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Formation of Iron Film on Plant Root Surface and Its Nutrition and Eco-environmental Effects

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Keywords: Eco-environmental Effect, Root Surface Iron Film, Plant Nutrition, Heavy Metal Pollution.

Abstract: The nutritional absorption of plants is mainly completed by the roots, and the formation of iron films in the roots of plants directly affects the absorption of nutrients. A good ecological environment can promote the formation of iron films on the root surface of plants, and thus accelerate the absorption of nutrients by plants. However, a bad ecological environment will endanger the growth of plants. If plants are in a polluted ecological environment for a long time, then plants will absorb harmful substances. If they finally reach people's tables, they will inevitably have a great impact on people's health and safety. The research found in this paper found that heavy metals have a direct effect on the growth of rice. The experimental research analysis found that the concentration of MeHg in DCB of three varieties of rice was 1.8-2.6 times that of + P treatment under -P treatment, indicating that the iron film had an effect on MeHg in solution. Has a very strong adsorption effect. That is, heavy metals are very easily absorbed by the iron surface of the plant roots.

1. Introduction

Root surface iron film is an important mechanism for plants to adapt to environmental stress. Many plants can form iron films, such as Carex, Cattail, Reed, Yarrow, etc.In order to adapt to the ecological environment, the morphological structure and physiological characteristics of the aboveground and root systems have undergone special changes.Ventilation tissues change the oxygen in the atmosphere. The leaf is transported to the root system, and this part of the oxygen and other oxidizing substances are released to the rhizosphere by the root system, so that a large amount of reducing substances present in the soil, the iron film on the root surface of rice is mainly formed by the iron oxide film, thereby reducing The root system absorbs harmful ions and maintains normal growth. Studying the formation of iron film on the root surface of plants and how the

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nutrition is related to the ecological environment will allow us to take a closer look at botany.

Plants are widely used to treat mineral pollution and sewage in natural and artificial wetlands. These plants can not only quickly indicate the polluted environment, but also absorb pollutants and purify the environment through phytoremediation [1]. Rice is one of the important foods for people to survive. The formation of iron film on the root surface of rice directly affects the growth and development of rice. Some harmful substances such as heavy metals have a great influence on the growth of rice. Rice grows in the ecological environment of heavy metals. It must become harmful food, and then affect people's health and safety. Therefore, research on nutrient absorption, enrichment, and control of heavy metal pollution by iron film on the root surface of rice has become an urgent problem. Solving heavy metal pollution has important practical significance for the future development of human beings.

Plant root surface iron film formation is usually analyzed by biological studies. S. Fan's research found that in order to clarify the mechanism of humidification and over-humidity of the soil and the components of mineral soils with chemical hydration ability, the adsorption of water vapor was studied in combination with the synchronous conductance method. Effects of Organic Polyelectrolyte Molecules on the Hydration Kinetics of Dehydrated Calcium Silicate and Aluminate and the Formation of Hydrated Films on Their Surfaces. The drawing of the adsorption-desorption curve shows that the hydrate-polymer film formed by aliphatic or aromatic polyelectrolytes with different functional groups (–COOH, –OH, –NH2, and –CONH, etc.) has significant dispersibility and structure. difference. The change in dispersion during hydration is usually independent of the amount of hydrates formed. The content of hydrates is controlled by the crystalline chemical characteristics of the adsorbent, the structure and activity of polymer functional groups, and the conditions for the study of adsorption kinetics [2]. E. Umirzakov research has proved that Neotropical Bromeliaceae plants exhibit very rich ecological diversity, and their species have great differences in habits, photosynthetic pathways and growth patterns. So far, the differences in stomatal structure and function in processing the evolutionary physiology of Bromelia plants may be the key to the diversity of Bromelia plants in ecophysiological strategies. Since humidity is a key factor affecting the niche of pineapples, E. Umirzakov focused on studying the response of stomata to vapour pressure deficit (VPD) [3]. The results of N. Kurochkina study showed the sensitivity of C3 Bromelia stomata conductance and assimilation rate to VPD in eight different growth patterns and physiological and ecological strategies, and parameterized the stomatal response kinetics to VPD step changes. It is worth noting that, compared with rocky plants, three species of trough epiphytes show low conductance, high sensitivity, and fast kinetics; while three xerophytic land plants show high conductance, high sensitivity, and slow stomatal dynamics . Transpiration has a significant feedforward effect on VPD, and the effect of stomatal closure on water use efficiency is related to photosynthetic reactions. The difference in the stomatal response of species with different ecophysiological strategies to VPD is closely related to the change of stomatal morphology. We believe that the change of stomatal morphology is a key component of the high diversity evolution of this important plant family [4].

Nowadays, the ecological environment is getting more and more attention, and the research on the formation of iron film on plant roots, nutrition and ecological environment is an effective measure to promote human development. This article mentions the effects of heavy metals on plant nutrient absorption, further reflecting the importance of ecological environment to plant nutrient absorption. In this paper, a literature review method was used to explain the formation of iron film on the root surface of plants and their nutrition and ecological environment. The method of controlled experiments was used to study the impact of ecological environment on plants.

Comparison of growth conditions to verify the feasibility of the method in this paper.

