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Selection of a Vegetable Water–Retaining Material and Its Effects on the Growth and Quality of Cucumber under Drought Stress Part 2: Effects of Common Water Hyacinth on the Growth and Quality of Cucumber

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Common water hyacinth was selected as a vegetable water–retaining material suitable to crop cultivation in the area prone to seasonal drought in Part 1 of this study. A pot experiment was carried out to examine the effects of common water hyacinth on the growth and quality of cucumber under drought stress. Common water hyacinth was added at three levels equivalent to 1/2, 1 and 2 times of the water–retention capacity of SAP (super absorbent polymers), a presently used chemical water–retaining material. Addition of common water hyacinth improved the growth and quality of cucumber. At the same time, it increased the soil water content by 9.2 to 11.9%, depending on the growth stages, from the level of the control, which was equivalent to the increase by addition of SAP. Results of the pot experiment suggested that common water hyacinth could be a good alternative to SAP.

INTRODUCTION

Crop production has been frequently suffered from seasonal drought in the karst mountain area distributed largely in Guangxi Province, People's Republic of China. Construction of irrigation facilities is difficult due to steepness of the slope. Use of super absorbent polymers (SAP) is executed at present as a practical way to solve drought stress on crop production. However, SAP is hardly biodegraded in soil. In addition, its high cost limits the comprehensive use by farmers. It is necessary to look for another material to replace SAP. The material should be cheap and easy to be collected, and have least impact on the environment.

In Part 1 of the study (Yang *et al.*, 2008), three kinds of aquatic plants were tested on the function as a water–retaining material. Among them, common water hyacinth (*Eichhornia crassipes*) was regarded as an appropriate and actual water–retaining material in the crop production. In the present study, the function of common water hyacinth as a water–retaining material was further evaluated, under comparison with SAP, on the effects on the growth and quality of cucumber under drought stress.

MATERIALS AND METHODS

Experimental site

The experimental site is the same as Part 1 of the study (Yang *et al.*, 2008).

Pot experiment

The effects of addition of common water hyacinth on the growth and quality of cucumber were examined in the pot experiment under natural weather conditions in the greenhouse of the College of Agriculture, Guangxi University. The pot experiment was conducted from September 2006 to April 2007.

Soil and common water hyacinth

Red soil was collected from the sugarcane farm of Guangxi University in Nanning City to prevent the pot experiment from occurrence of soil–borne disease or happening of malfunction by cropping. Fundamental chemical properties of the soil were given in Table 1 of Part 1 (Yang *et al.*, 2008).

Common water hyacinth was collected from the pond near Guangxi University of Nanning City and was dried at 70 °C in an oven and pulverized into powder by a mechanical grinder before use. SAP was bought in market.

Cultivation of cucumber, fertilization and drought stress imposed

Two young seedlings of cucumber (variety of JinYan), bought in market, were planted in each plastic pot having 0.1 m^2 area and packed with 10 kg of red soil. At the first day of planting water equivalent to 80% of the maximum moisture–holding capacity of the soil was supplied, and pots were all placed in the greenhouse in order to avoid additional watering during the whole growing stage.

The following organic and chemical fertilizers were applied per 667 m^2: 2,500 kg of animal fecal waste, 25 kg of $(NH_4)_2SO_4$, 15 kg of $Ca(H_2PO_4)_2$ and 100 kg of plant and wood ash. Thirty % of all fertilizers were applied as basal dressing in time of planting, and the remaining 70% was applied as topdressing in the seedling, flores-

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cence and fruiting stages. A shallow furrow was dug near cucumber stems before fertilization, and fertilizers were applied and mixed with soil.

Drought stress was imposed to cucumber plants in the seedling, florescence and fruiting stages. In the usual cultivation practice, cucumber should be watered every day in the greenhouse because of cutoff of rainfall and of shallow root spreading. In the drought treatment, watering to cucumber was stopped when cotyledon started to spread out in the seedling stage, when the first flower was observed in the florescence stage, and when the first fruit was produced in the fruiting stage, and was continued for 7 consecutive days. The drought stress was imposed in a less strong extent in Part 2 (this study) than in Part 1 (Yang *et al.*, 2008), because some seedlings wilted to death by the 10–days drought treatment in Part 1 (Yang *et al.*, 2008). The soil sample for measurement of the water content was collected in each of the seedling, florescence and fruiting stages before re–watering after the drought treatment.

