TRANSACTIONS OF THE CHINESE SOCIETY FOR AGRICULTURAL MACHINERY
Vol. 47, No. 1, 2016

doi:10.6041/j.issn.1000-1298.2016.01.021

Effects of Cellulose Aquasorb on Properties of Substrate and Growth of Cucumber Seedling

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Abstract: As a new type of water-saving polymer materials, aquasorb can ameliorate soil structure, facilitate formation of soil aggregate, enhance water holding capacity of soil, adjust plant rhizosphere environment, reduce the loss of soil nutrients and promote crop growth. In the experiment, microcrystalline cellulose aquasorb and straw residue aquasorb were synthesized by orthogonal optimization. In the process, acrylic acid was employed as graft monomer, potassium persulfate (KSP) as initiator, and N,N-methylene bisacrylamide (NMBA) as crosslinking agent. The max water absorbency of two aquasorbs (microcrystalline cellulose aquasorb and straw residue aquasorb) were 401.20 g/g and 382.22 g/g, respectively. In this paper, the effects of these two kinds of cellulose aquasorbs on the physicochemical properties of the substrate and growth physiological indexes of cucumber seedlings such as root activity, seedling index and G value (the growth rate of the daily average dry mass) etc. were compared. The results indicate that after the addition of two cellulose aquasorbs in plug seedling, there are significant effects on promoting soil physicochemical properties and the growth of cucumber seedlings. After 36 days, when the mass fraction of microcrystalline cellulose aquasorb is 0.3%, the G value, seedling index and root activity of cucumber seedlings samples can reach (0.0154 ± 0.0009) g/d, 0.4892 ± 0.0762 and 61.82 μg/(g·h) respectively. When the mass fraction of added straw residue aquasorb is 0.3%, the G value, seedling index and root activity of cucumber seedlings samples can reach (0.0156 ± 0.0004) g/d, 0.5089 ± 0.0985, and 60.90 μg/(g·h) respectively. The research results show that straw residue aquasorb can be used as a new type soil aquasorb applied in field production.

Key words: cellulose aquasorb; cucumber seedling; straw residue

0 Introduction

Drought has always been an important factor restricting agricultural development[1] in some areas of China. Application of aquasorb provides farming an effective way to enhance water use efficiency[2]. Aquasorb with high water absorbency belongs to macromolecule polymer[3-4] which can absorb water tens or even hundreds of times more than its own mass to form hydrogel repeatedly[5-6]. Aquasorb can ameliorate soil structure, increase the contents of stable aggregate water[7-9] and adjust water, nutrition, air, heat and other rhizosphere factors to promote crop growth[10].

In order to explore the impacts of aquasorb on both substrate capacity of holding water and quality of vegetable seedlings, Jiang Yaqin et al.[11] selected eggplant, gourd and other plants treated by aquasorb with two kinds of particle size to conduct seedling experiment. Research results showed that aquasorb can enhance water holding capacity of substrate significantly besides it can provide sustained moisture to the growth of seedlings. Applying cucumber as the test crop, Han et al.[12] studied the impacts of aquasorb with different mass fraction on both nursery block and quality of seedlings, and the results indicated that excessive amount of aquasorb used in compressed block of substrate can decline the quality of cucumber seedlings. In lettuce pot cultivating, Luo et al.[13] tested the impacts of three kinds of aquasorb on nutrient leaching and lettuce growth. The results indicated that aquasorb can improve soil moisture, moderate the damage of water stress on tissues of plant and increase chlorophyll content indirectly.

As a new type of water-saving polymer materials,

Received date: 2015-10-08　Accepted date: 2015-11-04

Supported by Special Fund for Agro-scientific Research in the Public Interest (Grant Nos. 201303108, 201503137)

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three categories aquasorb including starch, cellulose and the synthetic are widely applied[14]. Traditional high absorbency materials such as polyacrylic acid and polyacrylamide belong to synthetic polymers, and the degradability of these materials in natural environment is low. One of disadvantages of starch aquasorb is that it is inferior to resist mildew[15]. Comparing with starch aquasorb, absorbency of cellulosic aquasorb is a little lower, but easiness of pH regulation, well performance of salt absorption and fine biodegradability in nature indicate that cellulosic aquasorb is a kind of environment friendly water-holding material[16]. With enlarging of cellulose aquasorb study, raw materials have been shifted from traditional cellulose derivatives (such as carboxymethyl cellulose, hydroxyethyl cellulose) to natural cellulose, in particularly straw, biogas residue and other rich cellulose agricultural wastes[17].

Under this circumstance, microcrystalline cellulose and straw residue aquasorb were synthesized by orthogonal experiment in the laboratory. In the process, acrylic acid was employed as graft monomer, potassium persulfate (KSP) as initiator, and N,N′-methylene bisacrylamide (NMBA) as crosslinking agent. Heating on microwave, two kinds of aquasorb (microcrystalline cellulose aquasorb and straw residue aquasorb) can be obtained and their maximum water absorbencies were 401.20 g/g and 382.22 g/g, respectively.

In this experiment, two kinds of aquasorb are employed in cucumber plug seedling. The effects of aquasorbs with different mass fractions on the physicochemical properties of substrate including bulk density, pH value, conductivity and growth physiological indexes of cucumber seedlings such as roots activity, leaf SPAD, root to shoot ratio (RTR), average daily amount of dry matter increase (G) and seedling index are tested and compared. The purpose is to provide reference for the development and extension of aquasorb in the field production.

1 Materials and methods

1.1 Test materials

Tested vegetable is cucumber which breed is called "Zhongnong 18" cultivated by the Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences.

Nursery substrate is mixed by peat, vermiculite and perlite. The volume ratio is 2∶1∶1. Substrate is offered by Beijing Zhentai Horticultural Facilities Limited Company. The basic physicochemical properties of substrate are listed on Tab. 1.

Tab. 1 Basic physicochemical properties of substrate

pH value	Conductivity/ ($mS\cdot cm^{-1}$)	Test weight / ($g\cdot cm^{-3}$)	N mass ratio / ($mg\cdot kg^{-1}$)	P mass ratio/ ($mg\cdot kg^{-1}$)	K mass ratio/ ($mg\cdot kg^{-1}$)
7.01	6.45	0.61	193.40	7.34	115.46

Two kinds of aquasorb were synthesized by orthogonal experiment in Key Laboratory of Agricultural Engineering in Structure and Environment, China Agricultural University. Order 1 of testing aquasorb is microcrystalline cellulose aquasorb. Order 2 of testing aquasorb is straw residue aquasorb.

1.2 Design of experiment

Experiment is to be conducted in the greenhouse at College of Water Conservancy and Civil Engineering, China Agricultural University, from March 7, 2015 to April 15, 2015.

Seven treatments, called CK, T1, T2, T3, T4, T5, and T6 are arranged in the experiment, and in the control group CK there is no any aquasorb. The groups treated by microcrystalline cellulose aquasorb are T1, T2 and T3 and their mass fractions of aquasorb are 0.3%, 0.6% and 0.9%, respectively. The groups treated by straw residue aquasorb are T4, T5 and T6 and their mass fractions of aquasorb are 0.3%, 0.6% and 0.9%, respectively. Plug tray each with 4 × 8 holes is employed. 50g substrate and 30mL water are filled in every hole and physicochemical properties of substrate at the initial state are monitored.

Two cucumber seeds are sowed in every hole of the plug trays. Before the seedling emerges, every day there is 300mL of water to irrigate substrate in the plug tray to ensure germinating of cucumber seeds. After emergence, only one seedling is retained in each hole of the plug tray. At the same time, corresponding to CK, every other treatment is provided equal amount of irrigating water. Every day 200 mL of Japanese-style Garden nutrient solution in each plug tray is applied after the first true leaf of cucumber seedling come out (15d after sowing). The nutrient formulation is: KNO_3 810 mg/L, $Ca(NO_3)_2$ 950 mg/L, $MgSO_4$ 500 mg/L, KH_2PO_4 155 mg/L, iron chelate 20 mg/L.

From unfolding of the first true leaf to the stage of 3-leave with a heart leaf, every five days in each treatment, every treatment there are six repeats of cucumber seedling to be monitored. Items of monitoring include seedling height, stem diameter and SPAD of leaf etc. From the 16^{th} day after emergence of seedling, every ten days samples are selected to test basic physicochemical properties of substrate, mass of fresh shoot, mass of dry shoot, mass of fresh root and mass of dry root. At 37^{th} day after cucumber seedling emergence, root activities of all treatments are measured.

1.3 Measurement items and methods

1.3.1 Physicochemical property of substrate

Measuring items include relative moisture content of substrate, bulk density, pH value and conductivity (EC). Testing methods of relative moisture content and bulk density refer to literature[18] and other items of measurement mainly refer to methods from Bao[19].

1.3.2 Morphology indexes of cucumber seedling

Seedling height: seedling height refers to the length from the growing point to substrate surface and testing tool is ruler.