2. Proposed Method

2.1. The Role of Plant Roots

Plants have six major organs: roots, stems, leaves, flowers, fruits, seeds. The root is the vegetative organ of the plant, usually located below the ground surface. It is responsible for absorbing water in the soil and dissolving ions in it, and it has the function of supporting and storing synthetic organic matter. The root can be divided into four regions. The top is the cap-shaped structure, the root crown. Above is the meristematic region and the elongation region, and the upper part is the root hair region with root hairs. The meristematic zone is the apical meristem located inside the root canopy. Cells in the meristematic zone can continue to divide. On the one hand, a small part is used to form root cap cells, while most of them undergo cell growth and differentiation backward to form various root structures. The cells in the elongation zone develop from the cells in the meristematic zone, and the ability to divide has weakened, and the cells extend the elongation axis. Elongation will cause damage to the virgin phloem and primary xylem, causing it to appear lacuna. Root hair zone cells are already mature cells. Root hair is generated by hair cells in the epidermis, which can effectively increase the absorption area of plant roots[5-6].

2.2. Nutrients Required for Plant Growth

Plant growth requires different nutrients, and different plants need different nutrients, and different parts of the same plant may require different nutrients. Research has found that different plants need a lot of nutrients The practical significance is conducive to promoting plant growth, scientific fertilization, and care is important to achieve high plant yield.

(1) The three elements of carbon, hydrogen and oxygen are abundant in plants, accounting for more than 90% of the dry weight of plants, and are the main components of plant organisms. They can also constitute active substances in plants, such as certain cellulose and plant hormones. In addition, hydrogen and oxygen also play a major role in the biological redox process of plants. Because carbon, hydrogen, and oxygen come mainly from carbon dioxide and water in the air, fertilizer application is generally not considered[7].

(2) Nitrogen Nitrogen is a component of many important organic compounds in plants, which affects the metabolic process and growth of plants in many ways. Without nitrogen, there is no life phenomenon. Nitrogen is a component of chlorophyll and a component of nucleic acids. Various biological enzymes in plants also contain nitrogen[8-9].

(3) Phosphorus Phosphorus is a component of many organic compounds in plants, and participates in various metabolic processes in plants in various ways, and plays an important role in plant growth and development. Phosphorus is extremely important in plant growth and metabolism and is indispensable for cell division and root growth. Phosphorus has the ability to improve plant stress resistance and adapt to external environmental conditions [10].

(4) Potassium Potassium is not a component of organic compounds in plants, and mainly exists in plant cell fluid in an ionic state. It is an activator of a variety of enzymes and plays an important role in the metabolic process. It can not only promote photosynthesis, but also promote nitrogen metabolism and improve nitrogen absorption and utilization in plants [11].

(5) Calcium, magnesium, and calcium sulphate can stabilize the structure of biofilms and maintain cell integrity, and play an important role in the selective absorption of plant ions, growth,

senescence, information transmission, and plant stress resistance. It is an important substance to promote plant photosynthesis. Sulfur is an indispensable component of proteins and enzymes [12-13].

(6) Trace element iron is necessary for the synthesis of chlorophyll and has a close relationship with photosynthesis. Different trace elements have different promotion effects on plant growth and development. Boron can promote the normal function of carbohydrates, promote the formation and development of reproductive organs, and improve the nitrogen-fixing ability of legumes. The role of manganese in plants is mainly achieved through the effect on enzyme activity, so manganese is also called catalytic element. Copper is a component of many oxidases in plants. It also participates in photosynthesis, affects nitrogen metabolism, and promotes the development of floral organs. Zinc is a component or activator of certain enzymes. Zinc has a wide range of effects on plant carbon and nitrogen metabolism and participates in photosynthesis, participates in auxin synthesis, promotes reproductive organ development, and improves stress resistance. Molybdenum is a component of nitrogenase and nitrate reductase. Molybdenum also promotes photosynthesis. Chlorine participates in photosynthesis of plants, regulates the opening and closing of stomata, and enhances the ability of crops to suppress certain diseases [14-15].

2.3. Iron Film on Plant Root Surface

(1) Definition of iron film on plant root surface

One of the important characteristics of plants is that the root system has the ability to grow in waterlogged soil. In order to adapt to its anoxic environment, a well-developed aeration tissue was formed during long-term evolution, which can efficiently transport atmospheric oxygen to Root surface, so that the rhizosphere is in a relatively oxidized state.

(2) Formation of iron film on plant root surface

The iron film on the root surface of the plant is the result of the plant adapting to the flooded environment for a long time in the condition of waterlogged soil.The aeration tissue unique to waterlogged plants transports oxygen to the root system, thereby oxidizing it to iron oxides and hydroxides. Biofilm research has shown that the root systems of many plants have the ability to form iron gel films.

(3) Conditions for iron film formation

Local oxidation conditions are one of the necessary conditions for forming an iron film in waterlogged soil. There are two main mechanisms for plant root oxidation: one is the oxygen released through the root system; the other is some oxidizing substances secreted by the root system, including some oxidases.1 Aquatic or emergent plants with aerating tissue can be removed from the leaves. Oxygen is transported to the root system and released into the medium. In addition to the oxygen delivered from the ground, enzymatic degradation of the root surface can also decompose some organic acids and release oxygen [16].