Treatments and addition rates of common water hyacinth

According to the water–retention capacity of SAP and its recommended application rate, the amount of common water hyacinth added was designed to be equivalent to 2, 1 and 1/2 times of the water–retention capacity of the recommended weight of SAP. As obtained in Part 1 (Yang *et al.*, 2008), the water–retention capacity of unit weight of SAP was 2.6 times of that of unit weight of common water hyacinth. Based on this rate, the following treatments were set:

Treatment CK: control without addition of any water–retaining material;

Treatment A: addition of 1.0 g of SAP (dry weight) to a pot, according to the instruction manual and the pot area, as another control;

Treatment B: addition of 5.2 g of common water hyacinth to a pot, which is equivalent to 2 times of the water–retention capacity of the recommended weight of SAP;

Treatment C: addition of 2.6 g of common water hyacinth to a pot, which is equivalent to the water–retention capacity of the recommended weight of SAP;

Treatment D: addition of 1.3 g of common water hyacinth to a pot, which is equivalent to 1/2 times of the water–retention capacity of the recommended weight of SAP.

SAP of the recommended weight and common water hyacinth of the designed weights were added to a furrow (15~20 cm deep) around cucumber stems, followed by watering and returning of soil.

Measurement of the water and organic matter contents

In each of the five treatments, soil was sampled from the depth of 0 to 20 cm after imposition of drought stress in the seedling, florescence and fruiting stages. The water content was obtained by weighing soil sample before and after oven–drying at 105 ˚C (Committee of Standard Methods for Analysis and Measurement of Soil (ed), 1986). Sampling for the determination of the organic carbon content was done before planting and after harvesting. The organic carbon content was determined by the Tyurin method (Committee of Standard Methods for Analysis and Measurement of Soil (ed), 1986) and was multiplied by the coefficient of 1.724 to give the organic matter content.

Assessment of the growth and quality of cucumber

As parameters relating to the growth of cucumber, length and weight of roots in the harvesting time after imposition of drought stress were assessed by the method of direct measurement (Committee of Standard Methods for Analysis and Measurement of Plant Nutrients (ed), 2001). In addition to the root length and weight, flowering days of the first male and female flowers after planting were recorded.

Parameters such as concentrations of total potassium, total phosphorus, free amino acid and vitamin C in cucumber fruits after imposition of drought stress were used for evaluation of the quality of cucumber. Among them, total phosphorus and potassium concentrations were measured for assessment of the composition of mineral nutrients in cucumber fruits. Their concentrations were determined by the ascorbic acid method and atomic absorption spectrophotometry, respectively, after digestion with the HNO_3–$HClO_4$ mixture (Committee of Standard Methods for Analysis and Measurement of Plant Nutrients (ed), 2001).

The free amino acid concentration was assessed as a parameter of the food composition in cucumber fruits. It was determined following the ninhydrin method described by Bao (2000) and Helena *et al.* (2007) with a little modification. That is, a 20–50 g sample of finely cutting cucumber fruit was placed in a 1,000–ml beaker, and ethyl alcohol was added to make the liquid volume to 750 ml L^{-1}. Ten ml of this liquid was taken into an eggplant–shape flask and this flask was placed in an oil bath kept at a temperature of 80 ˚C for 15 min with a cold–finger condenser. After removal of the flask from the oil bath and cooling to the room temperature, the suspension was filtrated through a funnel and the residue was washed with 50 ml of ethyl alcohol. The filtrate and washing were collected together in a 250–ml volumetric flask. The flask was kept at –20 ˚C for overnight to get the precipitate. The content in the flask was centrifuged at 6,000 rpm for 10 min. The supernatant was collected and evaporated using a rotary evaporator. The residue was dissolved by 10 ml of 0.2 mol L^{-1} sodium citrate buffered at pH 3.3 for the determination of free amino acid.

