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Effects of Wood Vinegar and Bio char on Germination of Pakchoi Seeds under Different Cadmium Stress Conditions

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ABSTRACT

Wood vinegar is widely used as a strong antioxidant, bacteria prevention, plant growth agent, an insecticide, and its effectiveness is shown in heavy metal treatment at this time.Wood vinegar liquid contains organic acids and phenols, which are effective in adsorbing heavy metals. Although a lot of studies have been conducted on the adsorption of heavy metals from biochar, the effect of mixing biochar and wood vinegar liquid on plant budding, and soil heavy metal morphology changes few studies have been analyzed.

This paper analyzes the effects of Wood vinegar and biochar on the sprouting of pakchoi grown in different threats of cadmium from the nature of Wood vinegar. As a result, it was confirmed that the optimum concentration of the applied fertilizer wood vinegar that lowers the plant effectiveness of Cadmium was 1.0%. The fresh weight of pakchoi changed significantly in the order of biochar + wood vinegar 1.0% mixing> biochar> control. When 5.0% Biochar was mixed with 1.0% wood vinegar, the immobilization effect of the residual state and the carbonate bound cadmium in the soil was the highest. The combined application of wood vinegar and biochar promotes the germination of pakchoi, and has a significant inactivation effect on cadmium-contaminated soil; the results of analyzing the effectiveness of the mixing of wood vinegar and biochar and separate fertilization for each soil index show that, Compared to before sowing the pH ratio of the mixed treatment of biochar + wood vinegar is higher than that of the single treatment zone, which is as high as between 6.6-6.8, the EC is reduced to 2-59mS/cm width, and the CEC is increased by 0.27-2.21 times. It shows that under heavy metal stress, the mixed treatment of biochar+wood vinegar solution 1.0% is more effective than the treatment of biochar alone and the control.

Keywords: Wood Vinegar, Biochar, Cadmium, Pakchoi, Seed Germination, Passivation

I. INTRODUCTION

At present, as a result of human activities such as mini ng industries, fertilizer, and pesticide application, hea vy (loid) metals (HMLs) pollution has become one of t he most serious environmental issues[1-3]. Soil heavy metal pollution can not only cause the decrease of soil fertility and grain yield and pollute surface water and underground water but also threaten human health t hrough the food chain. [4-5]. Many studies demonstra ted that Cd(II) were the main predominant contamin ants in soil[6].

Cadmium (Cd) is one of the most toxic elements to pl ants [7]. It can inhibit the hydrolysis of carbon-water compounds and sugar conversion, resulting inslower g rowth of seedlings [8], reducing the biomass and stem length of seedlings [9-15, 16]. Of primary concern is it s transfer from vegetable products of agriculture to th e human diet. It is widely concluded that vegetable fo ods contribute ≥ 70% of cadmium intake in humans. [17]. As a result, the amendment and remediation of h eavy-metal-contaminated soil have been a research h otspot in agriculture and environment [18]. Secondly, the researchers studied the heavy metal passivation of biochar. Many studies have shown that biochar has a dsorption and passivation effects on heavy metals, can reduce the damage caused by heavy metal cadmium t o plants, and can promote seed germination [8, 11]. B iochar is a safe carbonized solid product of high-temp erature pyrolysis of biological materials produced by p lants or animals. It can improve soil, store charcoal,an d repair the environment, and is widely recognized [1 9]. Biomass charcoalis mainly composed of monocycli c and polycyclic aromatic compounds. This structural feature makes it have higher chemical and biological s tability than the source parent charcoal and has stron ger anti-microbial degradation ability. Under certain conditions, it cans exist stably in the soil for thousand s of years. Biomass charcoal has a high adsorption cap acityfor heavy metals. When placed in the soil, it can reduce the bioavailability of heavy metalelements. It i s a low-cost and effective method to reduce the absor ption of heavy metalsby plants in the soil [20, 21, 22, 23].Studies have shown that adding biochar to heavy metal contaminated soil can reduce the absorptionof c admium by pakchoi, and reducethe concentration of c admium in the soil leaching solution by about one-ten th. 3% RHB can effectively hold Cd [24]. The use of b iochar can increase soil pH, increase the immobilizati on ofheavy metals, increase themaintenance of soil nu trients, improve the microbial communitystructure, a nd increase the growth and decline of crops [19]. Ho wever, the effect of biochar on plant growth depends onthe specific types of soil and plants and the interact ionbetween them. It is necessary to usebiochar in conj unction with other soil amendments to improve the e ffect. Second, the researchers researched the effect of wood vinegar on plant growth and the passivation of heavy metals. Wood vinegaris abrownliquid obtained by condensing and separating the gas mixture produc ed during the dry distillation of wood. It contains [25] aceticacid, alcohol esters, phenols, aldehydes, ketones ,aminoacids, etc[26]. The joint action of PWV and PB C can correspondingly promote the growth oftomatoe s [27]. The addition of biochar and bamboo vinegar re duced mobility of copper and zinc in pig manure com posts[28]. Wood vinegar or biochar is a prospective so il amendment to promote soil improvement and crop growth[24-27, 29-31]. However there is a lack of rese arch and understanding on the effect of its combined use, the inactivation of heavy metals in the soil, and t he improvement of the effect of heavy metal stress on plants. Through this experiment,the wood vinegar solution and biochar were combined into 90 potted plants to plant cabbage seeds. Through the analysis of the germination and growth of pakchoi under cadmium stress, the appropriate amount of wood vinegar and the changes in soil heavy metal forms under different cadmium concentrations were determined and analyzed the effect of wood vinegar and biochar fertilization alone or combined application on the growth of pakchoi.

II. MATERIALS AND METHODS

2.1. Research materials and physical and chemical properties

2.1.1. Materials

1) Pakchoi, the variety is Changfeng Four Seasons pakchoi, harvested 30 days later, the suitable growth temperature is 20~28°C.
2) Biochar is a rice husk biochar that is pyrolyzed at 700°C provided by Wuchang Runnong Company.
3) Wood vinegar is obtained from the production of rice husk pyrolysis biochar provided by Wuchang Runnong Company, with a pH of 3.20.
4) National standard reagent: $CdCl_2 \cdot 2.5\ H_2O$, environmental standard reference standard material: GBT 1286-1994)

   (National standard sample cadmium standard solution GSB 04-1721-2004, standard value: 1000ug/mL)

2.1.2. The physical and chemical properties of biochar and wood vinegar

Table1. Physical and chemical indexes of wood vinegar.