(4) Composition of plant iron film

1) Research proves that the root surface iron film is composed of crystalline and amorphous materials! It is generally believed that crystalline materials mainly include maghemite (γ-Fe2O3), wurtzite, and hematite (y-FeOOH) Hematite (a-Fe2O3) and goethite (a-FeOOH).! Due to inadequate research methods on the morphological composition of iron films, despite chemical extraction; and scanning electron microscopy, oxidation of the root surface iron film The actual extent of skepticism is suspected, and speculations: Chen et al. Believe that crystalline components are formed in hotter climate conditions, and low Mn concentration, high pH value, and low Eh

value in the soil are favorable for the formation of goethite. -Cyr and Knowder's research also found that the higher the CO2 concentration in the medium, the better the soil permeability and the greater the possibility of forming goethite.

2) The location of the iron film on the root surface The iron film generally starts to form at a distance of 0.1cm from the root tip. The root hair area, root elongation area and the rear part of the root are the areas where more iron film is formed! Further observation It is shown that the iron film can penetrate into the tissue at the root surface of the plant, and can penetrate into both dead and living cells. Chen observed by electron microscope that there are two models of iron film deposition on the root surface: iron film on its root surface because of different deposition forms! Other factors may also affect the deposition of iron films, such as iron-oxidizing bacteria in the soil. Iron-oxidizing bacteria may not have a positive effect on the oxidation of iron, but they can act as iron films on the root surface. The core site of the deposition affects the deposition form of the iron film.

3) Plant nutrition effect of root surface iron film The iron and manganese oxides in the soil are amphoteric colloids, and their charge comes from the adsorption and dissociation of protons by surface groups! The root surface iron film is an oxide film formed by iron oxides on the root surface, so It has similar electrochemical properties to iron and manganese oxides, and has an enrichment effect on certain anions and cations in the soil, which greatly affects the absorption of nutrients by plants! Iron in the soil solution and in the root surface iron film There is a recurring cycle between the iron, and the iron film iron is not static once deposited, so the iron film will not hinder the absorption of nutrient isolates by many roots! Many studies have also shown that the root surface iron film can be rich in the area near the root. Enriched nutrients can be activated and absorbed in the absence of nutrients in the medium!

2.4. Impact of Ecological Environment on Plant Growth

The ecological environment of crops not only has a great impact on the yield and quality of agricultural products. It is also the most important issue for farmers in growing crops. The growth of crops directly affects the level of farmers' income. The growth of crops includes several aspects: such as soil organic matter, soil moisture, root depth, temperature, humidity, light intensity, wind speed and so on.

(1) The effect of temperature on plant growth Plants can grow only within a certain temperature range. The effect of temperature on growth is comprehensive. It can affect the growth of plants not only by affecting metabolic processes such as photosynthesis, respiration, transpiration, etc., but also by affecting metabolic processes such as the synthesis and transportation of organic matter.It can also directly affect soil temperature and air temperature by affecting the absorption and transduction of water and fertilizer. Affects plant growth.Plants can grow only in a certain temperature range. The influence of temperature on growth is comprehensive. It can affect the growth of plants not only by affecting photosynthesis, respiration, transpiration and other metabolic processes, but also by affecting the synthesis and transportation of organic matters, and directly by affecting soil temperature and air temperature, and by affecting the absorption and transportation of water and fertilizer.

(2) The effect of humidity on plant growth Relative air humidity or poor saturation is one of the important factors affecting plant water absorption and transpiration. When the relative humidity is low (the saturation difference is larger), if there is sufficient soil moisture, the plant transpiration is more vigorous.Most leaves of plants are dark (such as green, blue, etc.). Dark leaves have strong

ability to absorb light and heat. Through photosynthesis, plants can produce organic matters such as starch, fat, protein, etc. to realize the conversion of light energy into chemical energy, which is just in line with the law of energy conservation. The roots of plants have the characteristics of growing towards the ground. This is the plant's reaction to gravity. The mineral nutrients in the soil must be dissolved in water before they can be absorbed by the root. This is the diffusion phenomenon. Some plants have aromatic glands in their petals, which emit special fragrance through diffusion. The fragrance and color of corolla are suitable for insect pollination. Most of the water absorbed by plants evaporates from the leaves to the air, thus forming a kind of transpiration tension. This tension is the main driving force for the root system to absorb water, mineral nutrients and mineral conduction in the plant. Plants absorb heat through evaporation It can also adjust the temperature of the leaves, so that the leaves will not be burned due to excessive temperature.

(3) Effect of light intensity on plant growth Light is the energy source for photosynthesis of plants. Photosynthesis is mainly accomplished by the plant's chlorophyll, an organ. The same plant has different requirements for light at different stages of growth and development. In order for the plant to grow normally and quickly, light is essential.