Stem diameter: diameter of lower end of the seedling cotyledons and diameter of the stem base are measured by the electronic digital caliper.

Chlorophyll relative content: measuring 10 selected positions randomly on the seedling leaf with chlorophyll relative content testing instrument (model: SPAD-502) on selected day between 10:00 to 11:00.

Mass of dry and fresh matter: removing water on the surface of washed seedlings, their masses can be measured by the electronic balance. Drying the sample of seedlings to the constant, the mass of dry shoot and the mass of dry root can be measured.

Furthermore, root to shoot ratio (RTR), growth rate of daily average dry matter (G) and seedling index (SI)[20, 21] are used to evaluate the quality of cucumber seedlings.

Root activity: root activity is tested by TTC (triphenyl tetrazolium) reduction method[22].

2 Results and discussion

2.1 Effects on physicochemical properties of substrate

2.1.1 pH value and conductivity (EC)

Changes of pH value and EC value in each treatment are listed in Fig. 1. It shows that pH value and EC values were increased gradually as the days of cultivation went on.

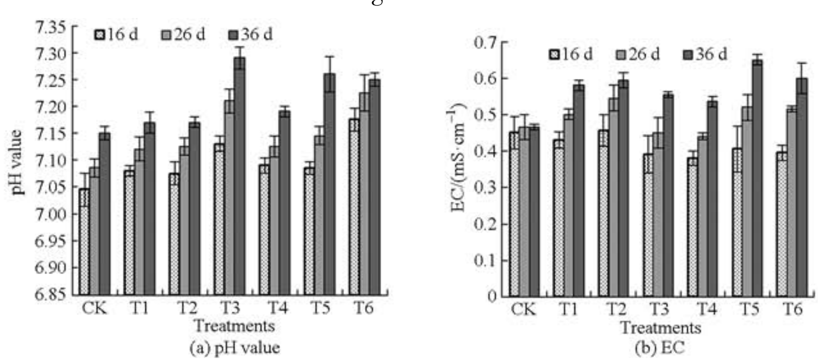

Fig. 1 Comparison of each treatment for pH value and EC value on different cultivation days

Due to the cellulose aquasorb weak alkaline, Fig. 1a reflects that mass fraction of aquasorb and the pH value are correlated positively in the treatments. Fig. 1b shows the effects of two kinds of aquasorb on EC of the substrate. At the beginning, EC was increased and then decreased, EC values in the group CK is the lowest on the 36^{th} day after seedling emergence.

2.1.2 Bulk density and relative moisture content

Changes of substrate bulk density and relative moisture content in each treatment are showed in Tab. 2. On the 16^{th} day after seedling emergence, bulk densities of the group CK and treatments T1, T4 are larger than those of other treatments, and there is no significant difference in the three treatments at the level

Tab. 2 Comparison of bulk densities and relative moisture content

Treatment	16th day		26th day		36th day	
	Bulk density/ ($g\cdot cm^{-3}$)	Relative moisture content/%	Bulk density/ ($g\cdot cm^{-3}$)	Relative moisture content/%	Bulk density/ ($g\cdot cm^{-3}$)	Relative moisture content/%
CK	0.44 ± 0.03^{ab}	34.25 ± 2.52^{b}	0.45 ± 0.01^{a}	28.17 ± 0.23^{d}	0.70 ± 0.02^{a}	40.39 ± 0.11^{c}
T1	0.45 ± 0.03^{ab}	36.47 ± 1.99^{b}	0.43 ± 0.02^{abc}	31.05 ± 0.67^{c}	0.58 ± 0.01^{b}	41.13 ± 0.71^{bc}
T2	0.41 ± 0.02^{b}	37.93 ± 2.09^{ab}	0.45 ± 0.01^{ab}	28.48 ± 0.25^{d}	0.48 ± 0.01^{c}	41.75 ± 0.61^{abc}
T3	0.41 ± 0.01^{b}	35.92 ± 2.97^{b}	0.42 ± 0.02^{bc}	30.56 ± 1.38^{c}	0.45 ± 0.01^{cd}	43.36 ± 0.84^{a}
T4	0.48 ± 0.03^{a}	42.92 ± 2.65^{a}	0.43 ± 0.02^{abc}	34.63 ± 0.85^{b}	0.54 ± 0.03^{b}	40.53 ± 0.36^{c}
T5	0.41 ± 0.01^{b}	34.03 ± 1.14^{b}	0.41 ± 0.02^{c}	39.42 ± 0.82^{a}	0.42 ± 0.04^{d}	41.16 ± 1.15^{bc}
T6	0.43 ± 0.01^{ab}	37.25 ± 0.45^{ab}	0.43 ± 0.02^{bc}	36.50 ± 1.18^{b}	0.45 ± 0.01^{cd}	42.42 ± 0.11^{ab}

Note: the data format is "average value ± standard deviation" and different lowercase letters indicate that the significant difference is less than the level of 0.05, the same below.

of 0.05. Both bulk density and relative moisture content in T4 have the biggest values at this stage.

On the 26th day after cultivation, relative moisture content in the group CK is still the least, and the bulk density in each treatment has no obvious change comparing with that of the 16th day.

On the 36th day, the value of bulk density in CK is still the biggest one, and its relative moisture content is the smallest one. The descending order of bulk densities in the groups treated by microcrystalline cellulose aquasorb is T1, T2 and T3. Obviously, the descending order of bulk densities in the groups treated by straw residue squasorb is T4, T6 and T5.

Under the same irrigating condition, mass fraction of squasorb is negatively correlated with bulk density and positively related to relative moisture content of substrate.

2.2 Effects on morphology of cucumber seedling

2.2.1 Seedling emergence rate

Emergence rates of cucumber seedling are checked 7 d after sowing. Fig. 2 shows the comparison of emergence rates in the group CK and all the other treatments. It is can be seen that the emergence rates in the seven groups are all higher than 90% and there is no significant difference among them. It indicates that these two kinds of aquasorb are safe on germinating of cucumber seeds.

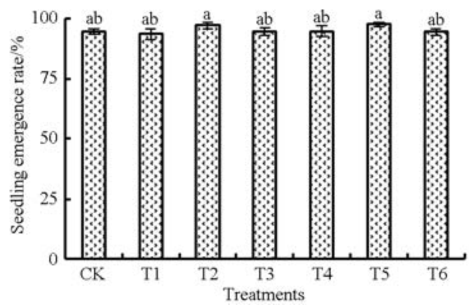

Fig. 2 The comparison of emergence rates of cucumber seedling

2.2.2 Cucumber seedling height

Changes of cucumber seedling height are shown in Fig. 3. All the time seedling heights in the control group (CK) are higher than that in the rest six treatments during the 37 d of cultivation. From the 15th to 30th day, there is no significant difference in seedling heights between T2 and T4 and their seedling heights are all higher than that among the other groups treated by aquasorb. Furthermore, there is no significant difference in seedling heights between T1 and T3, the same as treatments T5 and T6, but seedling heights in T5 and T6 are lower than that of treatments T1 and T3.

From the 35th to 37th day, among treatments T1, T2, T3 and T4, their seedling heights have no significant difference, and all of them are higher than that of in treatments T5 and T6 while T5 has the lowest seedling height. The descending order of seedling heights in the groups treated by "Order 1" aquasorb is T2, T1 and T3, while the descending order of seedling heights in the groups treated by "Order 2" is T4, T6 and T5.

Due to strong absorption of aquasorb, increase of moisture content in cultivating substrate could affect the permeability of rhizosphere environment and inhibit the growth of cucumber seedlings at their early stages. On the contrary, with the growth of the seedlings, they need more water. Gradually releasing of absorbed water in aquasorb can promote the growth of cucumber seedlings.