Moisture (wt %)	pH value	Acidity (mg/g)a	Acid (wt %)	Acetic acid (wt %)	Organic matter (wt %)	Density (mg m^{-3})
74.88	3.20	12.68	11.02	9.49	5.83	1.03

Acid-free degree was calculated by acetic acid content.

Table 2. Physical and chemical properties of biochar

pH	CEC (cmol/kg)	Specific surface area (m^2/g)	Organic carbon (g/kg)	Electrical Conductivity (mS/cm)	Micropore structure (%)	Cadmium Content (mg kg^{-1})
9.65	18.39	185.69	277.20	0.69	large aperture 38%、small-bore 43%	0.163

The test soil was black soil of Northeast China, and the cadmium reagent added was national standard cadmium.

2.2. Methods

2.2.1. Experiment design and preparation

This experiment was carried out in the form of potted plants, with a total of 25 treatment groups and 5 control groups, and each group was repeated 3 times for a total of 90 pots. The specific processing settings are shown in Table 1.

Table 3. Processing Settings Table

Dispose			Balanced array（Repeat 3 groups）	Number of pots（90）
Cadmium mg·kg^{-1}	Biochar（%）	Wood vinegar（%）		
Cd（0.0，	0.0	0.0	Check plot（5Group）	15 pots

0.5 ,	5.0	0.0	Laboratory	75
2.0 ,	5.0	0.25	area	pots
3.5 ,	5.0	0.5	5*5	
5.0）	5.0	0.75	（ 25Group	
	5.0	1.0	）	

The Cd concentration in the soil was adjusted to 0, 0.5, 2.0, 3.5, 5.0 $mg \cdot kg^{-1}$ by adding the prepared $CdCl_2$ solution to the soil sample, and it was equilibrated for 30 days under constant temperature conditions.

After the soil is balanced for 30 days, the rice husk biomass charcoal that has passed through a 2 mm sieve is applied to the soil. The addition amount per pot is 5.0%, and the addition amount of wood vinegar per pot is 0.0%, 0.25%, 0.5%, 0.75%, 1.0%, stir evenly, and equilibrate for 30 days under constant temperature conditions. All treatment settings were repeated three times. Seed disinfection treatment before sowing: The seeds are first immersed in 100% hydrogen peroxide for 20 minutes, and then thoroughly washed with distilled water. Plant 15 cabbage seeds per pot with 1 kg of soil. During the whole growth period, the soil temperature is controlled to 18±5°C, and the soil humidity is 60%~70%. The number of sprouted pakchoi buds was measured every day, and the buds were measured for various indexes after the seedlings were cultured for 10 days.

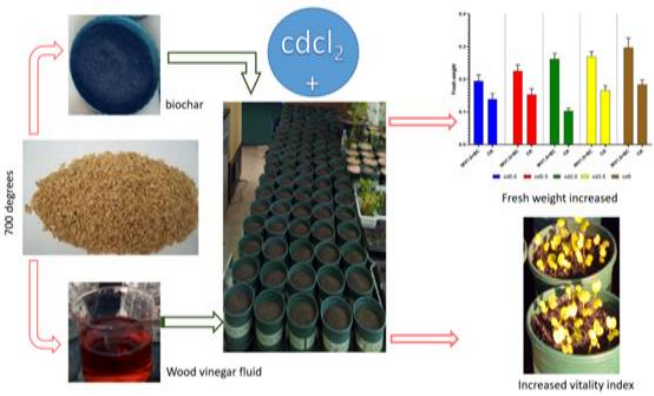


Figure 1. Effect of mixed fertilization of wood vinegar and biochar on growth of pakchoi under different cadmium stress

2.2.2. Measurement indicators and calculation formula

Germination rate (%) = number of germinated seeds/total number of seeds × 100 (1)

Germination potential (%) = the sum of the number of germinated seeds in the early stage of germination/total number of seeds × 100 (2)

Germination index (GI)=∑Gt/Dt (3)

In the formula, Dt is the germination timed, and Gt is the number of germinated seeds per day corresponding to Dt. Vigor Index (VI) = Germination Index (Gt) × Fresh Embryo Weight (g) (4)

