Technical Points of Green Prevention and Control Technology of Major Diseases and Pests in Lixian Rhubarb (*Rheum palmatum* L.)

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Abstract Based on different types of diseases, pests and weeds in the whole growth period of rhubarb (sowing period-harvesting period), the corresponding green prevention and control technology is proposed, aiming to further reduce the application amount of pesticides and fertilizers in the production of medicinal sources of Lixian rhubarb during the "14th Five-Year Plan" period. The results will provide a theoretical basis for increasing the promotion and application of agricultural prevention and control (including disease-resistant varieties, ecological regulation), physical prevention and control, biological prevention and control measures, thus ensuring effective protection of the ecological environment, green, healthy and sustainable development of traditional Chinese medicine agriculture in Longnan, and source quality of authentic medicinal materials.

Key words Lixian rhubarb; Disease; Pest; Weed; Green prevention and control

1 Introduction

Lixian rhubarb is the dry root and rhizome of *Rheum palmatum* L., a perennial herb in the Polygonaceae family, and has the effects of purging and eliminating accumulation, clearing heat and cooling blood[1-2]. As the birthplace of Qin culture, Lixian County, Gansu Province, is the genuine producing area of rhubarb, known as the "millennium medicine town". The rhubarb produced in Quanshui area of Lixian County is famous for its large mass, firm quality, clear flavor and high content of anthraquinones (0.668% free anthraquinones and 7.38% combined anthraquinones). Quanshui is recognized as the origin of "Lixian rhubarb", with *R. palmatum* as the main variety, known internationally as "China Quanhuang", which is welcomed by domestic and overseas markets and exported to Hong Kong and Macao, Japan, Canada, France, Spain, *etc.*[3-4].

Lixian rhubarb has been artificially cultivated for more than 1700 years, covering 17 towns and townships, with a planting area of more than 2 733.33 hm^2 and an annual output of more than 5 000 t. Its export volume accounts for 70% of the total export volume of Gansu Province and 56% of the national volume. Lixian rhubarb production area is listed as the national rhubarb breeding standardization demonstration area, original ecological protection demonstration area and export quality and safety demonstration area, and the rhubarb produced has obtained the national geographical indication of origin protection product certification, foreign trade department high-quality product, pollution-free origin and product certification. Since the 21st century, due to the long planting history of rhubarb in Lixian County, stable price, rising labor cost and strong support from the local government, there have been years of continuous cropping of pharmaceutical sources production, seriously shortened production period of medicinal materials and misuse of pesticides and chemical fertilizers by farmers, leading to frequent occurrence of diseases, pests and weeds, decreased content of effective ingredients of medicinal materials and excessive pesticide residues, which affect the product sales of authentic medicinal materials and the brand benefits established. Relevant literature has recorded the development problems, countermeasures, planting and processing technology, and pest control technology of rhubarb production industry in Lixian County[5-8], but there are few materials on the green prevention and control technology of major diseases, pests and weeds of rhubarb in Lixian County. After more than 5 years of experimental research, this paper summarized the types of diseases, pests and weeds in the whole growth period of rhubarb, and the corresponding green prevention and control technology, in order to provide a theoretical basis for green, high quality and efficient development of Lixian rhubarb.

2 Major diseases and prevention and control

Rhubarb is the dry root and rhizome of *R. palmatum* L, *R. tanguticum* Maxim. ex Balf., or *R. oficinale* Ball.[9]. Lixian rhubarb specifically refers to *R. palmatum*. According to investigation, the main diseases of *R. palmatum* include root rot, ring rot, smut, spot blight, *etc.*[10]. In addition, leaf smut, rust, leaf spot gray spot, powdery mildew, gray mold and other diseases have also been found in *R. palmatum*[11].

2.1 Agricultural prevention and control Selection of resistant rhubarb varieties is the most effective way to control anthracnose, and breeding resistant materials with high yield and high re-

Received: November 10, 2023 Accepted: January 5, 2024

Supported by Science and Technology Plan Promoting Regional Collaboration Project of Longnan City (2022-S.BF-01); Key Talent Project of Gansu Province (2021RCXM042, 2020RCXM041).

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sistance is carried out by screening resistant resources. More than 3 years of rotation with Gramineous plants like wheat, corn, millet and barley is an effective measure to prevent and control anthracnose, while continuous cropping and alternate cropping are strictly prohibited. It is suitable for late sowing to avoid the peak of diseases, and the measures such as strengthening field management, reasonable dense planting, timely removal of rotten roots and leaves, dredging drainage, ventilation and light transmission should be implemented. The application amount of fertilizer should be reasonably controlled by increasing the application of phosphate fertilizer combined with potassium fertilizer, advocating the application of base fertilizer, increasing the application of organic fertilizer, and applying nitrogen, phosphorus, potassium and trace elements in a reasonable combination. According to the seedling situation, combined with rainfall, topdressing can be opportunely performed. The green planting technology of dipping rhubarb seedling roots can be promoted, which can kill the root bacteria at one time and maximize the protection against root diseases.