The total vitamin C concentration was measured following the DNP–hydrazine method described by Bao (2000) with a little modification. Twenty g of fruit sample and the same weight of the 20 g L^{-1} oxalic acid solution were placed in a grinder to get slurry. Twenty g of the slurry was washed with the 10 g L^{-1} oxalic acid solution into a 100–ml volumetric flask to make volume to 100 ml. The filtrate was collected for the determination of vitamin C.

All measurements were done in triplicate.

Statistical analyses

Duncan's SSR test was used for the statistical analyses.

RESULTS AND DISCUSSION

Effects of addition of different levels of common water hyacinth on the water and organic matter contents of soil

Addition of common water hyacinth in different levels significantly increased the soil water content in every growing stage, except some cases, compared with the control with no–addition of water–retaining material (treatment CK) (Table 1). However, the increasing effect of addition of common water hyacinth on the soil water content was gradually reduced with advancement of the growing stage. It may suggest necessity of addition of common water hyacinth in every cropping for keeping the soil water content in a desired level. The result of the present study showed the similar tendency to the report of Sun *et al*. (2001).

Addition of SAP (treatment A) increased the soil water content larger than did addition of common water hyacinth (treatments B through D), but there was recognized no significant difference in the soil water content between treatments A and B except the florescence stage. That is, the soil water content was improved in the nearly same level as addition of SAP by addition of common water hyacinth at the rate equivalent to double of the water–retention capacity of SAP.

The soil organic matter content of all treatments was in the nearly same level or insignificantly different with one another at each of before–planting and after–harvesting (Table 1). However, it was greatly reduced after harvesting to the level of 45 to 60% of the content before planting. The relatively high organic matter content before planting, irrespective of the treatments, is probably due to application of organic fertilizers. They were expected to be quickly decomposed during a growing season of cucumber.

After harvesting, the soil organic matter content tended to be higher for the treatment with common water hyacinth than for the treatment with SAP and the control. However, no significant difference was observed among the five treatments. Namely, the soil organic matter content was insignificantly different between with and without addition of common water hyacinth, between common water hyacinth and SAP, and between the three levels of common water hyacinth.

Effects of addition of different levels of common water hyacinth on the growth of cucumber

The effects of addition of different levels of common water hyacinth on the growth of cucumber are shown in Table 2. Flowering days of the first male and female flowers after planting were within 39 to 40 days and 41 to 43 days, respectively, throughout the treatments. No significant difference was found in flowering of cucumber between with and without addition of common water hyacinth, between common water hyacinth and SAP, and between the three levels of common water hyacinth.

The length and weight of cucumber roots were only 16.7 cm and 25.7 g for the treatment CK (the control with no–addition of water–retaining material), 23.7 cm and 29.0 g for the treatment A (addition of the recommended weight of SAP), and ranged from 22.7 to 24.7 cm and from 28.0 to 33.3 g for the treatments B through D (addition of different levels of common water hyacinth). Contrast to the flowering performance, the root growth was clearly and positively affected by addition of common water hyacinth.

Table 1. Effects of addition of different levels of common water hyacinth on the water and organic matter contents of soil

Treatment	Water content (g kg^{-1})			Organic matter content (g kg^{-1})	
	Seedling stage	Florescence stage	Fruiting stage	Before planting	After harvesting
CK	449b	312c	222c	14.0	6.3a
A	542a	502a	336a	13.9	7.3a
B	541a	431b	315a	14.1	8.4a
C	531a	421b	262bc	14.4	7.8a
D	500a	367c	247bc	14.3	7.3a

Different alphabets mean statistical difference at the 5% level.

Table 2. Effects of addition of different levels of common water hyacinth on the growth of cucumber

Treatment	Flowering days after planting (days)		Root	
	First male flower	First female flower	Length (cm)	Weight (g)
CK	40a	43a	16.7b	25.7c
A	39a	41a	23.7a	29.0abc
B	39a	43a	22.7a	33.3a
C	39a	42a	24.7a	33.0a
D	40a	41a	23.3a	28.0abc

Different alphabets mean statistical difference at the 5% level.

