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Preliminary study of application effect of bamboo vinegar on vegetable growth

Mu Jun[1*] *Yu Zhi-ming*[1] *Wu Wen-qiang*[2] *Wu Qing-li*[3]

[1]College of Materials Science and Technology, Beijing Forestry University, Beijing 100083, P. R. China
[2]Beijing Soil and Fertilizer Station, Beijing 100029, P. R. China
[3]Beijing Forestry University Forest Science Co., Ltd, Beijing 100083, P. R. China

Abstract This paper reports the effects of moso bamboo (*Phyllostachys pubescense*) vinegar, with different diluents, on the growth of lettuce, cole and cucumber based on field tests. The results show that moso bamboo vinegar with 500–800 times dilution had good effect on the growth of tested vegetables. The harvest of vegetables increased from 18.8%–20.2% compared with a control. The height and the weight of the average single vegetable tested also increased. The main components of moso bamboo vinegar were analyzed by GC-MS and the positive effect on the growth was, in the first instance, attributed to a synergistic effect of trace amounts of the main components of bamboo vinegar.

Key words bamboo vinegar, vegetable growth, dilution

1 Introduction

Bamboo vinegar is a condensed acidic liquid obtained in the process of producing bamboo charcoal. It has a special smoky odor and its color is light-yellow to brown. There are over 200 kinds of chemical components involved and these components mainly include organic acids, phenolic, alkone, alcohol and ester compounds. Of these, acetic acids are the main components, accounting for about 50% of the organic chemicals. Bamboo vinegar has been found to have an effect on improving soil against plant diseases and insect pests, promoting plant growth and decreasing the necessity for fertilizer utilization as well as improving the quality of agriculture plants without any toxicity to people and animals (Ikeshima, 1999).

Given our rapid economic and technical development, many artificial fertilizers are manufactured and utilized, which not only impose heavy loads and pollution on the environment but also threaten our health. The cycle for planting vegetables is short and the use of fertilizers has a discernable effect on productivity. Moreover, the long-term application of fertilizers exposes the following problems: exhaustion of soil organics, lower conservation of water and nutrition, deterioration of the soil structure and heavy losses of water and soil. The incidence of disease and insect pests increases with excessive continuous-cropping in the pursuit of high yields. The higher the level of vegetable production, the larger the amount of fertilizer used. Excessive fertilization not only pollutes the soil, water and air but also keeps most residues in vegetables, which decreases the quality and security of our food supply. Therefore, it is very important to study and develop natural materials for vegetable production. Bamboo vinegar is one such good source, given the principle of organic production in agriculture.

Bamboo vinegar has been widely used in agriculture and daily life in Japan. There are about 4×10^7 L produced every year, over half of it used in agriculture (Higashino et al., 2005). Presently, studies on the bio-effect of bamboo vinegar are also carried out in China. But most investigations remain at the laboratory level, which present little instruction on actual applications.

2 Experimental material and methods

2.1 Material

The bamboo vinegar used was produced in Guangxi, south China and had been refined. The color of the bamboo vinegar was light brown with a specific gravity of 1.016,3, acidity of 8.94%, a pH value of 2.46 and soluble tars of 1.99%.

2.2 GC-MS analysis

A GC-MS analysis was performed on a Finnigan

*Author for correspondence. E-mail: mujun222@sina.com

Trace GC ultra-Trace DSQ, equipped with a DB-1 capillary column (30 m×0.25 mm×0.25 μm). The column temperature was kept at 60°C for 5 min and then increased at a speed of 5°C·min^{-1} until the temperature reached 230°C. The operating conditions of the mass spectrometer were as follows: ionization voltage 70 eV and temperature of the ionization source 250°C. Identification of the peaks was based on references and published MS spectra data.

2.3 Field tests

Field tests were carried out in the Changping District in Beijing in sandy soils. Vegetables tested were lettuce, cole and cucumber. The vegetables were planted in a randomized plot design at a plot area of 21.6 m^2 with five different treatments, each replicated three times.

Treatments were the usual fertilizer application of bamboo vinegar at the following rates: 800 times dilution, 500 times dilution, 300 times dilution and water at the same amount as the normal fertilizer application. The bamboo vinegar was sprayed on the leaves of the vegetables during the growing period with amounts of 75 kg per 667 m^2.