2.2.3 Stem diameter of seeding

The comparison of cucumber seeding stem diameters is shown in Fig. 4. On the 15th day, stem diameters of

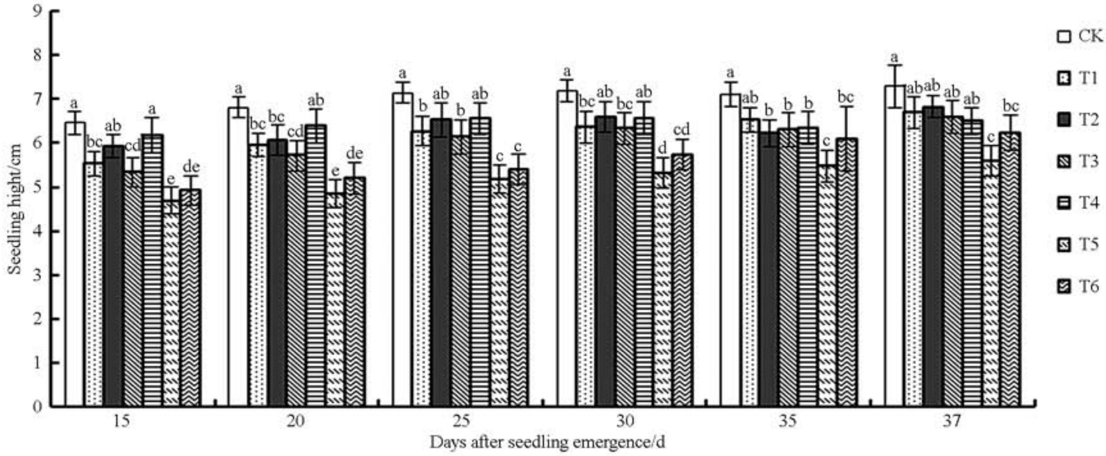

Fig. 3 The comparison of cucumber seeding heights

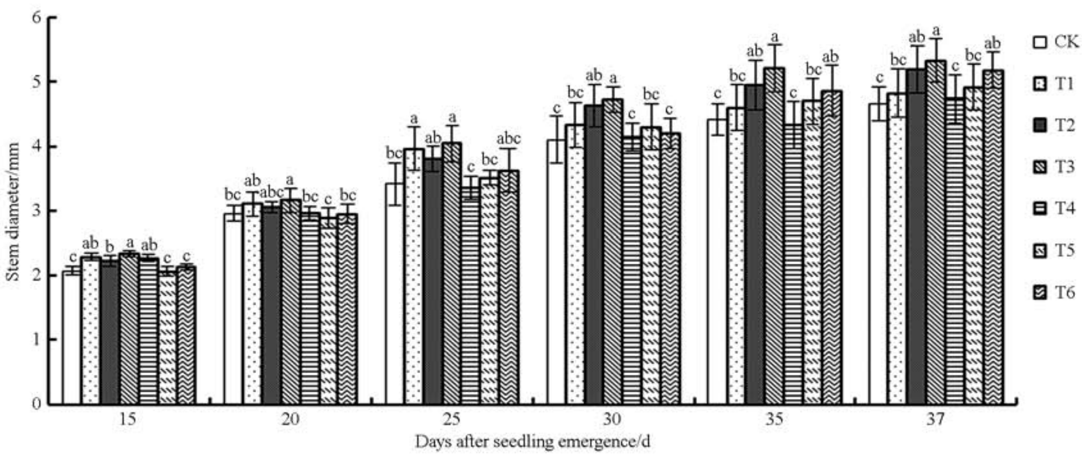

Fig. 4 Comparison of cucumber seeding stem diameters

seedling have no significant difference among treatments T1, T3 and T4, but T3 has the tallest seedling stem diameter. CK, T5 and T6 have no significant difference in stem diameters and their seedling diameters are smaller than that of the rest treatments. With the increment of cultivating days, stem diameters in treatments T2 and T6 are becoming larger.

On the 30^{th} day after seedling emergence, the stem diameters in the group CK and T4 are smaller than that of the rest treatments. There is no significant difference in stem diameters among T1, T5 and T6, but they are lower than that of treatments T2 and T3.

On the 35^{th} day, among CK, T1, T4 and T5, there is no significant difference in stem diameters, and stem diameters in CK and T4 are smaller than that of the rest treatments. At this stage there are no significant difference in stem diameters among T2, T3 and T6, but treatment T3 has the tallest stem diameter.

On the 37^{th} day, the ascending order of stem diameters in the groups treated by "Order 1" aquasorb is T1, T2 and T3, and the ascending order of stem diameters in the groups treated by "Order 2" aquasorb is T4, T5 and T6.

2.2.4 Seeding chlorophyll relative content

The photosynthetic rate is an important indicator to reflect dry matter accumulation of crop and closely related to the chlorophyll content of seedling. Fig. 5 shows the comparison of cucumber seeding chlorophyll relative content (SPAD value) in the group CK and the other treatments.

At the stage (period of first true leaf) of 15 d after seedling emergence, SPAD values in all treatments are higher than 30. There is no significant difference among groups CK, T1, T2, T3, T4 and T5, but the difference between CK and T6 is significant at the level of 0.05. SPAD value in the group CK is the largest one and T6 has the smallest SPAD value.

On the 35^{th} day, the SPAD value in treatment T1 declines in some extent and it has significant difference comparing with that of T2 and T4 at the level of 0.05. At 37^{th} day, the SPAD values in all groups treated by

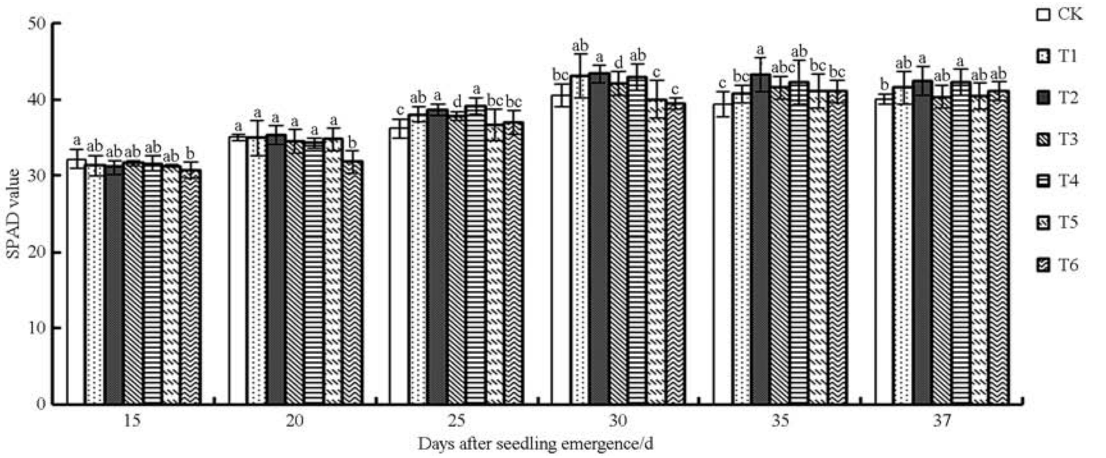

Fig. 5 Comparison of cucumber seeding chlorophyll relative content (SPAD value)

aquasorb are higher than that of the group CK, and the SPAD values in T2 and T4 are larger than that of the other treatments as well.

2.2.5 Fresh and dry mass of seedling

The mass of dry and fresh matter are important indicators to measure growth condition of cucumber seedlings. Fig. 6 shows the changes of fresh and dry matter of cucumber seedlings in each group.

On the 16th day, it can be seen from Figs. 6a, 6b that among T1, T2, T3 and T4 there is no significant difference in both fresh and dry mass of shoot, and treatment T5 has the lowest shoot fresh mass and dry mass. Figs. 6c, 6d show that the group CK has the smallest root fresh and dry mass. Comparing with other treatments, T1, T2 and T4 have larger root fresh and dry mass, but there is significant difference among them. 26 d later, the difference of seedling mass is becoming clear.

On the 36th day, the group CK has the lowest fresh seedling mass comparing with that of the rest treatments. The descending order of seedling mass values in the groups treated by "Order 1" aquasorb is T1, T2 and T3. At the same time, the descending order of dry shoot mass in the groups treated by "Order 2" squasorb is T4, T6 and T5, but the descending order of root dry mass in the groups treated by "Order 2" squasorb is T4, T5 and T6.

2.2.6 Quality of cucumber seedling

Tab. 3 shows the changes of cucumber seedlings root/shoot ratio (RTR), average daily amount of dry matter increase (G) and seedling index (SI) on the 36th day after seedling emergence.

On the 16th day, the root/shoot ratio (RTR) in T5 and T6 are larger than that of the other treatments, and

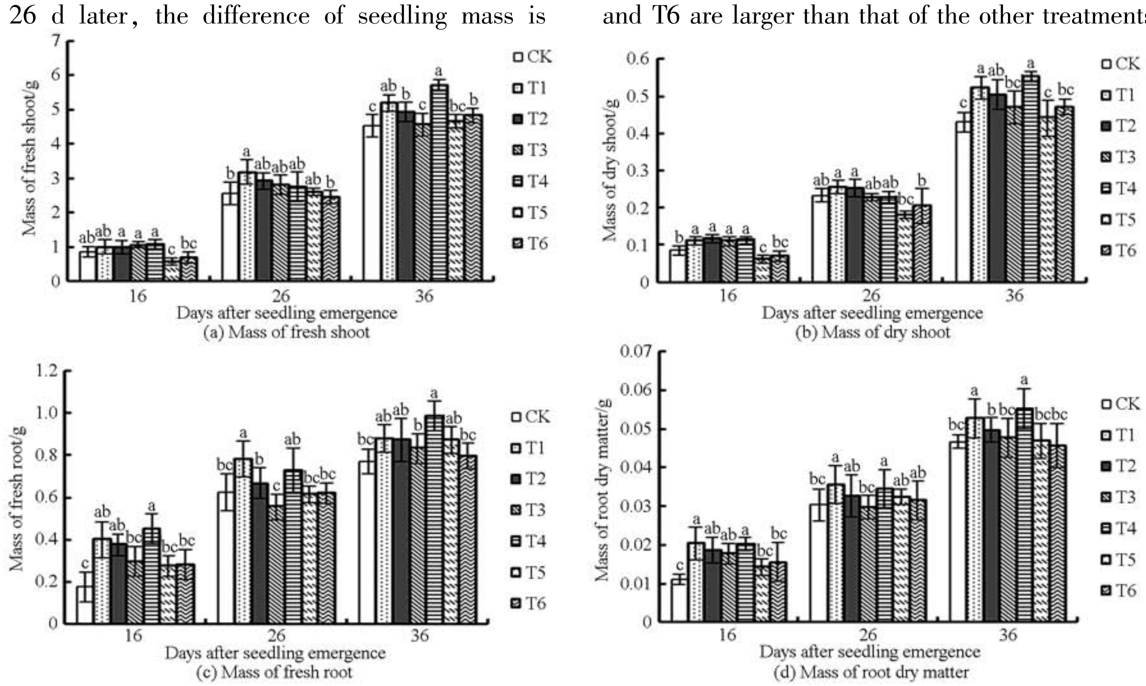

Fig. 6 The comparison of each treatment on fresh mass of cucumber seeding and dry mass of shoot and root