2.2.3. Soil cadmium determination method

Using graphite furnace atomic absorption spectrophotometry to determine the content of soil available Cd is as follows:Mix the collected soil sample (generally not less than 500g) and divide it into about 100g by quarter method. After the reduced soil sample is air-dried (naturally air-dried or freeze-dried), the foreign matter such as stones and animal and plant residues in the soil sample is removed, and it is pressed with a wooden rod (or agate rod), and passed through a 2mm nylon sieve (removal of more than 2mm Gravel) and mix well. Grind the soil sample that has passed through a 2mm nylon sieve with an agate mortar until all the soil samples have passed through a 100 mesh (aperture 0.149 mm) nylon sieve, and mix them for later use. Accurately weigh 0.1~0.3g (accurate to 0.0002g) sample in a 50mL PTFE crucible, wet it with water, and add 5 ml of hydrochloric acid (hydrochloric acid (HCI): p=1.19 g/mL, excellent grade pure)， heat at low temperature on the electric hot plate in the fume hood to decompose the sample initially. When it evaporates to about 2~3 ml, take off slightly cold, then add 5ml nitric acid (nitric acid (HN03): p=1.42 g/mL, pure superior grade), 4 ml hydrofluoric acid (hydrofluoric acid (HF): p=1.49 g/ml), 2 ml perchloric acid (perchloric acid ($HCIO_4$): p=1.68g/mL, pure superior grade), after capping Heat it on the electric hot plate at medium temperature for about 1 hour, then open the lid and continue heating to remove silicon. In order to achieve a good flying silicon effect, the crucible should be shaken frequently. When heated to a thick white smoke of perchloric acid, cover it to fully decompose the black organic carbide. After the black organic matter on the crucible disappears, the lid is opened to drive off the white smoke and steamed until the content is viscous. Depending on the digestion situation, you can add 2mL nitric acid (nitric acid ($HN0_3$,): p=1.42g/mL, excellent grade pure), 2mL hydrofluoric acid (hydrofluoric acid (HF): p=1.49g/mL), 1 mL Perchloric acid (perchloric acid ($HClO_4$): p=1.68g/mL, high-grade pure), repeat the above digestion process. When the white smoke is almost exhausted again and the content is viscous, remove it slightly cold, rinse the crucible cover and inner wall with water, and add 1ml. nitric acid solution (nitric acid solution, 1+5: use nitric acid ($HN0_3$): p =1.42 g/mL, premium-grade pure) dissolve the residue by warming. Then transfer the solution to a 25mL volumetric flask, add 3ml of diammonium hydrogen phosphate solution (diammonium hydrogen phosphate ($(NH_4)_2HPO_4$) (excellent grade pure) aqueous solution, weight fraction is 5.0%) after cooling to a constant volume, shake well for measurement. As there are many types of soil, the organic matter contained in it is quite different. During the digestion, attention should be paid to observe. The number of various acids can be increased or decreased according to the digestion situation. The soil digestion solution should be white or light yellow (soil with high iron content), and there should be no obvious sediments. Exchangeable cadmium: Take 1.0 g of the dried and sieved soil sample in a 50 mL plastic centrifuge tube, add 10.0 mL of 1.0 mol·L^{-1} $MgCl_2$ solution, and shake and extract for 1 h at (25±1) ℃, then Centrifuge for 30 min, and filter the supernatant with a 0.22μm microporous membrane. Carbonate-bound cadmium: Transfer all the residues obtained from the above centrifugal separation to a 50 mL plastic centrifuge tube, add 10.0 mL of 1.0 mol·L-1CH_3COONa solution, shake and centrifuge, and filter the supernatant with a 0.22μm microporous membrane. Iron-manganese oxide-bound cadmium: Transfer all the residues obtained from the above centrifugal separation into a 50 mL plastic centrifuge tube, add 0.004 mol·$L^{-1}$$NH_2OH·HCl$ solution 20.0mL, water bath heat preservation, and extraction for 6 hours, shake centrifugation with 0.22μm micro The supernatant is filtered through a pore filter membrane. Organic matter and sulfide-bound cadmium: Transfer all the residues obtained from the above centrifugal separation to a 50 mL plastic centrifuge tube, add 0.02 mol·$L^{-1}$$HNO_3$ 3.0 mL and 30% H_2O_2 5.0 mL, and shake and extract for 2 hours. Then add 3.0mL 30% H_2O_2, shake and extract for 3h. After cooling, add 3.2 mol·L^{-1} 5.0mL, continue to shake for 30 minutes, centrifuge, and filter the supernatant with a 0.22μm microporous membrane. Residual cadmium: Subtract the cadmium content of the first 4 forms from the total cadmium content to get the residual cadmium content. In addition, to measure soil positive ion exchange performance and future, the measurement method refers to soil agrochemical analysis and national standard analysis.

2.2.4. Statistical analysis

All experiments were triplicated. Analysis of variance (ANOVA) of the results was performed using Design-Expert version 11. All data is processed by using SPSS 26.0 and GraphPad Prism 8.0.1 software.

III. RESULTS

3.1. 3.1 The effect of wood vinegar and biochar on the germination of pakchoi under different cadmium concentrations

Table 4. Experimental design

Process gradient			Code
Cadmium concentration(mg kg^{-1})	Biochar (wt %)	Wood vinegar(wt %)	
Cd（0.0，0.5， 2.0，	0.0 5.0	0.0 0.0	CK A

3.5，5.0）	5.0	0.25	B
	5.0	0.5	C
	5.0	0.75	D
	5.0	1.0	E

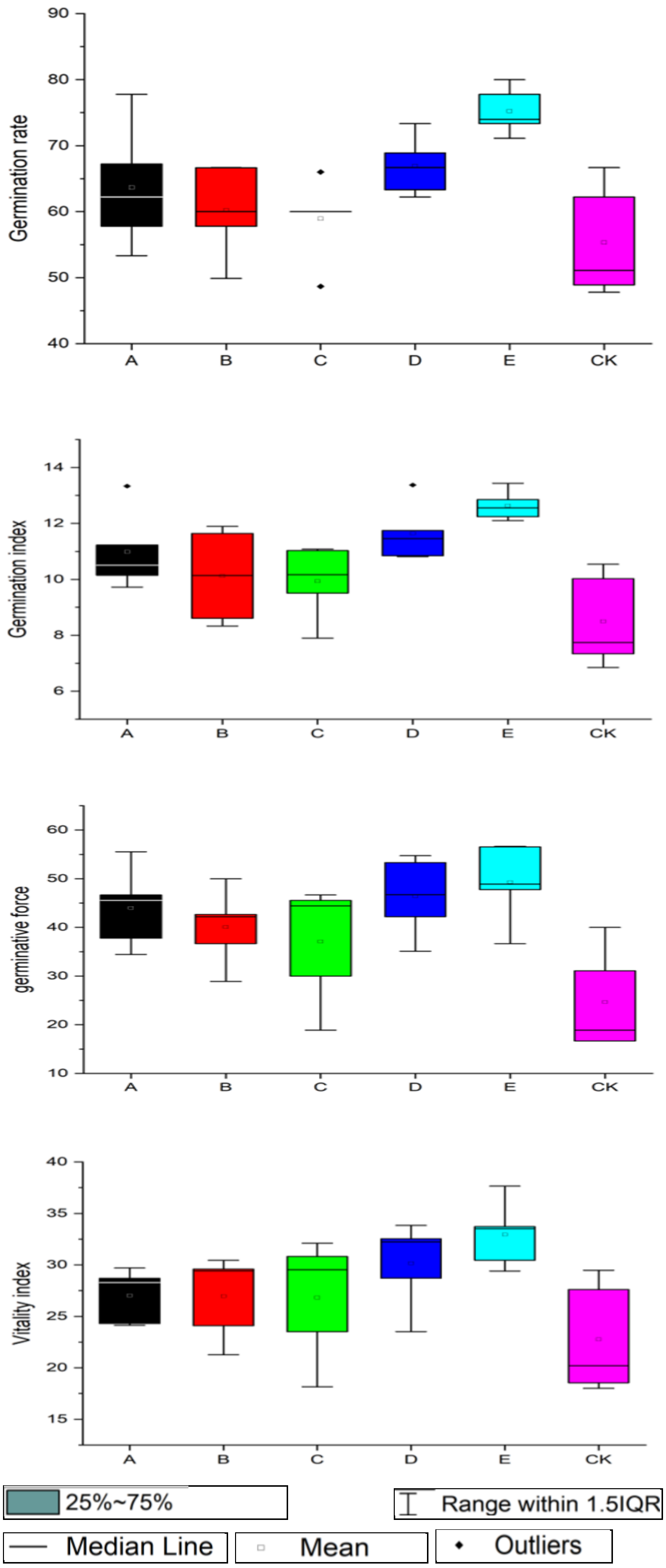


Figure 2. The effect of combined application of wood vinegar and biochar on the germination of pakchoi seeds under different concentrations of cadmium stress (WV （0.0, 0.25, 0.5, 0.75, 1.0% diluted 200 times）+ 5.0% biochar)