(4)Wind speed is also an important factor affecting the growth of plants. In many places, because of the impact of typhoon disaster, people have planted windbreaks to weaken the wind and protect plants. Windbreak forest refers to the forest or forest belt that is used to prevent the invasion of cold wind, dry wind or storm. It can reduce the wind speed, prevent rapid cooling and strong evaporation. Plants can reduce wind speed. The degree of wind speed reduction mainly depends on the size of plants, the degree of flourish of branches and leaves, the windproof ability of trees is better than that of shrubs, and shrubs are better than herbs; broadleaf trees are stronger than conifer trees, and evergreen broadleaf trees are larger than deciduous broadleaf trees.

3. Experiments

3.1. Pretreatment and Grouping of Tested Rice

The tested rice varieties were low-mercury rice tianyou196 (TY196, kernel mercury content 22.8ngg-1), low-mercury rice NanJing35 (NJ35, kernel mercury content 20.5ngg-1), and high-mercury rice ZiXiangnuo (ZX, kernel mercury content). 28.5ngg-1). After 30% H2O2 washes the surface of the tested rice cultivars for 15min, it was rinsed with deionized water. The washed seeds were artificially cultured in a glass petri dish lined with filter paper.

After 21 days, 24 rice seedlings with the same growth size were selected and placed in a PVC tube containing 500 ml of culture medium for 1 week. The culture medium should contain the following components:5mmolL-1NH_4NO_3,2mmolL-1K_2SO_4,4mmolL-1$CaCl_2$,1.5mmolL-1$MgSO_4 \cdot 7H_2O$, 1.3mmolL-1KH_2PO_4,50μmolL-1Fe(II)-EDTA,10μmolL-1H_3BO_4,1μmolL-1$ZnSO_4 \cdot 7H_2O$,1μmolL-1 $CuSO_4 \cdot 5H_2O$,5μmolL-1$MnSO_4 \cdot H_2O$,0.5μmolL-1$Na_2MoO_4 \cdot$2H2O, 0.2μmolL-1$CoSO_4 \cdot 7H_2O$.

During the cultivation, the pH of the culture solution was adjusted to 5.5 with 1 molL-1 of KOH or HC1. The culture medium is changed twice a week, and the light should be guaranteed for 14 hours (260-350 μmolm-2s-1) per day, the temperature should be controlled at 28 ℃ during the day and 20 ℃ at night, and the relative humidity should be maintained at 60% -70%.

After 1 week of culture, the rice seedlings were evenly divided into two groups, one group was treated with phosphorus (+ P) (5mmolL-1NH_4NO_3 and 1.3mmolL-1KH_2PO_4), and the other group was treated without phosphorus (-P) ((4.4mmolL-1NH_4NO_3 and 1.4mmolL-1KNO_3), the other components are consistent with the culture medium in 4.2.1, and after 2 weeks of cultivation, the two groups of rice seedlings are placed in a culture solution containing 0.2mgL-1MeHgCl for 4 weeks. Each treatment was set to repeat 4 times.

3.2. Extraction of Iron Surface from Rice Root

DCB (dithionite-citrate-bicarbonate, sodium bicarbonate-trisodium citrate-sodium dithionite) method was used to extract the root surface iron membrane: the washed root tissue was cut along the base and placed in 30ml containing 0.03molL-1 Extract from a mixed solution of trisodium citrate ($Na_3C_6H_5O_7 \cdot 2H_2O$), 0.125molL-1 sodium bicarbonate ($NaHCO_3$) and 0.5g insurance powder (Na2S2O4) for 1 hour at room temperature. bottle. ICP-OES (Optima2000DV, PerkinElmer, USA) was used to determine the Fe content in the DCB extract, and the MeHg in the DCB extract was determined according to the method of Liu Baoxian et al. After extraction with DCB extract, the roots, stems and leaves of rice were dried at 70 ℃ to constant weight.

3.3. Sample Digestion and Determination

Accurately weigh 0.2000g of rice root and aerial samples into a polytetrafluoroethylene-tetrafluoroethylene (PTFE-TFE) digestion tube, add 2ml of 5molL-1 HCl, and perform microwave heating (80 ℃) for 60min extraction. After cooling, it was transferred to a 10ml centrifuge tube, centrifuged for 10min (4000rmin-1), filtered out through a 0.45μm filter to a 25ml volumetric flask, and the volume was determined by ICP-MS (ThermoElementalX7, USA).

3.4. Data Statistics and Analysis

The transfer coefficient of MeHg from the DCB extract to the roots of rice and from the roots to above-ground rice is as follows:

Transfer coefficient from iron film to root: TFroot = Croot / Cirot-planque

Transfer coefficient from root to above ground: TFsboot = Cshoot / Croot

[Ciron-plaque] indicates the content of MeHg in the iron film; [Croot] indicates the content of MeHg in the root; [Cshoot] indicates the content of MeHg above the ground.

4. Discussion

4.1. Comparison of Element Content in Iron Film

Contents of Fe, P, and MeHg in iron film The root surface of rice under white treatment was white, while the surface of rice root system under red-P treatment showed obvious reddish brown, indicating that an iron film was formed on the root surface. As shown in Figure 1.