Tab. 3 Comparison of each treatment on cucumber quality

Treatments		CK	T1	T2	T3	T4	T5	T6
16th day	RTR/($g \cdot g^{-1}$)	0.13 ± 0.02c	0.18 ± 0.01b	0.16 ± 0.01b	0.16 ± 0.01b	0.18 ± 0.01b	0.23 ± 0.01a	0.22 ± 0.02a
	G/($g \cdot d^{-1}$)	0.005 3 ± 0.000 5b	0.007 0 ± 0.000 5a	0.007 3 ± 0.000 7a	0.006 9 ± 0.000 8a	0.007 1 ± 0.000 4a	0.003 8 ± 0.000 2c	0.004 3 ± 0.000 2bc
	SI	0.047 7 ± 0.006 7b	0.078 0 ± 0.007 5a	0.079 9 ± 0.008 4a	0.081 9 ± 0.005 2a	0.078 7 ± 0.005 4a	0.057 5 ± 0.003 3b	0.055 5 ± 0.001 2b
26th day	RTR/($g \cdot g^{-1}$)	0.14 ± 0.02bc	0.12 ± 0.01bc	0.13 ± 0.01bc	0.12 ± 0.01bc	0.12 ± 0.02c	0.18 ± 0.02a	0.15 ± 0.02ab
	G/($g \cdot d^{-1}$)	0.008 7 ± 0.000 7bc	0.009 6 ± 0.000 7ab	0.010 5 ± 0.000 9a	0.008 7 ± 0.000 4bc	0.008 8 ± 0.000 5bc	0.007 0 ± 0.000 4d	0.007 9 ± 0.000 8cd
	SI	0.182 9 ± 0.020 7b	0.232 5 ± 0.030 9a	0.248 3 ± 0.019 4a	0.206 9 ± 0.014 7ab	0.176 1 ± 0.026 2b	0.170 5 ± 0.015 3b	0.216 2 ± 0.028 7ab
36th day	RTR/($g \cdot g^{-1}$)	0.09 ± 0.01a	0.09 ± 0.01a	0.10 ± 0.01a	0.10 ± 0.01a	0.09 ± 0.01a	0.10 ± 0.02a	0.09 ± 0.02a
	G/($g \cdot d^{-1}$)	0.012 5 ± 0.000 7c	0.015 4 ± 0.000 9a	0.015 4 ± 0.001 9a	0.014 6 ± 0.001 5ab	0.015 6 ± 0.000 4a	0.012 5 ± 0.001 3c	0.013 1 ± 0.000 6bc
	SI	0.370 5 ± 0.012 9b	0.489 2 ± 0.076 2ab	0.490 8 ± 0.100 2ab	0.457 2 ± 0.109 9ab	0.508 9 ± 0.098 5a	0.471 0 ± 0.031 9ab	0.408 0 ± 0.037 1b

the group CK has the smallest RTR value. 36 d later, there is no significant difference on RTR values among all treatments and all of them are stable at 0.09 ~ 0.10.

On the 16th day, there is no significant difference on G values among T1 ~ T4. Treatment T2 has the biggest G value (0.007 3 ± 0.000 7) g/d, and T5 has the smallest G value (0.003 8 ± 0.000 2) g/d. On the 26th day, G values in T3 and T4 are lower than that in T1 and T2 obviously, and G values in T5 and T6 are lower than that in CK significantly. On the 36th days, G values in T3 and T4 were increased, T4 has the biggest one and CK has the smallest one.

T1 and T2 which were treated by "Order 1" aquasorb have larger G values. The groups treated by "Order 2" aquasorb, their descending order of G values are T4, T6 and T5.

The values of seedling index in CK, T5 and T6 are lower than that of in T1 ~ T4 significantly on the 16th day. On the 36th day, the value of seedling index in CK is the lowest one, 0.370 5 ± 0.012 9. The values of seedling index in the groups treated by "Order 1" aquasorb have little difference at the level of 0.05. The descending order of seedling index values in the groups treated by "Order 2" aquasorb is T4, T6 and T5.

2.2.7 Root activities

Root is an important organ for plant to absorb water and mineral nutrition, and enzyme activity in root is the key indicator for its activity. TTC (triphenyl tetrazolium) reduction of roots can reflect the activity of succinate dehydrogenase which has higher correlation with respiration.

After 36 d of seedling emergence, the changes of root activity in all treatments are shown in Fig. 7. Root activities in treatments T1 and T4 are higher than that in the other treatments significantly. Root activities in the groups treated by "Order 1" aquasorb on descending order are T1, T2 and T3, and the groups treated by "Order 2" on descending order are T4, T5 and T6.

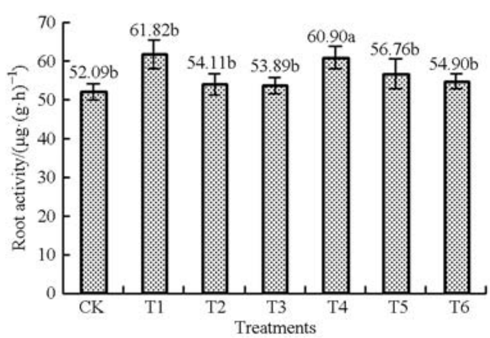

Fig. 7 The comparison of root activities 36 d after seedling emergence

3 Conclusions

(1) The two kinds of aquasorb can affect the physicochemical properties of substrate, ameliorate soil structure and enhance its water holding capacity. The tests show that cellulose aquasorb with weak alkaline can improve pH value of nursery substrate and also can cause fluctuation of conductivity (EC). Application of aquasorb can help to enhance substrate adsorbing on

nutrients, reduce their leaching losses and improve using efficiency of fertilizer.

(2) Aquasorb has the advantage of improving cucumber seedling index and root activity in plug seedling. Experimental results show that aquasorb with appropriate mass fraction is safe to cucumber seed germinating and seedling emergence. 36 d after seedling emergence, when the mass fraction of microcrystalline cellulose aquasorb is 0.3%, the G value, seedling index and root activity of cucumber seedlings can reach (0.015 4 ± 0.000 9) g/d, 0.489 2 ± 0.076 2 and 61.82 μg/(g · h), respectively. When the mass fraction of straw residue aquasorb is 0.3%, G value, seedling index and root activity of cucumber seedlings can reach (0.015 6 ± 0.000 4) g/d, 0.508 9 ±0.098 5, 60.90 μg/(g·h), respectively.

(3) Due to higher water absorption ratio, excessive application of aquasorb will affect permeability of substrate and inhibit growth of seedlings. By orthogonal experiment, microcrystalline cellulose and straw residue aquasorb are synthesized in the laboratory, and their maximum water absorption ratios can reach 401.20 g/g and 382.22 g/g, respectively.

(4) The absorbency of microcrystalline cellulose aquasorb is higher than that of straw residue aquasorb, but the cost of microcrystalline cellulose aquasorb also is higher. As fermentation material in large biogas project, the accumulation of straw residue will pollute the surrounding environment. Transforming straw residue into aquasorb is one of effective ways to use waste resources.