It can be seen from Figure 2 that under different cadmium stresses, the effects of biochar and forage liquid treatments on the germination of pakchoi seeds are quite high in the E treatment area. Without the addition of cadmium, the germination rate of the E treatment area was 30% higher than that of CK, and 14-29% higher than that of A, B, C, D areas. It is also said in the previous literature that wood vinegar promotes the germination of biological seeds[14] . Compared with area A, the seed germination rate in area E where wood vinegar was applied was 15% higher. Under the stress of 0.5, 2.0, 3.5, 5.0 the C, E treatment area increased by 24.4, 20.0, 17.7, 7.32% compared with CK, respectively; the A treatment area was 15.5, 17.7, 2.2, 6.7% higher than that of CK. But in the B and C treatment areas, under the stress of cd0.5, 3.5, 5.0 mg·kg^{-1}, the germination rate was lower than that in the biochar treatment area. This shows that 0.25%, 0.5% low-concentration wood vinegar has no positive effect on the germination of pakchoi under the stress of cd.

The germination index of cabbage with different cd concentrations was highest in the E treatment area. Under the condition of not being stressed by cd, the germination index of E treatment area was 4.3 times higher than that of CK, 1.2-4.2 times higher than that of A, B, C, D area, 1.9 times higher than that of A treatment area, and the cd concentration increased by 0.06-3.9 Times. Under the stress of cd 2.0, 3.5, and 5.0 mg·kg^{-1} in the B and C treatment areas, the germination index was lower than that in the A treatment area. But in the E and D areas, all the germination indexes were significantly higher than the A treatment area. The germination rate and vitality index were also the highest in the E treatment area, which was 16.6-32.2 and 4-14.0 higher than that in the CK treatment area, and 1-10 and 0.7-9.0 higher than that in the A treatment area. But in the B and C treatment areas, under the stress of cd2.0, 3.5, 5.0 mg·kg^{-1}, the germination price was lower than that in the A treatment area. The result is that the use of 200 times diluted wood vinegar and biochar can promote plant roots and increase seedling activity and growth. At the same time, the E and D areas of wood vinegar treatment did not show the phenomenon that the growth of seedlings was inhibited by cd stress in the CK treatment area. Compared with the control area, the shoot and root length of the E area increased by 12.0%. This is because wood vinegar and biochar can suppress cd stress and provide the main organic nutrients to the seedling embryo. In the CK area where wood vinegar or biochar was not added, the growth of pakchoi was inhibited due to cd stress. Under the higher cd concentration of Cd3.5mg/kg-1 and 5.0mg/kg^{-1}, biochar and wood vinegar were combined to fertilize areas E and D, and there was no phenomenon of inhibiting germination, and they were treated separately with the control area and biochar. Compared with the area, all germination indicators are significantly improved. That is to say, adding 1.0% wood vinegar liquid treatment did not inhibit the germination period of pakchoi. Believed that high concentrations of wood vinegar inhibited the germination of seeds [25]. There are two concentrations that are inhibitory. First of all, the pH of wood vinegar is 2.5~3.8, and high acid conditions are not conducive to plant seed germination. The main components of wood vinegar are acetic acid and phenols, which are harmful to rapeseed germination. However, biochar treatment (A, B, C, D, E) and then application of 1.0% wood vinegar has no significant effect on the germination of pakchoi seeds, indicating that wood vinegar and biochar can remove harmful components from seed germination. Under Cd stress conditions, the freshness and length of plants can only increase with cell expansion, because once the cell growth is stable, Cd cannot stimulate growth. Wood vinegar has a significant impact on biochar treatment areas and non-biochar treatment.

3.2. The effect of biochar and wood vinegar on the germination and growth of pakchoi seeds under different cadmium concentrations

3.2.1. The effect of fertilizing biochar alone on the fresh weight of pakchoi under different cadmium stress conditions

As shown in Figure 3, under different cadmium stress conditions, compared with the control area, the freshness of pakchoi increased by 115.6, 140.4, 211.7, 137.8, and 130.6% in different wood vinegar concentrations. This is due to the substances and effects of biochar, the cadmium in the soil is absorbed, and the plant is not stressed by Cd and grows safely. The addition of biochar increases the amount of cation exchange in the soil and increases the content of organic matter. In addition, it also affects the hydrolysis of Cd, chemical precipitation, and other effects to fix Cd.

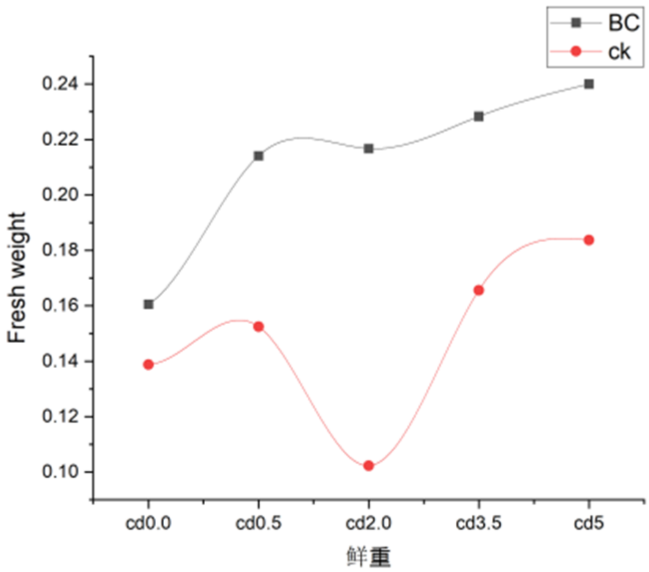


Figure3. The relationship between the fresh weight of pakchoi between biochar fertilization by Cd concentration (mg·kg^{-1}) and the control area BC-Biochar 5.0%， CK-Biochar 0.0%， Fresh weight Unit:g）

In addition, due to the high pH value of biochar itself (5.0%), it can significantly increase the pH value of the soil after adding it, so that the pH value can reach the range of 5-7 suitable for adsorbing heavy metals.