It can be seen from Figure 1:under the -P treatment, the content of Fe (DCB-Fe) in the DCB extract of the three varieties of rice was significantly higher than that of the + P treatment, and the DCB-Fe content of the NJ35 and TY196 varieties were + P treatment, respectively. 2.04 times and 2.24 times. At the same time, the DCB-Fe content (ie, the number of iron films on the root surface) of the three varieties of rice differed greatly, and the order of the number of iron films was NJ35> TY196> ZX. However, under the + P treatment, the number of root surface iron films of NJ35 varieties was significantly higher than that of TY196 and ZX varieties, and there was no significant difference in the number of root surface iron films between TY196 and ZX varieties. Phosphorus deficiency can significantly increase the number of iron films on the root surface of rice (Figure 1), and the number of iron films on the root surface is different among different rice varieties. This may be the adaptive mechanism of rice to phosphorus deficiency, which is consistent with previous research results. It was found that the nutritional status of phosphorus (P) could affect the formation of iron film on the root surface of rice. It was found that phosphorus deficiency or low phosphorus stress can induce the formation of red-brown iron oxide coating on the root surface of rice. Researchers have explored the mechanism of root film formation induced by phosphorus deficiency. It was found that phosphorus deficiency would increase the amount of oxygen secreted from rice roots, leading to the formation of an iron film on the surface of the roots. The basic principle of the root surface iron film formation is the release of the root system, which leads to the reduction of Fe2 + and Mn2 + to be oxidized to iron-manganese oxide and deposited on the root surface. Studies have shown that its formation is significantly positively related to the rate of oxygen secretion from rice roots. Rhizosphere pH and Eh are also two important factors affecting the formation of root surface iron film. The rhizosphere pH value of phosphorus deficiency treatment was significantly lower than that of phosphorus treatment, and phosphorus deficiency significantly increased the oxidative capacity of the root system. Based on the above information, it is not very clear so far whether the external phosphorus or the internal phosphorus concentration controls the formation of the root surface iron film. This experiment proves that phosphorus nutrition and iron film control MeHg content in rice shoots, which is expected to reduce MeHg through agronomic management measures in the future.

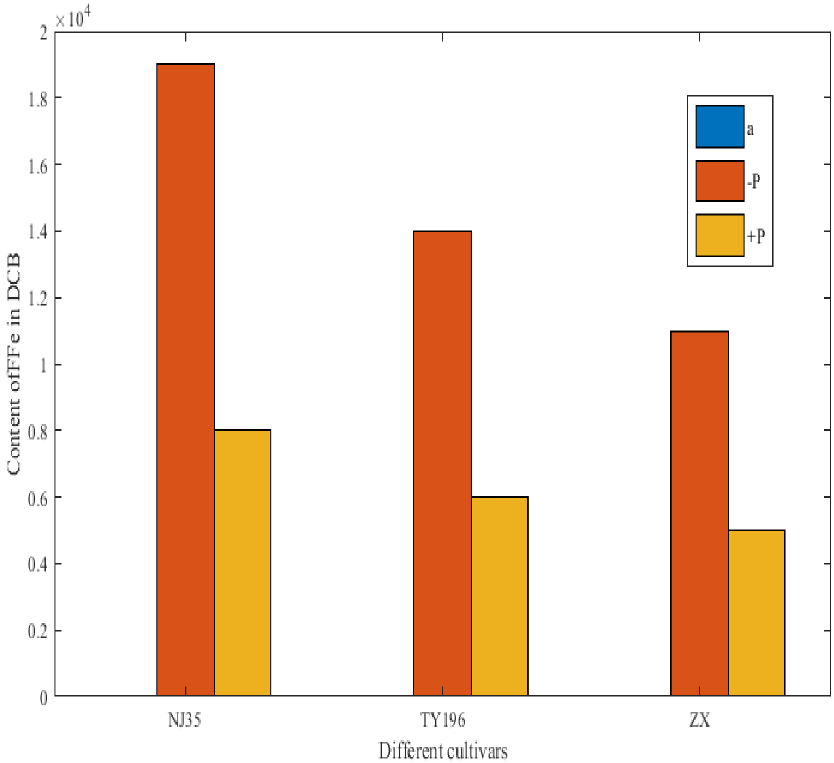

Figure 1. Contcnts of Fc and MeHg (mgkg-1DW)in dithionitc citratc -bicarbonatc(DCB)cxtracts from three cultivars under phosphorus trcament

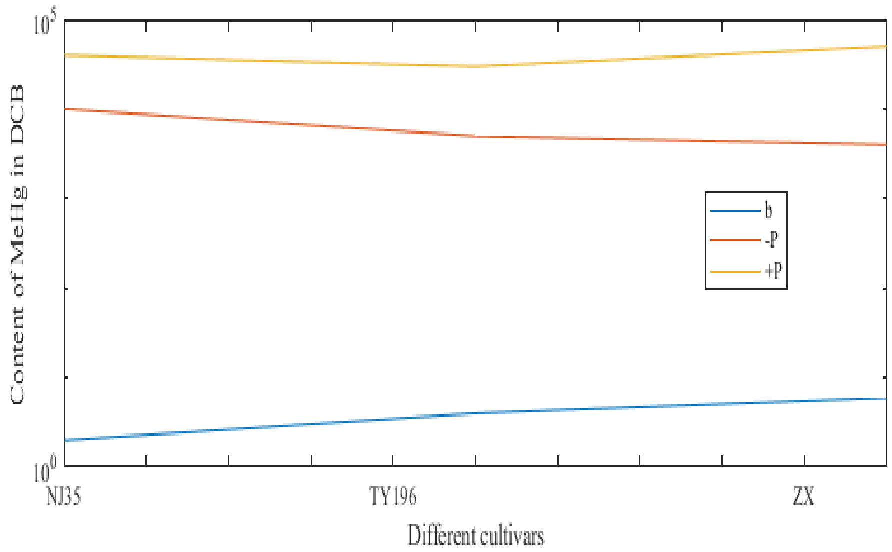

Figure 2. Contcnts of Fc and MeHg (mgkg-1DW)in dithionitc citratc -bicarbonatc(DCB)cxtracts from three cultivars under phosphorus trcament