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doi:10.6041/j.issn.1000-1298.2016.01.021

纤维素保水剂对基质特性和黄瓜幼苗生长的影响

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摘要: 作为新型高分子节水材料,保水剂能够改善土壤结构,提高土壤储水能力,促进作物生长。比较了微晶纤维素保水剂和秸秆沼渣保水剂在穴盘育苗中对基质理化性质和黄瓜幼苗根系活力、壮苗指数、日均干质量增长量等生长生理指标的影响。试验显示,2种保水剂的施用对改善土壤理化性质和促进黄瓜幼苗生长都具有显著的效果;第36天时,加入保水剂的各处理黄瓜幼苗壮苗指数均高于对照组,施用微晶纤维素保水剂质量分数在0.3%时,黄瓜幼苗日均干质量增长量可达(0.015 4±0.000 9)g/d,壮苗指数达0.489 2±0.076 2,根系活力达61.82 μg/(g·h);施用秸秆沼渣保水剂质量分数在0.3%时,黄瓜幼苗日均干质量增长量可达(0.015 6±0.000 4)g/d,壮苗指数达0.508 9±0.098 5,根系活力达60.90 μg/(g·h)。研究结果表明,秸秆沼渣保水剂可作为一种新型土壤保水剂应用到黄瓜育苗生产中。

关键词: 黄瓜幼苗; 纤维素保水剂; 秸秆沼渣; 基质

中图分类号: S626.5　　**文献标识码:** A　　**文章编号:** 1000-1298(2016)01-0162-08

Effects of Cellulose Aquasorb on Properties of Substrate and Growth of Cucumber Seedling

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Abstract: As a new type of water-saving polymer materials, aquasorb can ameliorate soil structure, facilitate formation of soil aggregate, enhance water holding capacity of soil, adjust plant rhizosphere environment, reduce the loss of soil nutrients and promote crop growth. In the experiment, microcrystalline cellulose aquasorb and straw residue aquasorb were synthesized using by orthogonal optimization. In the process, acrylic acid was employed as graft monomer, potassium persulfate (KSP) as initiator, and N, N′-methylene bisacrylamide (NMBA) as crosslinking agent. The the max water absorbency of two aquasorbs (microcrystalline cellulose aquasorb and straw residue aquasorb) were 401.20 g/g and 382.22 g/g, respectively. In this paper, the effects of these two kinds of cellulose aquasorbs on the physicochemical properties of the substrate and growth physiological indexes of cucumber seedlings such as roots activity, seedling index and G value (the growth rate of the daily average dry mass) etc. were compared. The results indicate that after the addition of two cellulose aquasorbs in plug seedling, there are significant effects on promoting soil physicochemical properties and the growth of cucumber seedlings. After 36 days, when the mass fraction of microcrystalline cellulose aquasorb is 0.3%, the G value, seedling index and root activity of cucumber seedlings samples can reach (0.015 4±0.000 9) g/d, 0.489 2±0.076 2 and 61.82 μg/(g·h), respectively. When the mass fraction of added straw residue aquasorb is 0.3%, the G value, seedling index and root activity of cucumber seedlings samples can reach (0.015 6±0.000 4) g/d, 0.508 9±0.098 5, 60.90 μg/(g·h), respectively. The research results show that straw residue aquasorb can be used as a new type soil aquasorb applied in field production.

Key words: cucumber seedling; cellulose aquasorb; straw residue; substrate

收稿日期: 2015-10-08　修回日期: 2015-11-04

基金项目: 公益性行业(农业)科研专项资金项目(201303108、201503137)

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引言

干旱问题始终是制约我国农业发展的重要因素[1]，土壤保水剂的开发为水资源高效利用提供了一条有效途径[2]。土壤保水剂属于具有很高吸水能力的高分子聚合物[3,4]，能够吸收自身质量几十甚至几百倍的水，吸水后形成水凝胶，并且可以反复吸水[5-6]。保水剂能够改善土壤结构，增加水稳性团聚体含量[7-9]，调节根际水、肥、气、热等生理环境，促进作物生长[10]。

为研究保水剂对基质保水能力和蔬菜幼苗质量的影响，蒋雅琴等[11]以茄子、丝瓜等为材料，利用 2 种不同粒径的保水剂进行育苗试验，结果显示育苗基质中加入保水剂后，能够明显提高基质的持水量，为幼苗生长持续提供必需的水分。韩旭等[12]利用黄瓜作为供试作物，研究保水剂添加量对育苗块成型效果及幼苗品质的影响，指出添加保水剂过多的育苗块会使育苗的成型率下降。罗华等[13]在盆栽生菜中施用 3 种保水剂，研究它们对土壤淋溶及生菜生长发育的影响，指出保水剂能够提高土壤含水量，减缓水分胁迫给植株带来的损害，间接提高了植株叶片中叶绿素含量。

作为新型高分子节水材料，淀粉类、纤维素类和合成类是目前应用较广的 3 类保水剂[14]。传统的高吸水性材料如聚丙烯酸、聚丙烯酰胺等均属于合成类聚合物，这些材料在自然环境中可降解性较低。淀粉类保水剂的不足是耐霉性差[15]。与淀粉类保水剂相比，纤维素类保水剂吸水率略低，但是其吸盐性能好，且 pH 值易调节，可生物降解，是一种环境友好型保水材料[16]。目前，纤维素保水剂的研究范围逐渐扩大，原料已经从传统的纤维素衍生物（如羧甲基纤维素、羟乙基纤维素）转变为天然纤维素，特别是秸秆、沼渣等富含纤维素的农业废弃物[17]。在这一背景下，课题组通过正交试验优化合成了微晶纤维素保水剂和秸秆沼渣保水剂。主要工艺路线是以微晶纤维素和秸秆沼渣纤维素为原料，丙烯酸为接枝单体，过硫酸钾（KSP）为引发剂，N，N′-亚甲基双丙烯酰胺为交联剂，在微波作用下接枝聚合，得到微晶纤维素保水剂和秸秆沼渣保水剂，2 种保水剂的最大吸水倍率分别为 401.20 g/g 和 382.22 g/g。

本文采用穴盘育苗，将制备的 2 种保水剂应用于黄瓜基质育苗中，通过对基质容重、pH 值和电导率等理化特性的测定以及对黄瓜幼苗根系活力、叶片叶绿素相对含量、根冠比、日均干质量增长量和壮苗指数等生长生理指标的检测和分析，研究不同用量水平下微晶纤维素保水剂和秸秆沼渣保水剂的应用效果，以期为该类保水剂的开发和推广提供参考。

1　材料与方法

1.1　试验材料

供试蔬菜：供试蔬菜为黄瓜，品种为“中农 18 号”，中国农业科学院蔬菜花卉研究所培育。

育苗基质：基质材料为草炭、蛭石和珍珠岩，北京振泰园艺设施有限公司提供，三者体积比为 2∶1∶1，土壤基质的基本理化性质见表 1。

表 1　土壤基质的基本理化性质

Tab.1　Basic physicochemical property of soil substrate

pH 值	电导率/($mS \cdot cm^{-1}$)	容重/($g \cdot cm^{-3}$)	有效氮质量比/($mg \cdot kg^{-1}$)	有效磷质量比/($mg \cdot kg^{-1}$)	速效钾质量比/($mg \cdot kg^{-1}$)
7.01	6.45	0.61	193.40	7.34	115.46

供试保水剂：2 种保水剂均由本课题组在中国农业大学、农业部设施农业生物环境工程重点实验室，通过正交试验优化合成。“1 号”保水剂：微晶纤维素保水剂；“2 号”保水剂：秸秆沼渣保水剂。

1.2　试验设计

试验于 2015 年 3 月 7 日—4 月 15 日在中国农业大学水利与土木工程学院日光温室进行。试验共设 7 个处理，微晶纤维素保水剂质量分数（保水剂/干基质）设为 0.3%（T1）、0.6%（T2）、0.9%（T3），秸秆沼渣保水剂质量分数设为 0.3%（T4）、0.6%（T5）、0.9%（T6），不加任何保水剂为对照组（CK）。采用 4×8 的穴盘育苗，每个空穴装干基质 50 g，将保水剂与干基质混合均匀后加入 30 mL 的水，测定初始状态下基质的理化性质。每个穴盘播 2 粒种子，出苗前，每天加入 300 mL 水，以保证黄瓜种子萌发。出苗后，每个穴盘只保留一棵幼苗，且对照组浇水时，保水剂的各处理组也同时浇水，且浇水量保持一定。黄瓜第 1 片真叶展开后，开始浇营养液（播种后 15 d），每 5 d 浇一次营养液，每个穴盘浇 200 mL。营养液采用日本园式营养液配方：KNO_3 810 mg/L、$Ca(NO_3)_2$ 950 mg/L、$MgSO_4$ 500 mg/L、KH_2PO_4 155 mg/L、铁螯合物 20 mg/L。

黄瓜第 1 片真叶展开（播种后 15 d）到 3 叶 1 心（苗龄 37 d）时期，每隔 5 d 测定瓜苗的株高、茎粗和叶绿素相对含量等指标，每组处理均选 6 个重复。

黄瓜幼苗长至第16天时,每隔10 d分别从7组处理中取样,测定基质的基本理化性质、瓜苗的株高、茎粗及地上部、地下部干鲜质量。37 d结束后测定每组处理的根系活力。