3.2.2. The effect of mixed fertilization of wood vinegar and biochar on the fresh weight of pakchoi under different cadmium stress conditions

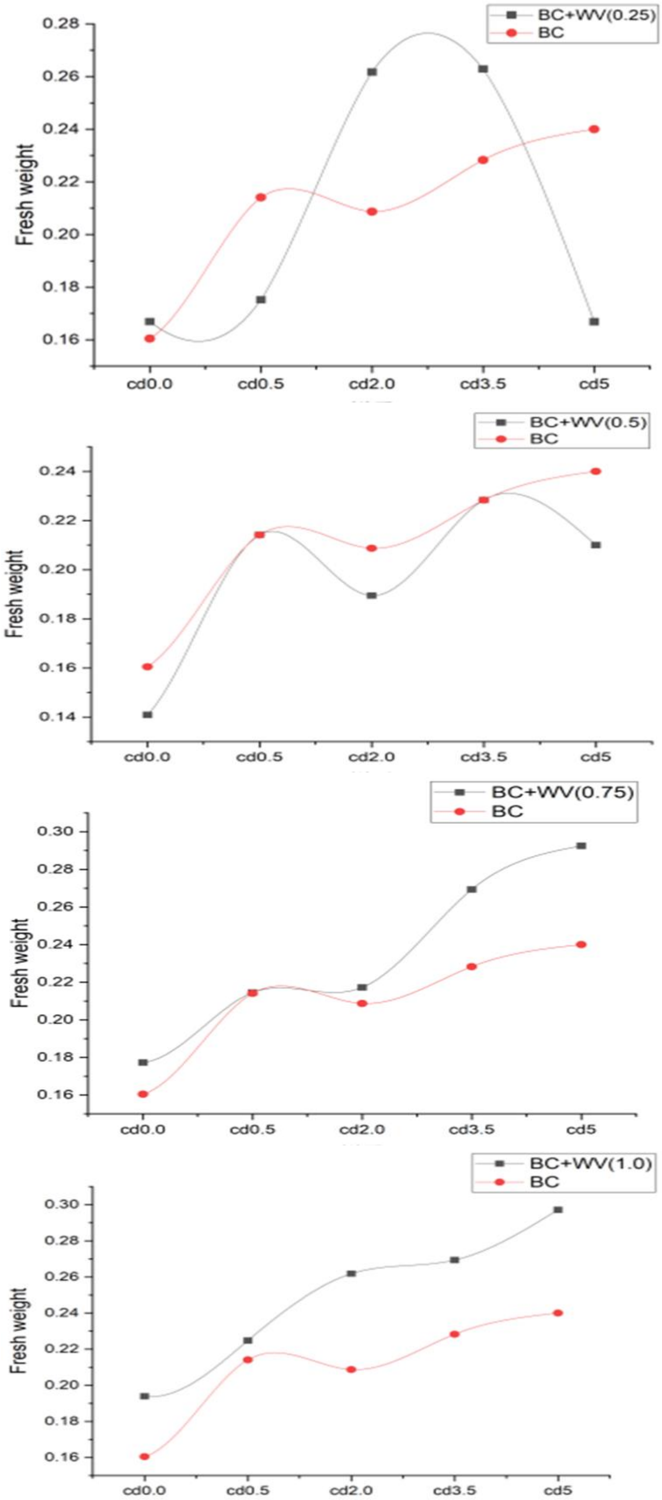
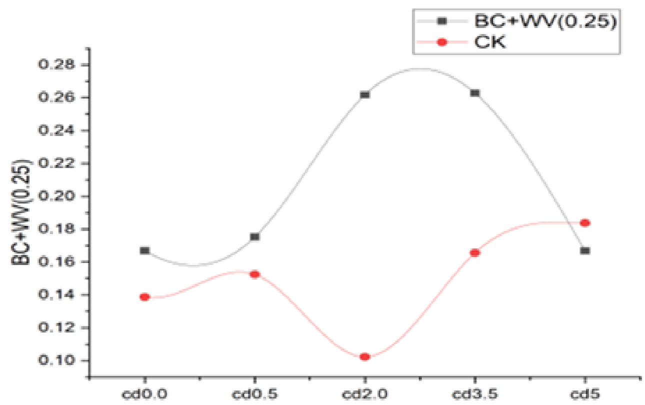


Figure 4. Effects of biochar and wood vinegar mixed fertilization and individual fertilization on the fresh weight of pakchoi under different cadmium stress conditions （BC-Biocha 5.0%，WV-Wood vinegar fluid 0.25，0.5，0.75，1.0%，Fresh weight Unit:g）

As shown in Figure 4, compared with the mixed fertil ization of wood vinegar and biochar with biochar alo ne, the fresh weight of pakchoi is not increased in all areas. At 0.25% wood vinegar concentration, Cd0.5m g·kg^{-1}, Cd5.0 mg·kg^{-1}, 0.5%wood vinegar Cd0.0 mg·kg^{-1}, Cd2.0 mg·kg^{-1}, Cd5.0mg·kg^{-1} day was lower than tha t of fertilization alone, which was 0.03 0.07 0.01 0.01 0.03g. However, when the application rate of wood vi negar was 1.0% and 0.75%, compared with the fertiliz ation area alone, with the increase of Cd concentratio n, the fresh weight value also showed a regularupwar d trend. From the results, under cadmium stress, com pared with the areas where only biochar was added, t he mixed-use of wood vinegar (1.0, 0.75%) and biocha r (5.0%) showed an upward trend with the concentrat ion of cadmium. The law is y=0.0251x+0.1741 R2=0.9 672, y=0.0285x+0.1486 R2=0.9519. This shows that th e mixed-use of wood vinegar and biochar has a more s ignificant passivation effect on heavy metal Cd than f ertilizing biochar alone, inhibiting the stress of cadmi um on plants and ensuring the safe growth of plants.

