67 days. The row spacing of conventional plantings in the field was 44 cm×50 cm. It was suitable for planting during summer leisure period and had high food consumption economic value.

Forage sweet sorghum: the planting variety was sweet variety 2, the average growth period was 135 d, and the row spacing of conventional plantings in the field was 25 cm×50 cm. It was planted during summer leisure period, with large biomass and high feeding value.

2.3 Test Processing and Management

The trials were carried out in the same greenhouse in the winter and spring of 2017 and 2018, after tomato harvest (early June), during summer leisure (from early June to early August). In the 2017 and 2018 trials, six treatments were designed, each treatment was repeated three times. The planting density design was tested at a conventional density of field, a conventional density of about 1.5 times, and a conventional density of 2 times. The test plot area was 30 m² (4.7 m ×6.4 m). Since the test routine density in 2017 was based on field planting conditions, there was no peak in the test density biomass results. Therefore, the 2018 test design increased the planting density, as shown in Table 2.

Table 2. Field experiment treatments.

Years	Crop species	Treat	Density / (plants/ 667m ²)	Plant spacing /cm
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2017	Waxy corn	WCD1	3300	40×50
		WCD2	5000	27×50
		WCD3	6600	20×50
	Forage sweet sorghum	FSS4	4500	30×50
		FSS5	7000	19×50
		FSS6	9000	15×50
2018	Waxy corn	WCD I	4500	30×50
		WCD II	7000	19×50
		WCDIII	9000	15×50
	Forage sweet sorghum	FSSIV	7000	19×50
		FSSV	10000	13×50
		FSSVI	14000	9.5×50

(Note: WCD was the abbreviation of "Waxy Corn Density" and FSS was the abbreviation of "Forage Sweet Sorghum".)

No fertilizer was applied during the test. The two-year test was planted at the beginning of June. In addition to the next day's irrigation, no irrigation was carried out during the growth period because of the film uncovering and sufficient precipitation in the current season. Regular weeding was carried out during the growing period, harvested in mid-August, and the two kinds of catch crops were not mature at the time of harvesting, but the waxy corn could be eaten fresh, the fresh biomass was measured at the time of harvesting, and the plant sample was collected to determine the total nitrogen content of the plant. The soil samples of 0~30 cm, 30~60 cm, 60~90 cm soil layers were collected before and after harvesting, and five points were collected for each repeated measurement. The indicators of total nitrogen, nitrate nitrogen and urease were determined. After August 30, broccoli was planted, and the soil samples of 0~30 soil layer were collected on September 15 and October 1, respectively, to determine the nitrate nitrogen content and urease activity.

2.4 Test methods

2.4.1 Biomass determination

At the time of harvest, the actual biomass of fresh plants in the plot was harvested, and then 5 plants with uniform

growth were randomly selected, and the roots (roots 0~20 cm soil layer root weight) and the aboveground parts were weighed separately, and the ratio of fresh weight to root and shoot was calculated the total root and above-ground fresh weight of the plot. At the same time, it was baked at 105 °C for 1 h, then dried at 75 °C to constant weight to prepare corresponding samples, determine the water content of different parts, and finally calculate the dry biomass of different parts (all biomass below was dry biomass).

2.4.2 Determination of total nitrogen in plants

Chemical analyses of the post-harvest residue of catch crops were performed after the mineralization of shredded plant material by digestion in concentrated H₂SO₄ and H₂O₂ applying the following methods: total nitrogen (NTOT) using the Kjeldahl method, and the various parts were calculated. The amount of nitrogen absorbed (1),

Nitrogen absorption=biomass×total nitrogen content (1)

2.4.3 Determination of total nitrogen, nitrate nitrogen and urease in soil

The soil total nitrogen was determined by Kjeldahl method. The soil nitrate nitrogen was measured by ultraviolet spectrophotometer at 210 nm, and the nitrate curve was calculated by the standard curve^[18]. The soil urease (urease) was based on urea, and the ammonia produced by enzymatic hydrolysis reacts with phenolic compounds to form blue indophenol. The color depth was related to the ammonia content, and the colorimetric was carried out at 578 nm, and then calculated by the standard curve^[19].

2.4.4 Statistical analysis

The experimental data were processed using Excel 2013 method, and statistical analyses were carried out using SPSS 22.0 for Windows software and the results were expressed as mean values. The reduction rate of soil nutrient content below is called pre-planting ratio after planting the same crops in the soil layer.