As shown in Figure 2, the content of P (DCB-P) in the DCB extract of the three varieties of rice under the + P treatment was 4.3-15.1 times that of the -P treatment, and the DCB-P content of the ZX variety increased the most 15.1 times).

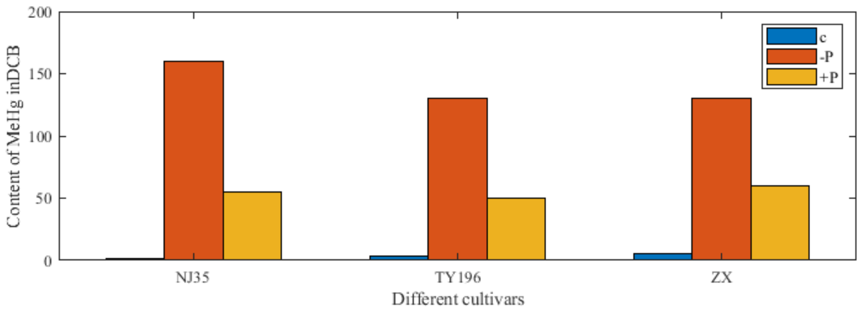

Figure 3. Contcnts of Fc and MeHg (mgkg-1DW)in dithionitc citratc -bicarbonatc(DCB)cxtracts from three cultivars under phosphorus trcament.

As shown in Figure 3, under the -P treatment, the content of MeHg (DCB-MeHg) in the DCB extracts of the three varieties of rice was significantly higher than that of the + P treatment, and the content of DCB-MeHg was 1.8-2.6 times that of the + P treatment, of which The DCB-MeHg content of TY196 and NJ35 varieties was 2.2 times and 2.6 times that of + P treatment, while the DCB-MeHg content of ZX varieties was only 1.8 times that of + P treatment.

4.2. Fe and P contents in Roots and Shoots of Rice Seedlings

It can be seen from Table 1 that under the + P treatment, the highest Fe and P content in roots and shoots of rice seedlings was the NJ35 variety; under the -P treatment, the highest Fe and P content in roots and shoots of rice seedlings were the TY196 variety.

Table 1. Iron and phosphorus (mgkg1DW) content in food and firearms

	Content of Fe		Content of P	
Cultivar/Treatment	Root	Shoot	Root	Shoot
TY196 +P -P	256±10.0 358±15.4	227±9.6 321±10.3	3402±22.3 586±22.1	9896±241 1135±31
NJ35 +P -P	266±30.0 301±10.5	271±12.6 305±12.5	4412±82.3 556±55.4	10164±258 1234±26.4
ZX +P -P	187±8.5 296±14.5	225±8.8 291±15.0	3825±281.2 581±15.4	10145±112 989±14.4
P treatment	p < 0.001	p <0.001	p <0.001	p <0.001
Cultivar	p <0.001	NS	p <0.001	NS
P×C	NS	NS	p < 0.05	NS

Note:Mean±SD(n=4),p<0.001meanssignificantdifferenceat<0.001level,"ns" means no significant difference. difference .Same as below.

Under the -P treatment, the Fe content in the root and aboveground of the three varieties of rice increased significantly compared with the + P treatment, in which the root increased by 13.2% -59.3%, and the aboveground increased by 12.5% -41.4%. Among the three rice varieties, NJ35 had the smallest increase in Fe content in the roots and above ground (root: 13.2%, above ground: 12.5%). + P treatment significantly increased the P content of roots (5.8-7.9 times) and above-ground (8.2-10.3 times) of the three rice varieties. It can be seen from the analysis of variance that different rice varieties have significant effects on root Fe and P concentrations (p <0.01, p <0.001), but have no significant effect on above-ground Fe and P contents (NS).