3.2.3. The effect of mixed fertilization of wood vinegar and biochar on the fresh weight of pakchoi under different cadmium stress conditio



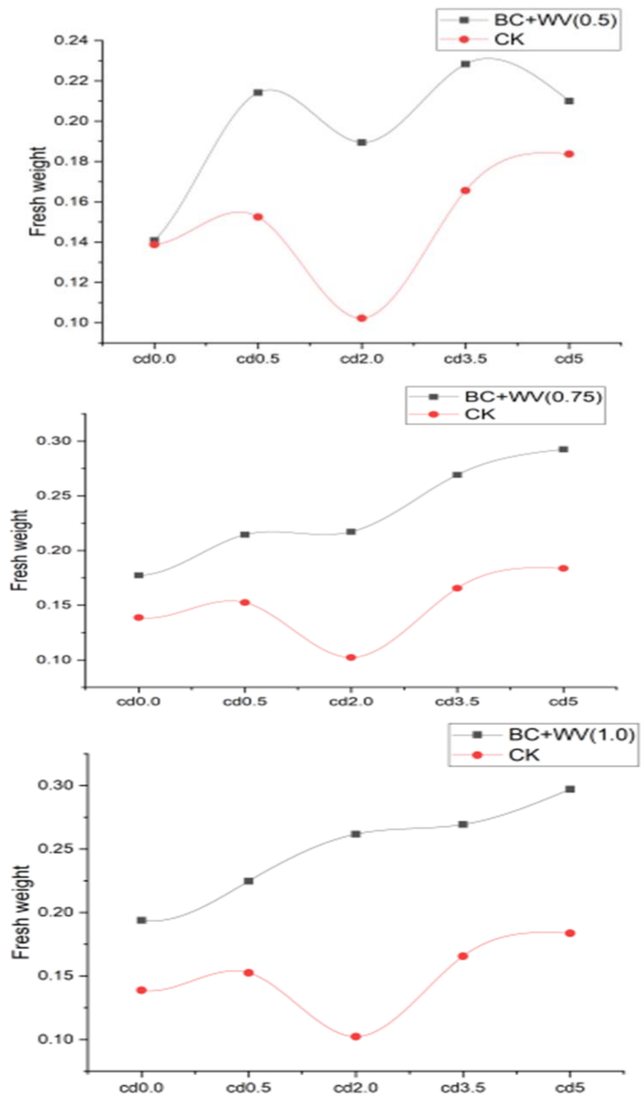


Figure 5. Effects of mixed fertilization of biochar and wood vinegar and control ball on the fresh weight of pakchoi under different cadmium stress conditions （BC-Biochar 5.0%，WV-Wood vinegar fluid 0.25，0.5，0.75，1.0%，Fresh weight Unit:g）

As shown in Figure 5, compared with the mixed fertil ization of wood vinegar and biochar, the fresh weight of pakchoi increased significantly compared with ferti lization in the control area.

Especially in areas where wood vinegar (1.0, 0.75%) is mixed with biochar (5.0%), as the concentration of ca dmium increases, its fresh weight also shows a regular upward trend.

This proves that the combination of wood vinegar and bio char has a greater inactivation effect on heavy me tal Cd than the application of biochar alone, and can i nhibit the stress of cadmium on plants.

3.3. The effect of combined application of wood vinegar and biochar on the changes of the main index of the research soil

3.3.1. Changes in the form of cadmium in the soil after adding biochar + wood vinegar

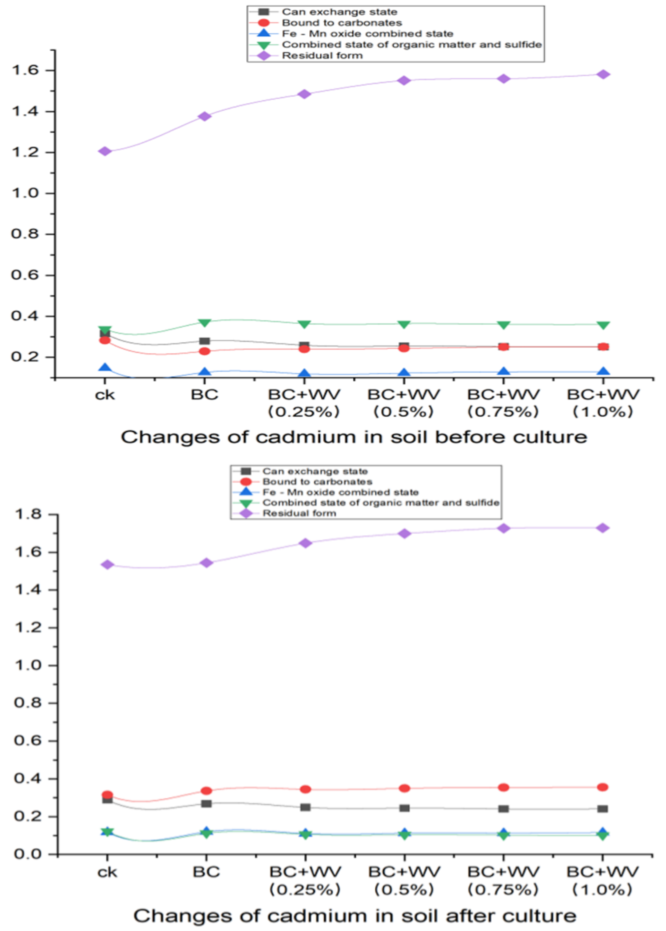


Figure 6. The effect of combined application of biochar and wood vinegar on the form of exogenous cd in different concentrations of soil mg·kg^{-1}

As shown in Figure 6, after adding biochar and wood vinegar, the average cadmium changes in thesoil at dif ferent concentrations are as follows: in the soil before cultivation, the average residual cadmium 50-62.1% is the highest, followed by organic matter and sulfide c ombined state 14.1-15.6%.