The yield of each plot was measured by the wet weight of the vegetables. The height of each single plant and weight of each fruit were measured in order to evaluate the growth of the vegetables.

2.4 Vitamin C (Vc) analysis

Determination of Vc in lettuce was measured with a 2,6-dichloro-indophenol titration method according to the GB6195-86VC.

3 Results and discussion

3.1 Components of bamboo vinegar

Fifty-seven components were found in the bamboo vinegar by GC-MS, of which 28 components were identified according to the MS data and references (Zhang et al., 2001; Lu et al., 2005) (Table 1). In bamboo vinegar, the identified components were 70.65% based on the spectra peak area, in which acetic components occupied 42.32%, with acetic acid as the main component, phenolic components of 23.22% with phenol, guaiacol and its syringol as the main components, neutral components of 5.11% with furfural and cyclopentenone as the main compounds.

According to the former studies, bamboo vinegar at low concentrations showed a clear positive effect on radicle growth of the seed plants (Mu et al., 2003, 2004). As well, the dilution of bamboo vinegar played an important role in plant application. Bamboo vinegar showed a positive effect on plant growth at high dilution rates such as 300–1,000 times, in which the main components were found in trace amounts when applied to plants.

Table 1 Constituents of bamboo vinegar

No.	Compound name	Relative quantity (%)
1	Acetic acid	40.04
2	Propanoic acid	1.51
3	Butanoic acid	0.33
4	3,5-Dimethoxy-4-hydroxyphenylacetic acid	0.54
	Total (acidic components)	42.32
5	Phenol	4.10
6	2-Methyl-phenol	1.03
7	2-Methoxy-phenol (guaiacol)	5.02
8	2-Ethyl-phenol	0.15
9	2,5-Dimethyl-phenol	0.45
10	4-Ethyl-phenol	2.06
11	4-Methyl-2-methoxy-phenol	1.44
12	1,2-Benzenediol	0.77
13	3-Methoxy-1,2-benzenediol	1.08
14	4-Ethyl-2-methoxy-phenol	0.85
15	2,6-Dimethoxy-phenol	5.99
16	4-Propyl-2-methoxy-phenol	0.28
	Total (phenolic components)	23.22
17	1-Hydroxy-2-butanone	0.24
18	Cyclopentanone	0.06
19	2-Cyclopenten-1-one	0.05
20	Furural	1.66
21	1-Hydroxy-3-methyl-2-butanone	0.10
22	Butyrolactone	0.05
23	2-Methyl-2-cyclopenten-1-one	0.76
24	3,4-Dimethyl-2-cyclopenten-1-one	0.03
25	2,3-Dimethyl-2-cyclopenten-1-one	0.02
26	5-Methyl-2-furancarboxaldehyde	0.57
27	1,2,4-Trimethoxybenzene	1.08
28	5-Methyl-1,2,3-trimethoxybenzene	0.54
	Total (neutral components)	5.11

3.2 Field tests

Field tests were carried out from July to November 2005 in the Changping District of Beijing. Tables 2 and 3 show the condition of each vegetable plantation and basic soil organics of the field. The three kinds of vegetables were planted in different fields with different soil organics.

During the prolific period of plant growth, bamboo vinegar was sprayed on the leaves every ten days with a sprayer. The control plants were sprayed with a similar amount of water. The vegetable harvest was measured in plot yield. The average height of each

plant and average weight of each fruit for each vegetable were also evaluated for assessing plant growth.

Different dilutions of bamboo vinegar were applied to investigate the effect on regulating vegetable growth.

Table 2 The condition of field tests

Species	Cultivar name	Breeding time	Planting density (seeding amount per 667 m^2)	Seeding time	Harvest time
Cucumber	No.2 Qiupeng	Jul.11	2,000	Aug.16	Oct.14
Lettuce	Emperor	Jun.30	5,000	Jul.31	Oct.8
Cole	No.605	Sept.19	15,000	Sept.27	Nov.4

Table 3 Base organics of the soil for field tests

Species	Field site	Organics (%)	Total nitrogen (%)	Alkaline hydrolyzable N ($mg \cdot kg^{-1}$)	Effective Phosphorus ($mg \cdot kg^{-1}$)	Fast acting Potassium ($mg \cdot kg^{-1}$)
Cucumber	Student farm in Nanshao County	21.20	1.27	176.4	153	187.5
Lettuce	Plant farm in Nanshao County	18.74	1.13	112.0	84	105.0
Cole	Vegetable field in Nanshao County	17.34	1.05	117.6	46	92.5

Determination of the soil organics was carried out before applying fertilizer and planting.