Reduction rate = (pre-plant nutrient content - nutrient content after planting)/pre-plant nutrient content (2)

3 Results

3.1 Different treatments of two catch crop biomass and soil nitrogen status of absorption greenhouse

Table 3 showed the soil nitrogen and planting biomass and absorption greenhouse of different treatments of two kinds of catch crops. In 2017, the total biomass and aboveground biomass of the catch waxy corn were increased with the increase of planting density, and the aboveground biomass accounted for more than 88.2% of the total biomass. And the aboveground and total

biomass of WCD3 treatment was significantly higher than WCD1 and WCD2 treatments. Root biomass decreased with the increase of planting density, and WCD1 treated root biomass was significantly higher than WCD2 and WCD3 treatment; The nitrogen uptake trend of catch waxy corn was the same as that of biomass. The nitrogen uptake of aboveground nitrogen accounted for more than 88.5% of total nitrogen uptake, indicating that the increase of planting density of waxy maize increased biomass and nitrogen uptake, but affected root growth. The aboveground biomass accounted for more than 89.1% of the total biomass, and the aboveground and total biomass of FSS5 and FSS6 was significantly higher than those of FSS1, and the root biomass of that was significantly lower than FSS4 treatment. It indicated that forage sweet sorghum would increase the planting density, which would affect the growth and development of roots. The nitrogen uptake of the aboveground part accounted for more than 91.3% of the total nitrogen uptake, and the nitrogen treatment trend of different treatments was the same as the biomass. In general, the increase of planting density of the two catch crops could significantly increase crop biomass and nitrogen uptake, and reduce soil nitrogen accumulation in the greenhouse.

In 2018, the total biomass and aboveground biomass of the different treatments of catch waxy corn increased first and then decreased with the increase of planting density, and the aboveground biomass accounted for more than 92.1% of the total biomass. The total biomass of WCDII treatment was significantly higher than that of WCDI and WCDIII treatments, and the root biomass treatment did not reach significant difference. Nitrogen

absorption of catch waxy corn had the same trend as biomass of that, and the nitrogen uptake in the aboveground part accounted for more than 93.3% of the total nitrogen uptake. The total biomass and aboveground biomass of forage sweet sorghum increased first and then decreased with the increase of planting density, and FSSII treatment was significantly higher than FSSIV treatment, and aboveground biomass accounted for more than 83.5% of total biomass. The total nitrogen uptake and aboveground nitrogen uptake of FSSV treatment was significantly higher than FSSIV and FSSVI treatments. The nitrogen uptake of roots decreased with the increase of planting density, but the nitrogen uptake of each treatment did not reach significant difference. On the whole, the biomass and nitrogen uptake of the two kinds of catch crops increased first and then decreased with the increase of planting density, and WCDII and FSSV treatments had a great advantage in reducing the nitrogen accumulation in the vegetable fields.

After two years of catch crops density test, the biomass and nitrogen uptake of catch waxy corn in 2018 was lower than that in 2017, and there was no significant difference in the biomass and nitrogen uptake of forage sweet sorghum. Increasing the planting density of the catch crops, the total biomass and nitrogen uptake both increased first and then decreased, and affected the proportion of aboveground biomass to total biomass. WCDII, WCD3, FSS4 and FSSV treatments had higher biomass and nitrogen uptake during the two-year planting, which had a better effect on reducing soil nitrogen accumulation and leaching risk.

Table 3. Biomass and nitrogen uptake of different catch crops in different treatments. Unit: kg/667m²

Years	Treat	Biomass			Nitrogen absorption		
		Root	aboveground	total	Root	aboveground	total
2017	WCD1	159.86	1191.41	1351.27	1.72	13.2	14.93
		±7.19a	±80.66b	±80.09b	±0.08a	±0.86b	±0.82b
	WCD2	97.3	1555.45	1652.75	1.24	16.93	18.17
		±16.66b	±13.04b	±20.47b	±0.21b	±0.22b	±0.39b
	WCD3	89.86	2448.83	2538.69	1.07	27.61	28.68
		±2.65b	±302.05a	±299.93a	±0.03b	±3.18a	±3.15a
2017	FSS4	132.27	1083.39	1215.66	1.08	11.38	12.47
		±13.73a	±112.49b	±126.22b	±0.11a	±1.18b	±1.29b
	FSS5	68.62	1660.67	1729.3	0.37	19.14	19.51
		±2.41b	±58.41a	±60.82a	±0.01c	±0.67a	±0.69a
	FSS6	84.83	1845.47	1930.3	0.61	21.06	21.67
		±6.09b	±132.43a	±138.52a	±0.04b	±1.51a	±1.55a