The second is the exchangeable state, the carbonate c ombined state, and the iron-manganese oxide combin ed state. Coupled with biochar and wood vinegar solution, after 30 days of equilibrium, the different cadmium binding states in the soil, the residual cadmium increased by 5.8-13.8%, and the carbonate bound content increased to 1.3-4.5%. In addition, the combined state of organic matter and sulfide is reduced to 10%, the combined state of iron-manganese oxide is reduced to 0.25-1.25% and the exchangeable state is 0.02-2.67%. If wood vinegar is mixed with biochar and put into the soil, the combined state of residue and carbonate will increase, the combined state of organic matter and sulfide will be combined with iron and manganese oxide, and the content of the exchangeable state will decrease. The mixed treatment of wood vinegar and biochar is more effective than the single treatment, and it becomes more obvious with the increase of the concentration of wood vinegar.

Among them, in 1.0% wood vinegar, the residue state and carbonate combined state have the best effect. Compared with the control, the exchange potential was 2.7%, the iron-manganese oxide boundstate was 0.4%, the organic matter and sulfide bound state decreased to 1.16%, the residue state increased to 3.5%, and the phosphate bound state increased to 0.7%. Compared with the treatment of biochemical charcoal alone, the exchangeable state is increased by 1.8%, the combined state of iron-manganese oxide is decreased by 0.48%, the combined state of organic matter and sulfide is decreased by 0.7%, the residual state is increased by 3.1%, and the combined state of carbonate is increased by 0.14%. It can be seen that after a period of time, wood vinegar and biochar have a goodeffect on the changes in the form of all cadmium in various concentrations in the soil; that is, it reduces the bioavailability of cadmium and plays a role in the immobilization and the role of passivation. That is, it can effectively fix the average amount of residue in the soil and the combined stateofcarbonate. At this time, it is proved that a concentration of 1.0% wood vinegar is the most effective.

3.3.2. Changes in major soil indicators after adding biochar + wood vinegar + cadmium

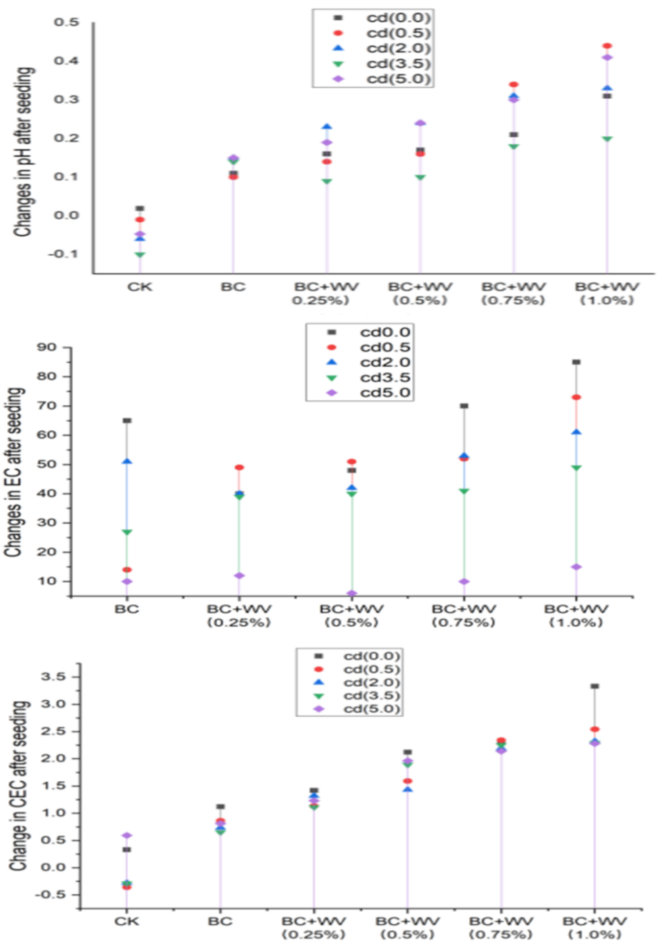


Figure 7. Changes of test soil index values after adding cd+BC+WV

（BC-Biochar 5.0%，WV-Wood vinegar fluid 0.25，0.5，0.75，1.0%）

The availability of soil cadmium has a relatively strong correlation with soil pH and electrical conductivity; as shown in Figure7 after sowing, the biochar + wood vinegar solution treatment, the biochar treatment compared to the control area, respectively, the soil pH value was 0.1-0.38, 0.09-0.24times improved. Through the above results, the soil pH values of the two groups were all over6.6 compared with that before sowing, which proved to have a beneficial effect on inhibiting the absorption of Cd in the soil by pakchoi. The reason is the superior heavy metal passivation effect of biochar and wood vinegar. Biochar has a high cation exchange capacity, and the pH value is weakly alkaline. A dding to soil can increase the exchange capacity of soil pH value and cations. Studies have also shown that the use of biochar on the tea garden soil with a pH of 4.3 can increase the pH of the soil by 0.5 to 1 unit in two years [32]. After the biomass carbon enters the soil, under the action of biological or non-biological oxidation at the edge of the aromatic structure, it improvest headsorption capacity of cations, reduces the soil bulk density, increases the soil's farmland water storage, and improves the soil properties. The addition of biomass charcoal increases the pH value, heavy metal ions from metal hydroxide, carbonate or phosphate precipitation, and the metal ions interact with the surface charge of carbon electrostatically. Metal ions from metal complexes with the functional atomic groups on the surface of the biochar. This reaction is very important in the fixation and maintenance of heavy metal ions that have a strong affinity for specific ligands.

Biochar provides a good environment for the growth and reproduction of soil microorganisms, improves the activity of microorganisms, reduces soil nutrients, promotes nutrient circulation, and increasesthe content of soil organic carbon. Wood vinegar is a stable organic product that can improve the properties of the soil. Organic matter can not only form insoluble metal-organic compounds with the migrating heavy metals but also the acidic compounds in wood vinegar can be decomposed like carboxyl groups or proteins. The deposits of protein, amino acids, and peptides are decomposed into ammonia, and alkaline cations dominate, which promote the hydrolysis of high-solubility carbonates and increase the pH value. The carboxyl groups in the wood vinegar liquid combine with OH^-, metal ions and organic functional groups. When a stable metal-corrosion pledge is formed under fermentation conditions, the metal ions can be fixed on the rigid durable body composite. Within the concentration of 0.75%~1.0%, the increase of the germination rate of pakchoi is related to the ability of low-concentration wood vinegar. First, wood vinegar can promote the activity of hydrolyticenzymes, improve microbial metabolism and carbon source utilization. That is, wood vinegar can multiply microorganisms, and microorganisms can use wood vinegar to improve soil enzyme activity.