1.3　测定项目与方法

1.3.1　基质的理化性质

测定项目包括相对含水率、基质容重、pH值和电导率(EC)。其中,相对含水率、基质容重的测定方法参照文献[18],其他测定项目主要是参照鲍士旦[19]方法。

1.3.2　黄瓜幼苗生长形态指标

株高:用直尺测量从幼苗生长点到基质表面的距离。

茎粗:用电子数显卡尺测量幼苗子叶下端、茎基部的粗度。

叶绿素相对含量:在10:00—11:00采用SPAD-502型叶绿素仪测定,在植株的叶片上随机选取10个位置,取其平均值即为该植株叶片叶绿素相对含量。

地上部、地下部的干鲜质量:将洗净后的幼苗水分吸干,根部为地下部,剩下为地上部,称其质量,即为鲜质量;杀青并干燥至恒质量后即得干质量。黄瓜幼苗质量采用根冠比(RTR)、日均干质量增长量(G)和壮苗指数(SI)进行评价[20-21]。

根系活力:采用TTC(氯化三苯基四氮唑)还原法测定[22]。

2　结果与讨论

2.1　保水剂用量对基质理化性质的影响

2.1.1　对基质pH值和电导率(EC)的影响

各处理组基质pH值和EC的变化情况如图1所示。从图1可以看出,pH值和EC均随培养天数的增加而逐渐增大。图1a中反映出2种保水剂用量越多,pH值也越大,这是纤维素保水剂呈弱碱性所致,保水剂的用量与pH值呈正相关。图1b表示2种保水剂用量对基质电导率的影响先升后降,且不加保水剂的CK组在36 d后pH值和EC均为最低值。

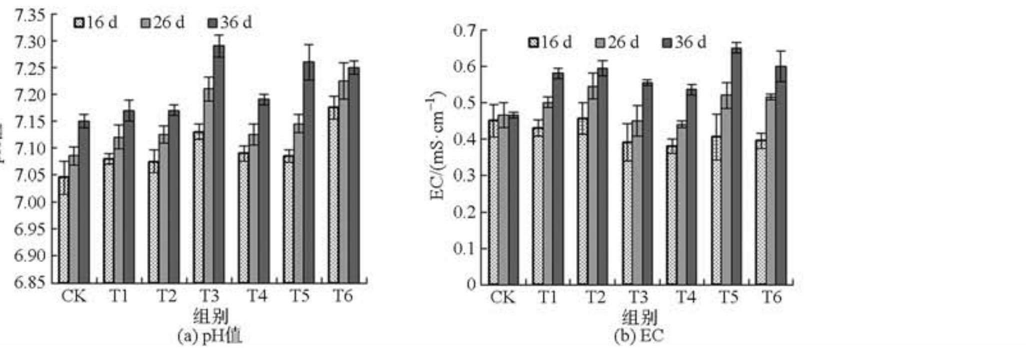

图1　不同培养天数各处理中基质pH值和电导率(EC)的比较

Fig. 1　Comparison of each treatment for pH value and EC value on different cultivation days

2.1.2　对基质容重和相对含水率的影响

36 d内各处理基质容重和相对含水率的变化见表2。从表中可以看出,在培养第16天时,不加保水剂的CK组和保水剂用量少的T1、T4组基质容重较大,这3组在0.05水平下差异均不显著,T4组的容重和相对含水率均为该时期的最大值。第26天时,各组之间容重与16 d时差别不大,CK相对含水率仍最小。到了第36天时,不加保水剂的CK组容重最大,相对含水率最小;且2种保水剂对基质容重影响由大到小顺序为T1、T2、T3,T4、T6、T5;2种保水剂对基质相对含水率的影响由大到小顺序为T3、T2、T1,T6、T5、T4,由此可以看出,相同灌水条件下,保水剂用量与基质容重呈负相关,而与基质相对含水率呈正相关。

2.2　保水剂用量对黄瓜幼苗生长形态的影响

2.2.1　对黄瓜出苗率的影响

种植7 d后检查各处理的出苗情况,每个处理组黄瓜出苗率如图2所示。从图2可以看出,各处理与对照组CK之间黄瓜出苗率均大于90%,差异均不显著,说明2种保水剂对黄瓜种子萌发和出苗都是安全的。

2.2.2　对黄瓜幼苗株高的影响

各处理中,黄瓜幼苗株高的变化情况如图3所示。在培养37 d内对照组CK的株高均高于其他加入保水剂的6个处理。在培养15—30 d时,T2与T4组株高差异不显著,且均高于其他加入保水剂的处理组;T1与T3、T5与T6之间的株高差异也不显著,但T5与T6的株高要低于T1与T3组。培养35—37 d时,T1、T3组黄瓜幼苗的株高与T2和T4组之间的株高无差异,均高于T5和T6组,T5组株高最低。由此可以看出,“1号”保水剂用量对黄瓜株高的影响由大到小为T2、T1、T3;而“2号”保水剂的用量对黄瓜幼苗株高的影响由大到小为T4、T6、T5。

表 2　各处理基质容重与相对含水率的比较

Tab. 2　Comparison of each treatment on substrate unit weight and relative water content

处理	第 16 天		第 26 天		第 36 天	
	容重/(g·cm^{-3})	相对含水率/%	容重/(g·cm^{-3})	相对含水率/%	容重/(g·cm^{-3})	相对含水率/%
CK	0.44 ± 0.03^{ab}	34.25 ± 2.52^{b}	0.45 ± 0.01^{a}	28.17 ± 0.23^{d}	0.70 ± 0.02^{a}	40.39 ± 0.11^{c}
T1	0.45 ± 0.03^{ab}	36.47 ± 1.99^{b}	0.43 ± 0.02^{abc}	31.05 ± 0.67^{c}	0.58 ± 0.01^{b}	41.13 ± 0.71^{bc}
T2	0.41 ± 0.02^{b}	37.93 ± 2.09^{ab}	0.45 ± 0.01^{ab}	28.48 ± 0.25^{d}	0.48 ± 0.01^{c}	41.75 ± 0.61^{abc}
T3	0.41 ± 0.01^{b}	35.92 ± 2.97^{b}	0.42 ± 0.02^{bc}	30.56 ± 1.38^{c}	0.45 ± 0.01^{cd}	43.36 ± 0.84^{a}
T4	0.48 ± 0.03^{a}	42.92 ± 2.65^{a}	0.43 ± 0.02^{abc}	34.63 ± 0.85^{b}	0.54 ± 0.03^{b}	40.53 ± 0.36^{c}
T5	0.41 ± 0.01^{b}	34.03 ± 1.14^{b}	0.41 ± 0.02^{c}	39.42 ± 0.82^{a}	0.42 ± 0.04^{d}	41.16 ± 1.15^{bc}
T6	0.43 ± 0.01^{ab}	37.25 ± 0.45^{ab}	0.43 ± 0.02^{bc}	36.50 ± 1.18^{b}	0.45 ± 0.01^{cd}	42.42 ± 0.11^{ab}

注：数据格式为“平均值 ± 标准差”，同列不同的小写字母表示在 0.05 水平下的差异显著，下同。

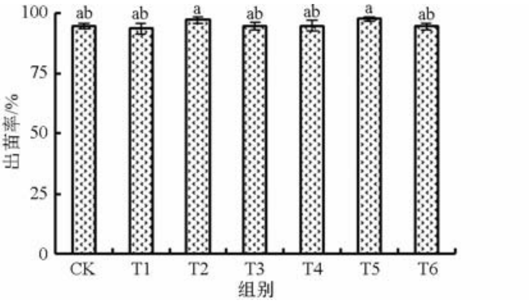

图 2　各处理黄瓜出苗率的比较

Fig. 2　Comparison of each treatment on emergence rate of cucumber seedlings

出现这种试验结果的原因是：由于保水剂的吸水和持水能力强，栽培基质中含水率增加，影响到根圈环境的透气性，从而在植株生育前期抑制了黄瓜幼苗的生长。随着幼苗生长时间的延长和对水分需求的增加，保水剂吸收的水分逐渐释放出来又有利于促进幼苗的生长。

2.2.3　对黄瓜幼苗茎粗的影响

各处理对黄瓜幼苗茎粗的影响如图 4 所示。从图中可以看出，培养 15 d 时，T1、T3 和 T4 组之间的差异不显著，T3 茎粗最大，CK、T5 和 T6 组之间差异不显著，均为该时期茎粗最小的处理。随着培养天数的增加，T2 和 T6 组的茎粗不断增大，到培养 30 d 时，CK 和 T4 组茎粗在 7 个处理中为最小，T1、T5 和 T6 之间差异不显著，但均低于 T2 和 T3 组。35 d 时，CK、T1、T4 和 T5 之间的茎粗无显著差异，但 CK 与 T4 茎粗最小，T2、T3 和 T6 之间差异不显著，T3 组茎粗最大。到培养第 37 天时，“1 号”保水剂不同用量对茎粗的影响由小到大为 T1、T2、T3，“2 号”保水剂不同用量对茎粗的影响由小到大为 T4、T5、T6。

2.2.4　对黄瓜幼苗叶绿素相对含量的影响

光合速率是反映作物物质积累的重要指标，且与幼苗叶片中叶绿素含量有密切关系。图 5 是采用 SPAD－502 型叶绿素仪测定的各处理黄瓜幼苗叶绿素相对含量（SPAD 值）。