2.2 Chemical prevention and control It has been found that root rot disease could be controlled by root-irrigation with thiophanate methyl or spray with 50% thiram · metalaxyl; ring spot can be controlled by spraying Bordeaux mixture, mancozeb WP, carbendazim WP, or triadimefon and chlorothalonil; smut can be treated with difenoconazole, *Trichoderma harzianum*, extract of Chinese traditional medicine berberine AS, and 1% matrine AS[12]; spot blight can be controlled by thiophanate methyl, chlorothalonil WP, oxadixyl mancozeb, mancozeb WP, and metalaxyl · mancozeb WP[13].

In the early stage of gray mold, 40% fosetyl-aluminum 300 times dilution or 25% metalaxyl 400 – 500 times dilution can be sprayed once every 7 – 10 d for 2 – 3 consecutive times; seed dressing with ziram · thiram, thiram, carbendazim, benomyl, thiophanate-methyl, and carbendazim · thiram WP can prevent the occurrence of anthracnose, or bromothalonil, propineb, ziram · thiram, and iprodione · thiram can be sprayed in the early onset of anthracnose.

3 Major pests and their prevention and control

There are more than 20 species of pests damaging Lixian rhubarb, belonging to 17 families, 7 orders, including *Holotrichia diomphalia*, *Serica orientalis*, *Pleonomus canaliculatus*, *Agriotes fusicolis*, *Monolepta hieroglyphica*, and *Mylabris ealida* in Coleoptera; *Agrotis ypsilon*, *Trachea tokionis*, *Agrotis segetum*, *Heliothis dipsacea*, *Scotogramma trifoli*, and *Mythimna separate* in Lepidoptera; *Phytormyza atricomis* in Diptera; *Adelphocoris lineolatus*, *Lygus pratensz*, *Eurydema gebleri*, and *Dolycoris baccarum* in Hemiptera; *Brassica oleracea*, *Cicadella vinidis*, and *Empoasca flavescens* in Homoptera; *Odontothrips loti* in Thysanoptera; *Gryllotalpa unispina*, *Oedaleus decorus asiaticus*, *Angaracris rhodopa*, *Haplotropis brunneriana*, *Pararcyptera microptera meridionalia*, *Calliptamus sitalicus*, *Acrida cinerea*, and *Atractomorpha sinensis* in Orthoptera.

3.1 Agricultural prevention and control

3.1.1 Strengthening forecast and prediction. Beetle larvae (grubs) are soil dwelling insects who live and harm underground, with concealability. It is necessary to strengthen the forecasting and prediction of such pests.

3.1.2 Plowing to eliminate pests. The plots with serious occurrence of grubs can be plowed in late autumn or early winter to expose to the air, and make them freeze to death or be pecked by natural enemies, which can reduce the insect quantity by 15% – 30%, thus significantly reducing the damage in the second year.

3.1.3 Reasonable arrangement of crops. The plots with beans, peanut, sweet potato, potato and corn in the preceding crop will trigger serious damage of grubs, which is related to the feeding activities of adult grubs.

3.1.4 More application of fully decomposed and fermented organic fertilizer. Undecomposed manure has strong taxis, which will attract most pests to spawn, and then bring a large number of eggs into the field when applied. Decomposed organic fertilizer can improve soil permeability and aeration characteristics to offer good conditions for soil microbial activity, and promote the quick development of roots, thus enhancing crop resistance to pests. Grubs do not prefer decomposed organic fertilizer, which can reduce their harm to crops.

3.1.5 Rational application of chemical fertilizer. Chemical fertilizers such as ammonium bicarbonate, ammonium humate, ammonium hydroxide, and ammoniated superphosphate can emit ammonia gas which has certain repellent effect on underground pests such as grubs.

3.2 Physical prevention and control Using the feign death of larvae, shaking off method can be adopted to exterminate the pests. Black light lamp or solar frequency vibration insecticidal lamp can be set up to trap and kill adult moths. Sweet and sour liquor can be prepared to trap and kill adult moths. Yellow board and white board can be hung to trap alatae in the field. The color board should be hung above the top of the plants following the direction of local wind. The solar frequency vibration insecticidal lamp can be installed in the field to carry out continuous trapping and killing of adult insects, which will significantly reduce the harm and control the damage rate below 5%, with the control effect up to 61.04%.