Secondly, in heavy metal soil, acetic acid, the main component of wood vinegar, is effective as an adsorbent. It shows that the superior effect of using biomass charcoal and wood vinegar to passivateheavy metals and improve soil quality can reduce the effectiveness of heavy metals on plants.

Biochar is rich in carbon, is conducive to pores in the soil, absorbs heavy metals, and provides favorable conditions for the safe growth of plants. It is a good ecological environmental protection material and a reasonable soil amendment. As shown in Figure 6, from the changes in soil conductivitybefore and after sowing, in the changes in soil conductivity before and after sowing, the conductivity increased with the concentration of wood vinegar after the organisms and wood vinegar was treated. Under the conditions of BC+WV (0.25%) and BC+WV (0.5%), in the cd0.0, 2.0mg·kg^{-1} treatment zone,compared with the single treatment of biochemical charcoal, the conductivity shows a tendency to decrease by 9-25μS/cm. However, according to the concentration of BC+WV (0.75%) and BC+WV (1.0%), they have increased by 2-38 and 5-59μS/cm, respectively. The results of the study show that there is a very significant negative correlation between the water and soil conductivity of the heavy metal capture in the rice-soil system. Soil electrical conductivity is a comprehensive reflection of soil texture, cation exchange capacity, salinity, moisture, temperature, and organic matter content. In particular, it has a strong relationship with the exchange capacity of soil cations. The resultsshow that the combined treatment of wood vinegar and biochar is suitable to increase soil conductivity, increase soil pH, and increase the ability of heavy metals to passivation than biochar alone. Changesin soil exchangeable cation performance before and after sowing: For every increase of 0.836 cmol/kg in the biochar treatment area, the concentration of wood vinegar increased by 1.24, 1.8, 2.25, 2.55 cmol/kg, respectively. It can be seen that the concentration of wood vinegar is significantly increased, especially when wood vineg ar is 1.0%, the effect is the best. As shown in Figure 6, the ratio of CEC to CK in the BC area is 0.22-1.22 tim es, and in the BC+WV area, the concentration of woo dvinegar is 0.27-0.59, an increase of 0.7-1.24, 1.46-1.6, 1.47-1.68 times. The size of CEC basically represents the number of nutrients that can be maintained in the soil, that is, the degree of maintaining fertility, and it also plays an important role in the environmental da mage behavior of pollutants and the attribution of hea vy metal pollutants. It also plays a role in regulating t he concentration of the soil solution, ensuring the div ersity of the composition of the soil solution and the " physiological balance". The higher the cation exchang e capacity, the higher the negative charge of thesoilco lloid, and the more cadmium ions in the soil through electrostatic absorption. Acid tropical acidic soil, it is pointed out that the adsorption of cadmium in the soil is positively correlatedwith CEC, and CEC controls t he adsorption of cadmium on the silicate layer and iro n and aluminum oxide [33]. As a result, the combinati on of biochar and wood vinegar can increase soil pH a nd EC values, improve soil exchangeable cation perfor mance, and change soil physical and chemical propert ies, thereby reducing the availability of heavy metals and promoting crop growth.

IV. DISCUSSION

Under the condition of soil cadmium stress, ensuring the safe planting and pollution-free production of crops is the primary issue to ensure human health. Therefore, it is necessary to choose the most suitable material to adsorb and fix the heavy metals in the soil, increase crop yield and ensure quality. As shown in Figure 2, under different concentrations of cadmium, pakchoi seeds grown in soil treated with 1% wood vinegar did not show the phenomenon of germination inhibition like OV and DV [25] compared with all regions, all germination effects have increased by more than 30%. As shown in Figure 3, compared with the control, the fresh weight of all pakchoi increased by more than 150%, thereby obtaining the best growth effect. After adding biochar and wood vinegar to the soil, after sufficient soil balance, the secondary fermentation of wood vinegar and its components reduces the bioavailability of cadmium. It shows that it can promote growth by acting as a catalyst and providing organic substances that are beneficial to crop growth. This is consistent with the research in [26] and [27]. As shown in Figure 6, the residual cadmium and carbonate-bound cadmium content in the soil rose to 5.8-13.8% and 1.3-4.5%, respectively resulting in a higher mitigation effect. As to be shown in Figure 7 compared to before sowing the pH ratio of the mixed treatment of biochar + wood vinegar is higher than that of the single treatment zone, which is as high as between 6.6-6.8, the EC is reduced to 2-59mS/cm width, and the CEC is increased by 0.27-2.21 times. The results of the study confirmed that under different cadmium concentrations, the combined application of biochar and 1% wood vinegar was the most effective for germinating cabbage and fixing heavy metals in the soil.

V. CONCLUSION

In this experiment, the effect of fertilization of wood vinegar and biochar mixture on the germination of pakchoi under different cadmium stress conditions was studied. Both biochar and wood vinegar has a positive effect on the adsorption of heavy metals, so people's interest is increasing. In particular, wood vinegar is a compound produced during the production of biochar, and the possibility of its introduction is increasing, and research is also constantly deepening. The purpose of this study is to verify whether the combination of biochar and wood vinegar is effective compared to the actual treatment alone and to focus on determining its concentration. The results showed that the most reasonable condition for pakchoi germination is 1.0%. Compared with single fertilization, the mixed fertilization of 1.0% wood vinegar and biochar is very effective in increasing the fresh weight of pakchoi. It can be seen that diluting 5.0% biochar and 1.0% wood vinegar 200 times and adding it to the soil has a very positive effect on the growth of pakchoi and the fixation of cadmium in the soil under different soil cadmium stress conditions. Secondly, 0.75% fertilization can improve soil indicators and reduce the effectiveness of cadmium on plants, but the effect is less than 1.0%. It can be seen that under the condition of cadmium stress, the application of 1.0% wood vinegar can create a good environment for the growth of crops and can be used to provide agricultural ecological data. In this study, the fertilization effect of wood vinegar in the range of 0.0 to 1.0% was studied, but there were some shortcomings in the study of root anatomy and photosynthesis, such as changes in fresh weight and high concentrations of cadmium.

VI. REFERENCES

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