从图 5 可以看出，在培养 15 d（第 1 片真叶）时期，各处理组黄瓜幼苗叶片叶绿素相对含量 SPAD 值均大于 30，但 CK 与 T1、T2、T3、T4、T5 组之间的差异不显著，与 T6 在 0.05 水平下差异显著。此时，CK 组黄瓜幼苗叶片 SPAD 值最大，T6 组黄瓜幼苗叶片 SPAD 值最小。

第 35 天时 T1 组黄瓜幼苗叶片 SPAD 值有所下降，与 T2 和 T4 组在 0.05 水平下差异显著。到第

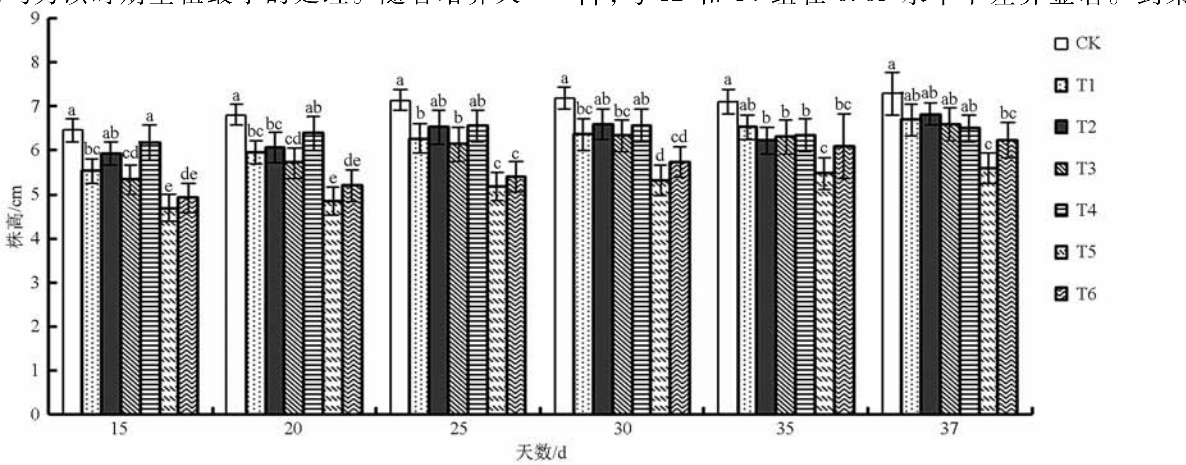

图 3　各处理组黄瓜幼苗株高的比较

Fig. 3　Comparison of each treatment on cucumber seeding height

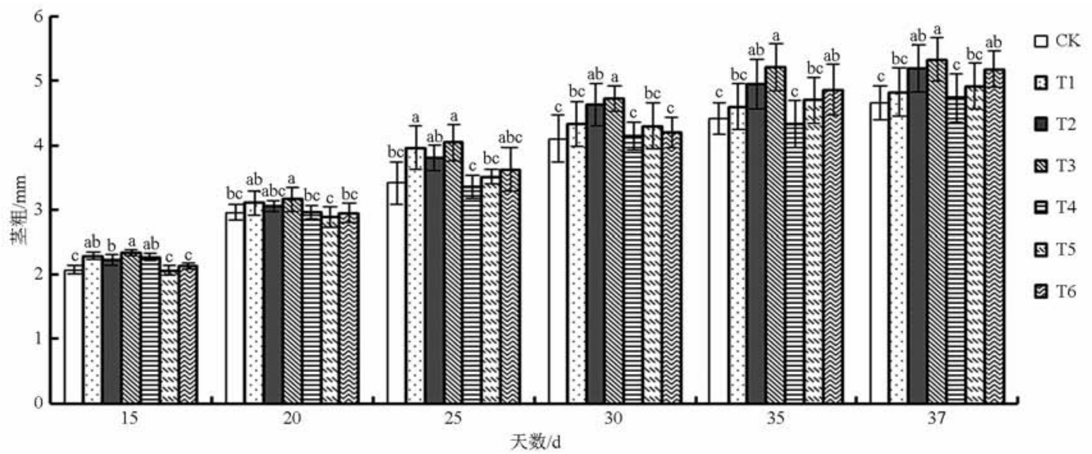

图4 各处理黄瓜幼苗茎粗的比较

Fig. 4 Comparison of each treatment on cucumber seeding stem diameter

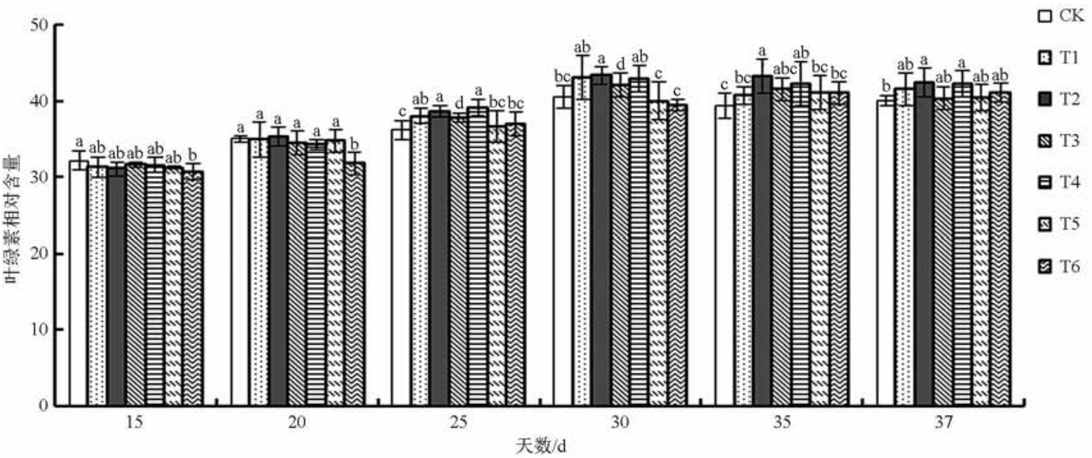

图5 各处理黄瓜幼苗叶绿素相对含量(SPAD值)的比较

Fig. 5 Comparison of each treatment on cucumber seeding chlorophyll relative content(SPAD value)

37天时,有保水剂的各处理黄瓜幼苗叶片SPAD值均高于不加保水剂的CK组,且T2和T4组黄瓜幼苗叶片SPAD值最大。

2.2.5 对黄瓜幼苗干、鲜质量的影响

干、鲜质量是衡量黄瓜幼苗植株长势的一个重要指标。图6列出了各处理中黄瓜幼苗地上部和地下部的鲜质量与干质量变化。

在培养16 d时,由图6a和图6b可以看出,T1、T2、T3与T4组之间黄瓜幼苗地上部干、鲜质量差异不大,T5组最小;图6c和图6d可以看出此时CK组黄瓜幼苗地下部干、鲜质量最小,T1、T2和T4地下部黄瓜幼苗干、鲜质量都比较大,三者之间的差异不显著。培养26 d时黄瓜幼苗地上部和地下部的干、鲜质量差异逐渐明显。到培养第36天时,不加保水剂的CK组黄瓜幼苗地上部和地下部的鲜质量均最小,“1号”保水剂各处理对黄瓜幼苗地上部和地下部干、鲜质量的影响由大到小都是T1、T2、T3;“2号”保水剂各处理对黄瓜幼苗地上部的干、鲜质量影响由大到小为T4、T6、T5,对地下部干、鲜质量的影响由大到小为T4、T5、T6。

2.2.6 对黄瓜幼苗品质的影响

各处理36 d内黄瓜幼苗根冠比(RTR)、日均干质量增长量(G)和壮苗指数(SI)的变化如表3所示。

第16天时,T5和T6组根冠比最大,CK组最小;到培养36 d后,各处理间差异不显著,根冠比均稳定在0.09~0.10。黄瓜幼苗日均干质量增长量(G)在第16天时,T1~T4组差异均不显著,此时T2组G值最大,为(0.007 3 ± 0.000 7) g/d,T5组G值最小,为(0.003 8 ± 0.000 2) g/d;第26天时,T3与T4组的G值显著低于T1与T2组,T5与T6也显著低于CK组;到了36 d后,T3与T4组黄瓜幼苗日均干质量增长量升高,T4组G值最大,CK组G值最小,“1号”保水剂处理的T1与T2组G值都较大,“2号”保水剂各处理G值由大到小为T4、T6、T5。

黄瓜壮苗指数在16 d时,CK、T5和T6组显著低于T1~T4组。到第36天时,不加保水剂的CK组壮苗指数最低,为0.370 5 ± 0.012 9,“1号”保水剂各处理壮苗指数在0.05水平下差异不大,“2号”