2018	WCD I	78.94 ±13.08b	1611.44 ±45.09a	1690.38 ±50.48b	0.67 ±0.12a	18.7 ±0.91a	19.37 ±1.02b
	WCD II	151.40 ±51.85a	1770.34 ±132.82a	1921.74 ±96.96a	1.49 ±0.56a	20.87 ±1.46a	22.36 ±1.16a
	WCD III	87.20 ±5.72ab	1181.63 ±33.73b	1268.83 ±39.44c	1.05 ±0.07a	15.22 ±0.47b	16.27 ±0.54c
2018	FSS IV	259.18 ±45.53a	1333.62 ±27.21b	1592.80 ±60.02b	1.81 ±0.31a	18.67 ±2.11b	20.48 ±1.96b
	FSS V	315.77 ±37.34a	1598.56 ±127.44a	1914.33 ±163.48a	1.82 ±0.08a	22.57 ±1.63a	24.39 ±1.71a
	FSS VI	258.92 ±16.81a	1522.23 ±49.93a	1781.15 ±62.23ab	1.36 ±0.09a	18.76 ±0.90b	20.11 ±0.96b

Note: Different letters in the same column of the same species indicate a difference of 5% significant level.

3.2 Effects of different treatments of two kinds of catch crops on soil nitrogen in the greenhouse

3.2.1 Greenhouse soil total nitrogen

The soil total nitrogen content of the surface layer of the greenhouse before and after the catch crops was shown in Fig 1. In 2017, WCD2 treatment of catch waxy corn could significantly reduce the total nitrogen content of the greenhouse soil, the reduction rate was 15.6%, and the total nitrogen content of WCD1 and WCD3 treatments was also reduced, but it did not reach significant difference. FSS5 and FSS6 treatments of forage sweet sorghum significantly reduced soil total nitrogen content, and the reduction rates were 18.8% and 23.5%, respectively, but there was no significant difference between the two treatments. It was indicated that the increase of the planting density of forage sweet sorghum could significantly reduce the total nitrogen content of the greenhouse soil.

In 2018, the different treatments of the two kinds of catch crops could significantly reduce the total nitrogen content of the greenhouse soil. The reduction rate of total nitrogen content in the greenhouse soil at different density of catch waxy corn was 17.7%~27.0%. The reduction rate of total nitrogen content in the surface layer of forage sweet sorghum was 15.5%~23.2%. However, there was no significant difference between the different treatments.

From the perspective of planting two years of catch crops, WCD2, WCDI, WCDII, WCDIII, FSS5, FSS6, FSSIV, FSSV, FSSVI treatments could significantly reduce the total nitrogen content of the greenhouse soil, which is better for reducing the soil nitrogen environmental risk of the greenhouse.

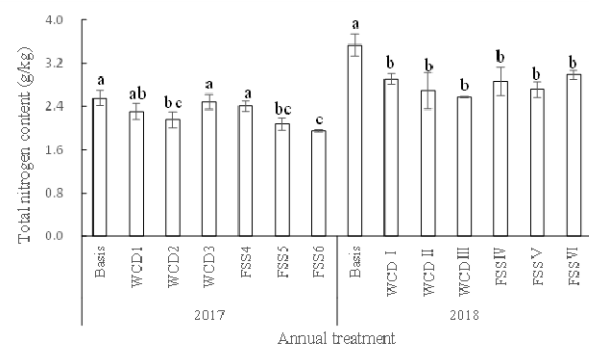


Fig.1. Total nitrogen content in surface soil before and after planting with different crops

3.2.2 Vertical distribution of soil nitrate nitrogen in greenhouse

As shown in Figure 2 and 3. In 2017, planting two kinds of catch crops could significantly reduce the nitrate content of the soil of the greenhouse. The reduction rate of nitrate nitrogen content in 0~30cm, 30~60cm and 60~90cm soil layers was 79.9%~90.8%, 49.6%~59.7%, 29.6%~42.0%, respectively. The different rates of nitrate-nitrogen content in the soil of the greenhouse were 84.4%~96.4%, 54.2%~69.6%, 25.2%~40.0%, respectively. This showed that planting catch crops could significantly reduce the mobile nitrogen content in the greenhouse soil, thereby reduce the nitrogen environmental risk of the greenhouse soil.

In 2018, the different treatments of the two kinds of catch crops could significantly reduce the nitrate nitrogen content in the surface soil. The reduction rate of WCDIII treatment was the highest, which was 90.5%, followed by FSSV treatment, which was reduced by 86.8%, but the treatment did not reach significant difference. The treatments of the two kinds of catch

crops in 30~60cm soil layer were significantly lower than those before planting. The nitrate content of each treatment of catch waxy corn and forage sweet sorghum decreased by 38.0%~69.9% and 46.7%~69.2%, respectively. The content of nitrate nitrogen in soil of 60~90cm soil layer of WCDIII and FSSV treatments was significantly lower than that before planting, which was decreased by 39.9% and 45.7%, respectively. WCDI treatment increased, indicating that soil nitrate nitrogen had downward leaching.