For each vegetable, the average height of single plant was determined from 30 single heights randomly selected from each plot. Table 4 shows the effect of bamboo vinegar on height growth of plants. The average height of the three kinds of vegetables all increased compared with the control. Of these, the 500 times dilution of bamboo vinegar displayed the largest increase with 15.3 cm for cucumber, 4.0 cm for lettuce and 2.2 cm for cole in increased height growth over that of the control. Other dilutions also show good increased effects at different rates.

Table 4 Effect of bamboo vinegar on height growth of plants

Dilution of bamboo vinegar	Cucumber		Lettuce		Cole	
	Average (cm)	Difference with control	Average (cm)	Difference with control	Average (cm)	Difference with control
800 times	201.0	+12.3**	21.3	+3.0**	16.6	+1.6**
500 times	204.3	+15.3**	22.3	+4.0**	17.2	+2.2**
300 times	197.3	+8.6**	21.0	+2.7**	16.1	+1.1*
Water	193.7	+5.0*	19.7	+1.4*	15.6	+0.6
Control	188.7	–	18.3	–	15.0	–

* shows significance at α=0.05 level, ** shows significance at α=0.01 level with LSD method.

The average weight of single fruits of each vegetable was determined from 30 fruits randomly selected from the harvest. Table 5 shows the effect of bamboo vinegar on the weight of fruit. The average weight of a single fruit for the three kinds of vegetables all increased compared with the control. Of these, the 500 times dilution of bamboo vinegar again displayed the largest increase with 33.6 g for cucumber, 42.4 g for lettuce and 2.68 g for cole per single fruit compared to that of the control.

Table 5 Effect of bamboo vinegar on weight growth of single fruits

Dilution of bamboo vinegar	Cucumber		Lettuce		Cole	
	Average (g)	Difference with control	Average (g)	Difference with control	Average (g)	Difference with control
800 times	245.0	+21.1**	416.3	+34.0**	13.56	+2.29**
500 times	257.5	+33.6**	424.7	+42.4**	13.95	+2.68**
300 times	238.3	+14.4*	408.0	+25.7**	13.33	+2.06*
Water	230.3	+6.4	392.7	+10.4	11.86	+0.59
Control	223.9	–	382.3	–	11.27	–

* shows significance at α=0.05 level, ** shows significance at α=0.01 level with LSD method.

Table 6 Effect of bamboo vinegar on yield of vegetables

Dilution of bamboo vinegar	Cucumber		Lettuce		Cole	
	Average (kg per plot)	Increased rate (%)	Average (kg per plot)	Increased rate (%)	Average (kg per plot)	Increased rate (%)
800 times	147.5	+13.1	66.4	+14.9	70.9	+14.7
500 times	154.9	+18.8	69.5	+20.2	74.2	+20.1
300 times	141.8	+8.7	63.9	+11.0	68.3	+8.9
Water	134.5	+3.1	61.4	+4.4	64.3	+4.0
Control	130.4	–	57.8	–	61.8	–

The yield of each vegetable was measured by the wet weight of all plants in the plot. The average yield in Table 6 was determined from three plots for each treatment. From the increased rates in Table 6, the 500 times dilution of bamboo vinegar showed the largest increase for all tested vegetables. Of these, the sequence of relative increase of the 500 times dilution is 20.2% for lettuce, 20.1% for cole, and 18.8% for cucumber. In field tests, the water effect on vegetable growth must be considered when compared with the bamboo vinegar because the bamboo vinegar was used in a diluted condition and water is its solvent. Though the treatment with only water showed some increased effect on the vegetables tested, the increased effect of diluted bamboo vinegar on vegetable growth can be confirmed from the results of field tests. The concentration of bamboo vinegar is an important factor affecting vegetable growth. The dilution of bamboo vinegar is not linear given the observed effect on vegetable. The optimum concentration for the tested vegetables is the 500 times dilution.