3.3 Chemical prevention and control

3.3.1 Seed dressing with chemical agents. Seeds can be mixed with 50% phoxim EC or 48% chlorpyrifos EC at the dose of 0.3% seed weight.

3.3.2 Soil treatment with chemical agents. 50% Phoxim EC or 48% chlorpyrifos EC 200 – 250 mL/667 m^2 diluted with 10 times water can be sprayed on 30 kg fine soil and mixed well to form toxic soil. The toxic soil should be applied along rows, then shallowly hoed. The same amount of toxic soil should be broadcasted in

planting ditches or on the ground, and plowed immediately; it can also be mixed with barnyard manure, or applied in combination with irrigation. 5% Phoxim GR, 5% diazinon GR, and 5% chlorpyrifos GR can be mixed with 50 kg fine soil at the dosage of 2.5 – 3.0 kg/667 m^2, and then evenly spread on the soil surface, which can control wireworms and mole crickets as well.

3.3.3 Application of phoxim poison grains. Half-cooked millet or bean cake, and sweet potato are ground and mixed with 50% phoxim EC and seeds, and sown in the hole, which has better effect on crickets and is also effective to other underground pests. Phoxim capsule mixed with millet and other baits is also effective to underground pests such as mole crickets and wireworms.

Moths can be controlled by spraying indoxacarb, chlorfenapyr, lambda-cyhalothrin, phoxim, cyfluthrin, imidacloprid, esfenvalerate, chlorpyrifos · abamectin, phoxim · abamectin EC or 90% trichlorfon crystals before the third instar of larvae.

In middle and late July, field survey of aphids should be strengthened, and it should be controlled promptly when the number of aphids per hundred plants reaches 1 200 – 1 500 and the ratio of natural enemies and aphids is less than 1 ∶ 150.

3.4 Biological prevention and control Natural enemies or plant-derived solutions are good measures for biological prevention and control. Aphids can be killed by natural enemies such as ladybugs, hoverflies, lacewings, assassin bugs, spiders, and *Aphidius* sp., or it is advocated to release *Aphidius* sp. and ladybugs in biological control. Besides, matrine alcohol solution, matrine AS, hypertonic rotenone EC, emamectin benzoate EC and abamectin EC can be sprayed.

4 Main weeds and their prevention and control

Using the inverted "W" nine-point sampling method[14], the dominant weeds in the field of Lixian rhubarb are mainly *Convolvulus arvensis*, *Datura stramonium*, *Setaria viridis*, *Solanum nigrum*, *Digitaria sanguinalis*, *Panicum miliaceum*, and *Chloris virgata*, *etc.* The weeds usually emerge in groups with the seedling emergence of rhubarb, and cause serious damage at seedling stage and seedling transplanting and greening stage.

4.1 Agricultural prevention and control

4.1.1 Selecting *R. palmatum* seeds. Weed seeds are usually mixed in crop seeds, and enter the field along with sowing, becoming a source of weeds in farmland. It is the main way of weed propagation and diffusion. Introduction quarantine and seed selection before sowing are indispensable procedures to improve the purity of seeds.

4.1.2 Reducing weed seed propagation in straw turnover. A large number of weed seeds will be left in the field in straw turnover or harvest with high stubble (low weeds continue to thrive). In the place where crop straw is not needed as fuel, it is advocated to cut and decompose the straw, and then put it into the field to fertilize the field, in order to reduce the initial seed quantity in the field.

4.1.3 Plowing the soil deeply. Before sowing, the soil should be plowed about 30 cm deep, and the weed seeds in the soil surface are buried deep through deep plowing. Large amount of rhizomes are turned to the ground, which will dry out and freeze to death, thus reducing the harm of weeds. The plots with fewer perennial weeds can perform shallow rotary tillage to eliminate stubbles. Deep ploughing for stubble removal is adopted in the plots with serious occurrence of perennial weeds.

4.1.4 Rational application of fertilizer. Decomposed organic fertilizers are mainly applied, with rational combination of nitrogen, phosphorus, potassium and trace elements, while excessive application of nitrogen fertilizer should be avoided, to reduce the harm caused by weeds.

4.1.5 Reasonable intercropping and rotation. The competitiveness of weeds can be improved by using complementary advantages of crops, and the growth and development of weeds can be inhibited by allelopathy between plants, so as to achieve the purpose of controlling weeds. The use of light energy and space, intercropping and interplanting corn, sunflower and other tall crops can reduce the harm of weeds and improve the planting efficiency.