According to the comprehensive two-year experiment, the reduction of soil nitrate nitrogen content in the lower facilities in 2018 was not obvious in 2017. Probably because of the large rainfall in 2018, the greenhouse vegetable fields were soaked in rain, that caused the upper layer of nitrate nitrogen to move to the lower layer. The each treatment of two kinds of catch crops in 2017 and WCDII, WCDIII, FSSIV and FSSV in 2018 could significantly reduce the nitrogen content of the soil in the greenhouse, and control the soil nitrate nitrogen leaching in the greenhouse, thereby reduce the nitrogen pollution of the greenhouse soil.

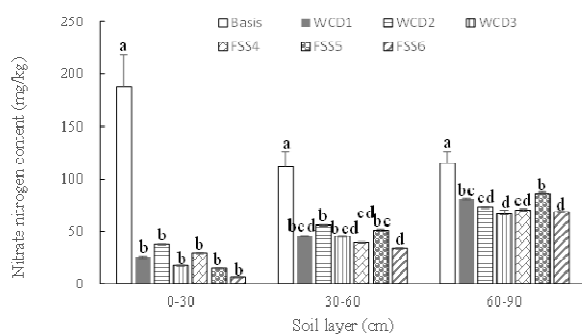


Fig.2. Nitrate nitrogen content in each soil layer before and after planting of different crops (2017Year)

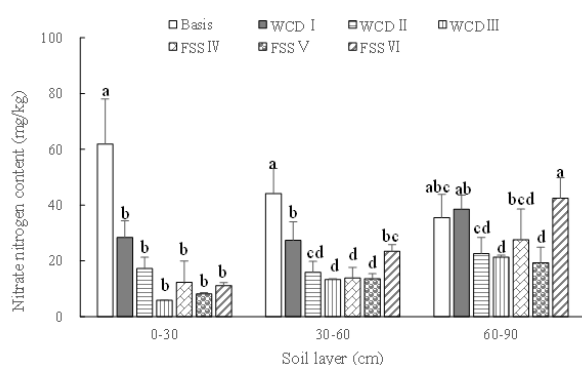


Fig.3. Nitrate nitrogen content in each soil layer before and after planting of different crops (2018Year)

3.3 Soil urease activity before and after planting of crops and the status of soil surface nitrate nitrogen in the early stage of catch

Soil urease is involved in soil nitrogen transformation, it provides a nitrogen source for crop growth^[20]. Qiu

Liping et al^[21] showed that urease was significantly positively correlated with soil fertility. As shown in Figures 4 and 5, the soil urease activity of the two kinds of catch crops increased at different densities in 2018, but it was not obvious. When the broccoli was planted for half a month, WCDII and FSSII treatments had lower urease activity than other treatments, and the nitrate nitrogen content was significantly lower than other treatments. After one month of colonization, the soil urease activity of WCDII and FSSV treatment increased, and the nitrate nitrogen content did not decrease significantly, which could provide quick-acting nitrogen fertilizer for the late growth of broccoli. On the whole, WCDII and FSSV treatments could reduce the urease activity and soil nitrate nitrogen content in the early stage of sorghum, which was consistent with the low nutrient demand in the early growth stage of broccoli, which reduced the nitrogen environmental risk of the greenhouse.

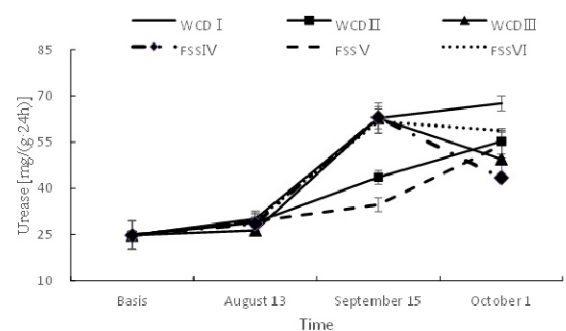


Fig. 4. Soil urease activity in different treatments (2018Year)