Bamboo vinegar is considered to have an effect on the coordination for absorbing and assimilating organic elements such as N, P and K. However, our results did not show any relation between vegetable growth and organic conditions of the soil after spraying bamboo vinegar. Although grown under different soil organic conditions, the vegetables tested all increased. Further experiments will be needed to investigate the coordination of bamboo vinegar for vegetables to absorb effectively the soil nutrients and their effect mechanism.

3.3 Effect of bamboo vinegar on the quality of lettuce

The quality of the vegetableis of greater concern for the consumer although the producer pays more attention to yield. We obtained quality by measuring the amount of Vc in lettuce because lettuce is often eaten uncooked. Figure 1 shows the Vc amount of lettuce with different dilutions of bamboo vinegar.

From the result of Vc amount, the lettuce with 800 times dilution of bamboo vinegar involved the highest Vc amount followed by that of 500 times dilution, which means that the appropriate dilution of bamboo vinegar not only increased the yield but also improved the quality of the vegetables. It seemed that applying only water had no effect on Vc amount in lettuce.

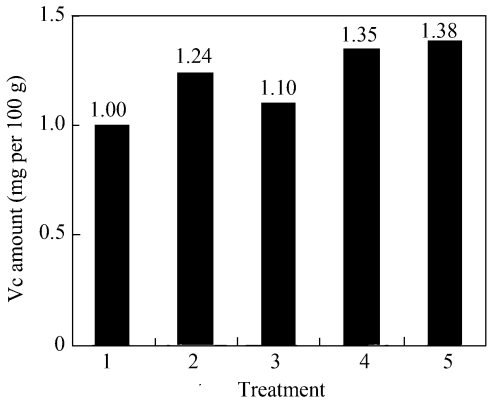

Fig. 1 Vc amount in lettuce with different dilutions of bamboo vinegar. Treatment 1: water; treatment 2: control; treatment 3: 300 times dilution; treatment 4: 500 times dilution; treatment 5: 800 times dilution.

4 Conclusions

From the field test, the increased effect of bamboo vinegar application was confirmed by spraying different dilutions on three kinds of vegetables during the growing period. The yield of the vegetable increased at a rate of 18.9%–20.2% with the 500 times dilution compared with the control. The height of single plants and the weight of the fruit increased significantly. The amount of Vc in lettuce increased and the quality improved by applying a 500–800 times dilution of bamboo vinegar. It can be concluded that, compared with the control and water condition, the increased growth effects on the vegetables derive from the diluted bamboo vinegar. The increase mechanism might be that the main components in the bamboo vinegar induce the hormones of the plant itself at trace amount or increase the photosynthesis of the leaves, which further regulate the growth of the plant. On the whole, the increased effect could be a synergistic effect of bamboo vinegar on vegetable growth. The mechanism should be explored by further studies on plants.

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References

Higashino T, Shibata A, Yatagai M. 2005. Basic study for establishing specifications for wood vinegar by distillation I. Study of regulation and reproducibility of compounds contained in distilled wood vinegar. Mokuzai Gakkaishi, 51(3): 180–188 (in Japanese with an English abstract)

Ikeshima Y. 1999. Method of Producing and Using Bamboo Charcoal and Bamboo Vinegar. Tokyo: Nosan Gyoson Bunka Kyokai. 23, 84–97 (in Japanese)

Lu B W, Du G H, Matsui T, Matsushita Y, Sugamoto K. 2005. Effect of pretreatment with freezing on carbonization of sugi (*Cryptomeria japonica*) sapwood. Sci. Silvae. Sin., 41(1): 131–135 (in Chinese with an English abstract)

Mu J, Uehara T, Furuno T. 2003. Effect of bamboo vinegar on regulation of germination and radicle growth of seed plants. J. Wood Sci., 49(3): 262–270

Mu J, Uehara T, Furuno T. 2004. Effect of bamboo vinegar on regulation of germination and growth of seed plants Ⅱ: Composition of moso bamboo vinegar at different collection temperature and its effect. J. Wood Sci., 50(5): 470–476

Zhang W B, Zhang Q S, Ye L M, Chen W Z, Ye X L. 2001. Bamboo vinegar constituents analysis on two methods. In: Symposium of International Academic Discussion on Bamboo Charcoal & Bamboo Vinegar in 2001. Beijing: China Forestry Publishing House. 46–60 (in Chinese)

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