Table 3. Effects of addition of different levels of common water hyacinth on the quality of cucumber

Treatment	Concentration (mg kg^{-1})			
	Total potassium	Total phosphorus	Free amino acid	Vitamin C
CK	4673a±155	220a±20.0	59.7a±12.1	80.0a±10.0
A	4960a±226	250a±26.5	67.0a±4.4	86.7a±5.8
B	4837a±104	260a±20.0	67.7a±5.0	96.7a±15.3
C	4637a±186	247a±15.3	60.0a±6.2	100.0a±10.0
D	4590a±311	226a±15.3	57.3a±13.1	93.3a±15.3

Different alphabets mean statistical difference at the 5% level.

The root length of cucumber was significantly improved by addition of common water hyacinth, compared with the control (treatment CK). However, no significant difference was noticed between common water hyacinth and SAP and between the three levels of common water hyacinth. In case of the root weight of cucumber, it was significantly improved by addition of common water hyacinth at the rate equal to double and equal levels of the water–retention capacity of SAP (treatments B and C) but not by addition of common water hyacinth at the rate equal to half level of the water–retention capacity of SAP (treatment D) and SAP (treatment A), compared with the control (treatment CK).

The above results clearly showed that addition of common water hyacinth had a better effect on the growth of cucumber root and that its improving effect was equal to or greater than the effect of SAP.

Effects of addition of different levels of common water hyacinth on the quality of cucumber

The effects of the treatment with different levels of common water hyacinth on the quality of cucumber are shown in Table 3. The total potassium concentration of cucumber fruits was highest for SAP (treatment A) with a value of 4,960 mg kg^{-1} which was higher by about 300 mg kg^{-1} than the concentration for the control (treatment CK). The total potassium concentration of cucumber fruits for the treatments with the three levels of common water hyacinth (treatments B through D) ranged from 4,590 to 4,837 mg kg^{-1} and rose with the increasing level of addition of common water hyacinth. However, no significant difference was found among the five treatments.

The total phosphorus concentration of cucumber fruits showed the almost same tendency as the total potassium concentration. The results suggested that addition of common water hyacinth at the rate equivalent to double of the water–retention capacity of SAP tended to improve the mineral nutrients composition of cucumber fruits, although the effect was statistically insignificant, with maintaining the soil water content in an improved level and stimulating the growth of cucumber roots.

The free amino acid concentration of cucumber fruits was 59.7 mg kg^{-1} for the control (treatment CK) and 67.0 mg kg^{-1} for addition of SAP (treatment A). It was 67.7, 60.0 and 57.3 mg kg^{-1} for the treatments of B, C and D, respectively, of addition of the three levels of common water hyacinth. Although there was recognized no significant difference among the five treatments, addition of common water hyacinth at the rate equivalent to double of the water–retention capacity of SAP showed a tendency to improve the free amino acid concentration of cucumber fruits in the same level as addition of the recommended weight of SAP.

The vitamin C concentration of cucumber fruits tended to be increased by addition of SAP and common water hyacinth, but no significant difference from the control was recognized. The vitamin C concentration was higher by 6.7 mg kg^{-1} for the treatment with SAP (treatment A) while by 13.3 to 20.0 mg kg^{-1}, depending on the addition rates, for the treatment with the three levels of common water hyacinth (treatments B through D) than for the control (treatment CK). The increased vitamin C concentration of cucumber fruits was apparently greater for common water hyacinth, at all addition rates, than for SAP.

Based on the above results, it was indicated as follows: addition of common water hyacinth showed an improving effect on the quality of cucumber fruits but the effect was statistically insignificant under the addition rates of the present study.

CONCLUSIONS

For examination of a new type of the vegetable water–retaining material to replace super absorbent polymers (SAP) of a chemical water–retaining compound, common water hyacinth was tested on the effects on the soil characteristics and the growth and quality of cucumber under drought stress in the pot experiment. Common water hyacinth could be a vegetable water–retaining material to replace SAP. Function of common water hyacinth as a water–retaining material varied with the addition rates, and addition of common water hyacinth at the rate equivalent to double of the water–retention capacity of SAP increased the soil water content and improved the growth and quality of cucumber in the nearly same level as addition of the recommended weight of SAP.

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