Table 2. Contents of mehg, iron spot-root transfer factor and root-bud transfer factor in roots and shoots of three rice cultivars under phosphorus stress

Cultivar/Treatment	Content of MeHg in root	Content of MeHg in shoots	TFroot	TFshoot
TY196 +P -P	325±11.5 330±24.4	26±2.1 22±1.5	5.21±0.05 2.01±0.01	0.08±0.01 0.07±0.01
NJ35 +P -P	315±34.5 321±18.0	27±2.15.1 21±1.52.3	1±0.110.0 5±0.050.0	9±0.01 7±0.01
ZX +P -P	388±33.4 371±24.4	38±2.1 31±1.32.6	4.89±0.05 4±0.040.0	0.10±0.01 8±0.00
P treatment	NS	p < 0.05	p < 0.001	NS
Cultivar	p < 0.001	p < 0.05	p < 0.001	NS
P×C	NS	p < 0.05	p < 0.05	NS

MeHg absorption and transport by rice seedlings Table 2 shows that the -P treatment significantly reduced the MeHg content in the above-ground three rice varieties (p <0.05), and there was a significant difference in root and above-ground MeHg content among different rice varieties. p <0.05). With or without phosphorus treatment, the MeHg content in roots and shoots of NJ35 and TY196 varieties was lower than that of ZX varieties. Among them, under the + P treatment, the MeHg content in roots and aboveground of the NJ35 and TY196 varieties were 16.2%, 18.8% (root) and 31.6%, 28.9% (above) respectively, compared with the ZX varieties; under the -P treatment, the roots of the NJ35 and TY196 varieties were lower And above-ground MeHg contents were 11.1%, 13.4% (root), 29%, and 32.3% (above-ground) lower than those of ZX varieties, respectively. As shown in Table 2, the presence or absence of phosphorus treatment and different varieties had a significant effect on the transfer of MeHg from iron film to rice roots ($p < 0.001$), but had no significant effect on the transfer of MeHg from roots to shoots (NS). The TFroot of the three rice varieties under -P treatment was significantly lower than that of + P treatment. Among them, the decrease of NJ35, TY196 and ZX varieties were 61.4%, 54% and 46%, respectively. However, there was no significant difference (NS) between TFshoot under -P and TFshoot under + P in the three rice varieties.

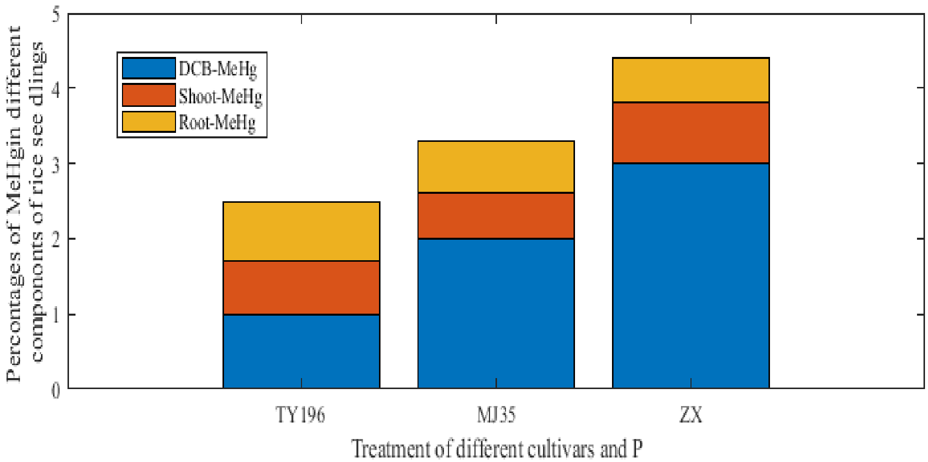

Figure 4. Total MeHg (μg) content and percentage of MeHg in different components of rice seedlings under treatment of different cultivars and phosphorus

As shown in Figure 4, with or without phosphorus treatment, the total MeHg content of the TY196 variety was the lowest, which was 77.7 μg (+ P) and 74.7 μg (-P), and the total MeHg amount of the NJ35 variety was the highest, which was 119.2 μg (+ P) and 98.7 μg (-P). Under -P treatment, the total MeHg content of three different rice varieties was reduced compared with + P treatment, but there was no significant difference among different rice varieties.With or without phosphorus treatment, the percentage of MeHg (% of total MeHg) in the roots of the three varieties of rice was the highest (ranging from 61.9% to 71.3%), and the percentage of MeHg above ground was the lowest (ranging from 7.2% to 14.7%). Compared with the + P treatment, the percentage of MeHg in the roots of the three varieties of rice decreased by 3.7% -9.2% under the -P treatment; the percentage of MeHg above ground decreased by 7.0% -7.6%; but the MeHg in the DCB extract solution The percentage increased by 10.8% -16.9% .At the same time, the percentage of MeHg in roots and aerial parts of TY196 variety decreased the most (9.2% and 7.6%), and the percentage of MeHg in DCB extract also increased the most (16.9%). Root and above-ground MeHg percentage reduction was the smallest (3.7% and 7.0%), and the percentage increase of MeHg in DCB extract was also the smallest (10.8%).

As shown in Figure 5, the content of DCB-MeHg and the content of DCB-Fe have a linear relationship, and its R2 value is between 0.1-1.0, indicating that the linear fit is higher. With the increase of the number of iron films, the concentration of DCB-MeHg also showed an upward trend, which indicates that -P treatment can significantly increase the amount of MeHg in iron films.