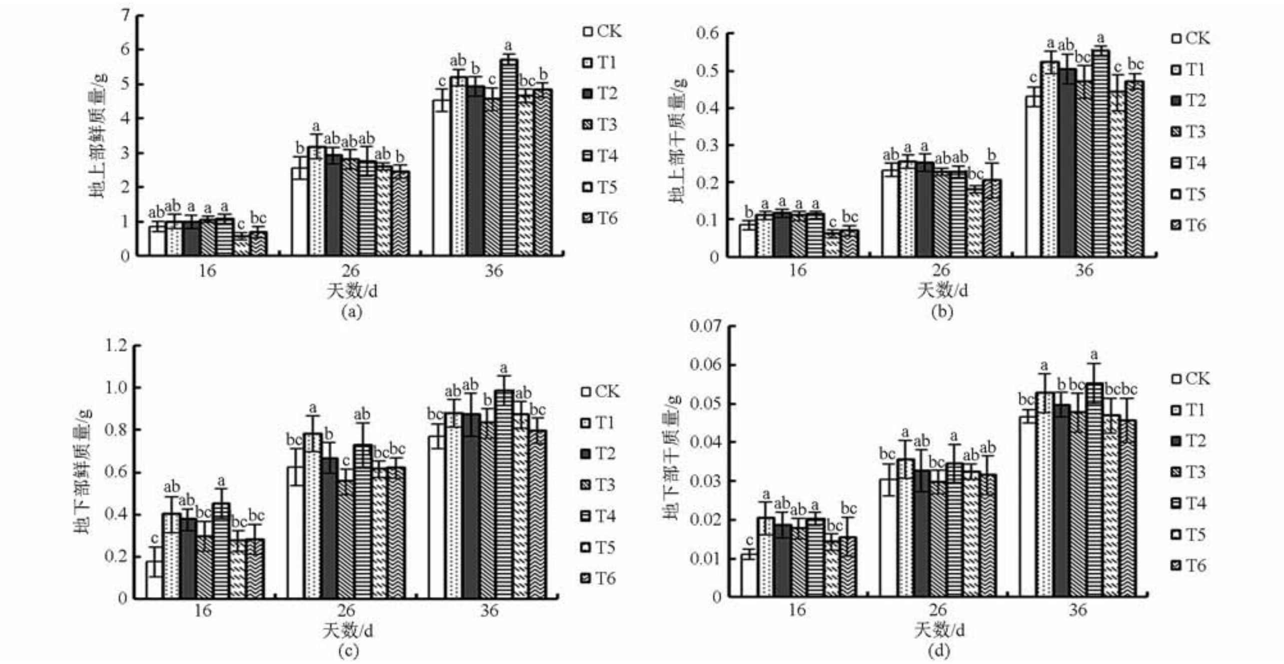

图 6　各处理组黄瓜幼苗地上部与地下部干、鲜质量的比较

Fig. 6　Comparison of each treatment on fresh mass of cucumber seeding and dry mass of shoot and root

表 3　各处理组黄瓜幼苗品质的比较

Tab. 3　Comparison of each treatment on cucumber qualities

天数/d	参数	CK	T1	T2	T3	T4	T5	T6
16	根冠比	0.13±0.02^{c}	0.18±0.01^{b}	0.16±0.01^{b}	0.16±0.01^{b}	0.18±0.01^{b}	0.23±0.01^{a}	0.22±0.02^{a}
	G/(g·d^{-1})	0.005 3±0.000 5^{b}	0.007 0±0.000 5^{a}	0.007 3±0.000 7^{a}	0.006 9±0.000 8^{a}	0.007 1±0.000 4^{a}	0.003 8±0.000 2^{c}	0.004 3±0.000 2^{bc}
	壮苗指数	0.047 7±0.006 7^{b}	0.078 0±0.007 5^{a}	0.079 9±0.008 4^{a}	0.081 9±0.005 2^{a}	0.078 7±0.005 4^{a}	0.057 5±0.003 3^{b}	0.055 5±0.001 2^{b}
26	根冠比	0.14±0.02^{bc}	0.12±0.01^{bc}	0.13±0.01^{bc}	0.12±0.01^{bc}	0.12±0.02^{c}	0.18±0.02^{a}	0.15±0.02^{ab}
	G/(g·d^{-1})	0.008 7±0.000 7^{bc}	0.009 6±0.000 7^{ab}	0.010 5±0.000 9^{a}	0.008 7±0.000 4^{bc}	0.008 8±0.000 5^{bc}	0.007 0±0.000 4^{d}	0.007 9±0.000 8^{cd}
	壮苗指数	0.182 9±0.020 7^{b}	0.232 5±0.030 9^{a}	0.248 3±0.019 4^{a}	0.206 9±0.014 7^{ab}	0.176 1±0.026 2^{b}	0.170 5±0.015 3^{b}	0.216 2±0.028 7^{ab}
36	根冠比	0.09±0.01^{a}	0.09±0.01^{a}	0.10±0.01^{a}	0.10±0.01^{a}	0.09±0.01^{a}	0.10±0.02^{a}	0.09±0.02^{a}
	G/(g·d^{-1})	0.012 5±0.000 7^{c}	0.015 4±0.000 9^{a}	0.015 4±0.001 9^{a}	0.014 6±0.001 5^{ab}	0.015 6±0.000 4^{a}	0.012 5±0.001 3^{c}	0.013 1±0.000 6^{bc}
	壮苗指数	0.370 5±0.012 9^{b}	0.489 2±0.076 2^{ab}	0.490 8±0.100 2^{ab}	0.457 2±0.109 9^{ab}	0.508 9±0.098 5^{a}	0.471 0±0.031 9^{ab}	0.408 0±0.037 1^{b}

保水剂对壮苗指数的影响由大到小为 T4、T5、T6。

2.2.7　对根系活力的影响

根系是植物吸收水分和矿质营养的重要器官，根内酶活性是衡量根系活力的重要指标，根系的 TTC（氯化三苯基四氮唑）还原作用反映了根内琥珀酸脱氢酶的活性，它和呼吸作用有较高的相关性。

各处理 36d 后根系活力变化情况如图 7 所示。从图 7 可以看出，T1 与 T4 的根系活力显著大于其他组，其中“1 号”保水剂各处理对根系活力的影响由大到小为 T1、T2、T3，“2 号”保水剂各处理对根系活力的影响由大到小为 T4、T5、T6。

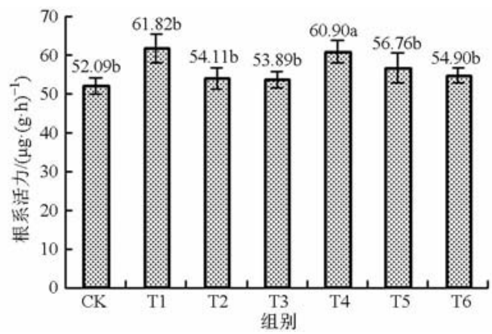

图 7　培养 36 d 后各处理组黄瓜幼苗根系活力的比较

Fig. 7　Comparison of each treatment on cucumber root activity after cultivating 36 d

3 结论

（1）2 种保水剂均能影响基质理化特性，有助于改善土壤结构，增加基质持水和保水能力。试验显示纤维素保水剂呈弱碱性，可以提高育苗基质的 pH 值，同时也引起基质电导率（EC）的波动。保水剂的施用有利于增强基质对营养物质的吸附作用，减少养分淋失，提高肥料利用效率。

（2）穴盘育苗中，保水剂有助于提高黄瓜幼苗根系活力和壮苗指数。试验表明，适当浓度的保水剂对黄瓜种子萌发和出苗是安全的。第 36 天时，施用保水剂的处理黄瓜壮苗指数均高于对照组；微晶纤维素保水剂质量分数在 0.3% 时，黄瓜幼苗日均干质量增长量可达到（0.015 4 ± 0.000 9）g/d，壮苗指数达到 0.489 2 ± 0.076 2，根系活力达到 61.82 μg/（g·h）；施用秸秆沼渣保水剂质量分数在 0.3% 时，黄瓜幼苗日均干质量增长量可达到（0.015 6 ± 0.000 4）g/d，壮苗指数达到 0.508 9 ± 0.098 5，根系活力达到 60.90 μg/（g·h）。

（3）保水剂的吸水倍率高，过量施用会抑制幼苗生长。本试验应用的 2 种保水剂通过正交试验优化合成，微晶纤维素保水剂和秸秆沼渣保水剂最大吸水倍率分别为 401.20 g/g 和 382.22 g/g。由于保水剂的吸水和持水能力强，高浓度施用容易导致基质含水率过大，影响到基质的透气性，降低幼苗根系活力，抑制黄瓜幼苗的生长。

（4）微晶纤维素保水剂吸水性能高于秸秆沼渣保水剂，但微晶纤维素保水剂合成成本较高。沼气工程中使用秸秆作为发酵原料，沼渣的大量堆积会对环境造成污染，利用秸秆沼渣合成新型土壤保水剂，是实现废弃物资源化高效利用的一种有效途径。

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