4.1.6 Planting at optimum period. In order to effectively reduce the occurrence and harm of weeds, *R. palmatum* can be planted 5 d later or 5 d earlier than the normal planting time, which basically has no impact on the yield. Weeds can be killed after emergence through the operation process of weeding and chemical treatment following the law of strong resistance of weeds and early emergence of seedlings in early spring.

4.1.7 Rational close planting. Practices have proved that the planting density of 23 800 plants/hm^2 could promote the growth and development of *R. palmatum* and reduce the harm of weeds.

4.1.8 Weed control. The weeds at the edge of fields, ditches or in fields should be removed to reduce the spread of weeds. When watering, the filter is set at the water inlet to block wild oat, barley, naked oat, hulled oat, buckwheat, duck wheat and other large seeds into the water, so as to reduce or avoid the harm.

4.2 Physical prevention and control Mulching cultivation on controlling weeds receives obvious effect in *R. palmatum* field. Black mulch has a very significant effect on weed control, with better yield increase effect than white mulch, being an effective herbicide-free physical control measure. The use of black degradable mulch film with a thickness of more than 0.01 mm can not only ensure the recycling of farmland residual film, but also significantly improve the control effect of weed damage in *R. palmatum* field, and reduce labor production costs, which can be widely applied in the green and standardized production of *R. palmatum* in Lixian County.

4.3 Chemical prevention and control At 5 d before *R. palmatum* sowing or transplanting, 48% trifluralin EC 150 – 200 mL/667 m^2 or 48% butralin EC 200 – 250 mL/667 m^2 can be di-

luted with 45 – 60 kg water and evenly sprayed on the soil surface, and the soil should be randomly mixed at the depth of 2 – 3 cm. The operations can effectively control annual weed weeds such as *Echinochloa crusgalli*, *Setaria viridis*, *Digitaria sanguinalis*, *Eragrostis cilianensis*, *Poa annua*, and *Chloris virgata*, and some small-seed broad-leaved weeds such as *Chenopodium album*, *Amaranthus retroflexus*, *Polygonum convolvulus*, *Polygonum aviculare*, *etc.*

5 Conclusions

In order to ensure the quality of traditional Chinese medicinal materials, it is recommended to adopt green comprehensive prevention and control technology during the whole growth period of *R. palmatum*, focusing on diseases, pests and weeds, and taking into account secondary objects. On the basis of agricultural measures, field microclimate conditions conducive to growth and not conducive to the occurrence of diseases, pests and weeds are created to achieve the purpose of controlling the damage of diseases, pests and weeds. The agriculture measures include selection of disease-resistant varieties, soil plowing, adjustment of sowing time and quantity, reasonable fertilization and irrigation, reasonable intercropping and rotation, cleaning fields, *etc.* Physical control is regarded as an auxiliary measure. Black light or solar frequency vibration insecticidal lamp can be set up in the field, or color boards can be hung to lure pests, while black mulch can be covered to control weed hazards. Biological control is adopted as a complementary measure. The interrelationships between biological species can be used to suppress one species or a group of organisms by another species or another group of organisms, and natural enemies of pests and beneficial microorganisms can be utilized to control the harm of diseases and pests. Chemical prevention and control is an emergency measure. In different growth stages of *R. palmatum*, according to the forecast and the actual occurrence in the field, chemical agents can be sprayed when the occurrence of diseases and pests has reached the standard, and biological pesticides are preferred when the occurrence of diseases and pests is mild. When other prevention and control measures have not received ideal effect, and the occurrence of diseases, pests and weeds reaches the prevention and control threshold, high-efficiency, low-toxicity and low-risk chemical agents are selected to carry out emergency prevention and control in time. Chemical agents are used alternately and in rotation to avoid circulation and continuous use in the producing area, so as to effectively delay the generation and development of resistance. The number and amount of drugs used should be reduced as much as possible, and it is better to promote green prevention and control technology.

The technical points of "suitable varieties + seed treatment + agricultural control + physical control + biological control + high-efficiency, low-toxicity and low-risk chemical pesticides + new high-efficiency application equipment + pesticide spray additives" model in the whole production process of *R. palmatum* are based on different types of diseases, pests and weeds occurred during the whole growth period (sowing period-harvesting period). On the basis of agricultural, physical and biological prevention and control, precision control is implemented at key time nodes of the occurrence of diseases, pests and weeds, which can achieve drug and fertilizer reduction and damage control, and effectively protect the ecological environment, thus ensuring the quality and active ingredient content of *R. palmatum*.

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