Different rice varieties have different numbers of iron films formed on the root surface. The higher the oxidizing power, the greater the number of iron films on the root surface. By selecting rice varieties with higher oxidizing power and phosphorus nutrient management measures, the absorption and transport of MeHg by rice were controlled. Paddy soil solution phosphorus is about 0.025-1.9mgL-1, which depends on soil type, rice growth period and phosphorus application amount. Therefore, in the production practice, the phosphorus concentration in the soil solution can be adjusted by the phosphate fertilizer nutrient management measures. In this study, we observed that the phosphorus concentration in rice shoots was not particularly low (about 1 gkg-1) under phosphorus deficiency treatment. Therefore, it is feasible to control the phosphorus concentration in the soil solution through phosphorus nutrient management to affect the amount of iron on the surface of the roots and to reduce the MeHg content in rice grains.

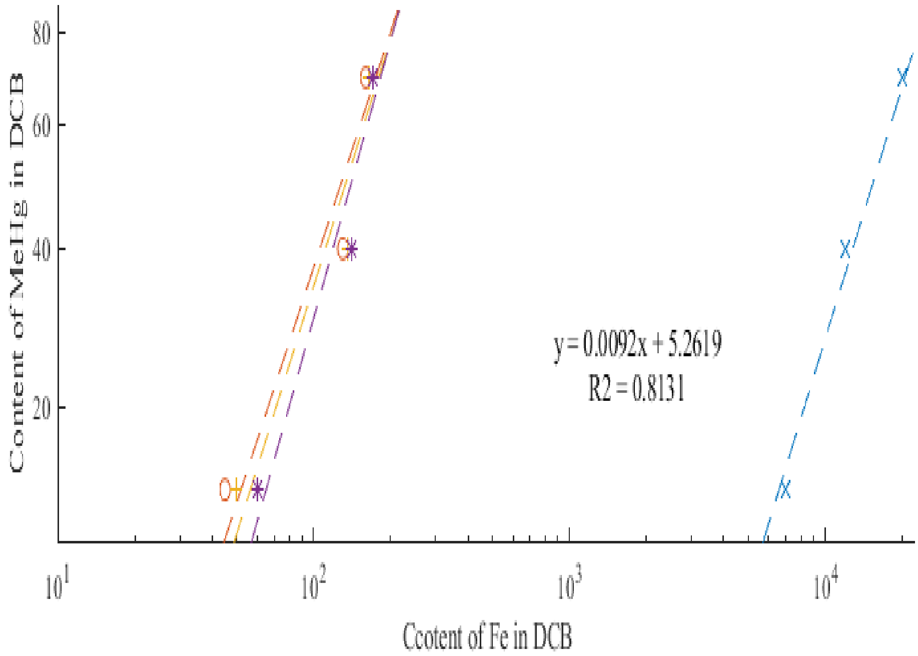

Figure 5. Relationship between the economics of mercury and the economics of cadmium (mgkg1DW) under different multivariate and phosphate treatments

There were significant differences in the MeHg content of the three rice varieties. The Shoot-MeHg% of low-mercury rice varieties (TY196 and NJ35) was significantly lower than that of high-mercury rice varieties (ZX) (Figure 2). At the same time, there were significant differences in the number of iron films formed on the root surface of the three rice varieties. Among them, the low-mercury rice varieties (TY196 and NJ35) had significantly higher DCB-Fe concentrations than the high-mercury rice varieties (ZX) (Figure 1). Whether this means that there is a wide genotypic difference between the difference in mercury content in the grains and the oxygen secretion from the roots remains to be further tested. The significant genotypic differences in MeHg uptake and transport by rice may be the result of a comprehensive effect. Wang et al. Found that low-mercury rice grains tend to form an apoplastic barrier in the endothelial layer of the root tissue, secrete less organic acids, and form more root surface iron films.The number of root surface iron films is positively correlated with the total mercury content in the iron films. As a result, the bioavailability of mercury and its accumulation in rice shoots were reduced. Therefore, screening and breeding low-mercury rice varieties in mercury-contaminated areas is of great practical significance to improve rice quality and ensure rice safety.

5. Conclusion

Plants are an integral part of the earth's ecosystem. It is of great significance to study the formation of iron films on the root surface of plants and their nutritional and ecological effects. The ecological environment affects the growth of plants, and the formation of iron membranes on the root surface of plants also directly leads to the absorption of plant nutrients. We need to use scientific methods to closely link the ecological environment and the formation of iron films on the root surface of plants.

This article has made some achievements through experimental research and obtained some practical progress. It was found that phosphorus-free treatment can significantly increase the amount of iron film formation on the surface of rice roots; iron films significantly reduce the transport of MeHg from iron films to roots. This allows more MeHg to be enriched in the iron film, and also reduces the transport of MeHg from the root to the above ground, so that most of the MeHg in the rice is accumulated in the root; different types of rice have large differences in absorption and transport of MeHg. The low-mercury rice varieties (TY196 and NJ35) had lower absorption and transport of MeHg than the high-mercury rice varieties (ZX).

After experimental research, it was found that the pollution of plants by heavy metals is fatal, and it will eventually affect people's physical and mental health. For example, some edible plants such as vegetables and rice grow in places with a severely polluted environment, and finally go to people's tables. It's us. So we must protect our ecological environment, which is good for every member of the ecological environment. The formation and nutrition of iron films on the root surface of plants depends to a large extent on the ecological environment. Based on this, this paper reviews the induction mechanism of iron film formation on the root surface of rice and the ecological and environmental effects of iron film, and discusses future research directions.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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