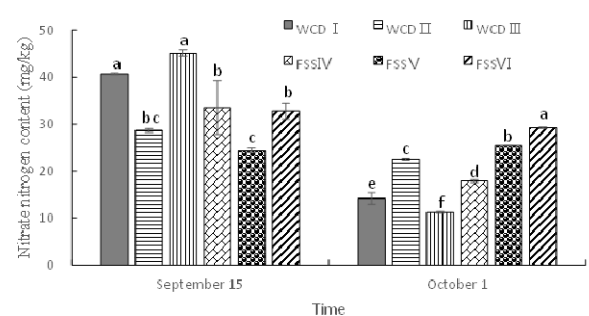


Fig.5. Status of soil nitrate nitrogen in the early stage of alfalfa after different treatments (2018Year)

4 Discussion

4.1 Biomass and nitrogen absorption

Reasonable close planting of crops was the basis for forming a good reproductive group and exerting group productivity^[22]. Relevant data showed that sorghum increased grain yield and biomass yield with planting density in the planting density range of 3000 plants/667m²~7000 plants/667m²^[23,24]. In this experiment, the biomass of catch waxy corn and forage sweet

sorghum increased first and then decreased with the increase of planting density, and the suitable planting density was higher than that of field planting density in high-fertility vegetable field. The biomass and nitrogen absorption of catch waxy corn in 2018 was lower than in 2017, which might be caused by differences in planting varieties. Ren et al^[25] showed that sweet corn grew rapidly, it had large biomass and strong ability to absorb nitrogen, and the nitrogen uptake could reach 13.71~16.41 kg/667m². After two years the test, the planting density of catch waxy corn was increased, the nitrogen absorption reached 22.15~28.68 kg/667m². The planting density of forage sweet sorghum was increased, and the nitrogen absorption reached 21.67~21.89 kg/667m², which was higher than the normal density of the field to grow nitrogen uptake. Therefore, this study played an important role in obtaining a high biomass and reducing the environmental risk of nitrogen in the vegetable planting field.

4.2 Catch crops and soil nitrogen

Roots were the main organs for crops to absorb nutrients, and their distribution, surface area and vigor were closely related to nitrogen absorption and absorption range^[9]. Ji Yanzhi's research found that corn and sorghum were deep root crops, and their 0~100 cm root length accounted for more than 91.0% of the total root length of 0~150 cm^[26]. The roots grew downward to absorb residual nitrogen in the soil, effectively reducing the amount of nitrate nitrogen accumulated in the soil^[27-29]. Planting the crops as shown in Figure 3 could significantly reduce the nitrate content of each soil layer, which was consistent with the Guo R' research^[30]. However, the content of nitrate nitrogen in the soil under the soil in Figure 4 was not significantly different, which might be caused by nitrate nitrogen leaching, or might be caused by root growth and development^[31]. The study showed that catch crops planting could reduce the total nitrogen content of the soil surface, the absorption of nitrate in the soil decreased with decreasing, which was consistent with the Kristensen's research^[32]. The relationship between nitrogen absorption and surface total nitrogen reduction was inconsistent, so an isotope tracer test should also be performed.

4.3 Catch crops and soil urease

Related studies had found that the summer planting catch crops could increase soil urease activity, and help to improve soil nitrogen transformation^[33,34]. This present study planting catch crops could reduce the soil total nitrogen content, soil urease activity had increased consistent results. Filling crops could change the amount and activity of soil enzymes in soil microbes and improve soil ecological environment^[35-37]. After this experiment, the increase of soil surface nitrate nitrogen in the vinegar planting for half a month was consistent with the study of Tian Y^[38]. However, WCDII and FSSV treatments remained at a lower level than other treatments. After one month of colonization, the content

of nitrate nitrogen in WCDII and FSSV treatments was not significantly reduced, which was consistent with the low nutrient requirement in the early growth stage of broccoli, and provided effective nitrogen for the late growth of broccoli.

5 Conclusions

5.1 Both the biomass and nitrogen absorption of the two cropping crops increased first and then decreased with the increase of planting density. The suitable density of catch waxy corn in the vegetable field was 6600~7000 plants/667m², and the nitrogen absorption was 22.36~28.68 kg/667m². The suitable planting density of forage sweet sorghum was 9000~10000 plants/667m², and the nitrogen absorption was 21.67~24.39 kg/667m².

5.2 Increasing the planting density of catch waxy corn and forage sweet sorghum could significantly reduce the total nitrogen content in the soil surface and the nitrate content in each soil layer. The reduction rates of total nitrogen content in the soil surface were 9.6%~27.0% and 5.7%~23.5%, respectively. The reduction rates of surface nitrate nitrogen content were 50.0%~90.8% and 80.1%~96.4%, respectively.

5.3 Catch crops planting could increase soil urease activity, regulate soil nitrogen transformation, reduce soil nitrogen content, and reduce nitrogen loss caused by low nutrient demand in the early stage of post-crop crop growth, and then reduce nitrogen environmental risk.

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