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A brief note on the incidence and management of *Plasmodiophora rassica*

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Plasmodiophora brassica is a causal agent of brassica clubroot, and synthetic and bio fungicides showed actions against *P. brassica*. Under controlled-environment conditions, the mechanism of suppression of *P. brassica* by bio fungicides was antibiosis and mediated host resistance. To promote the delivery of bio fungicides, various formulations like granular and seed treatment were produced, so neither bio fungicides nor chemical fungicides were sufficiently compelling to reduce the population of resting spore *P. brassica.* Resistant cultivars substantially decreased clubroot intensity and canola yield losses. *P. brassica* resistance is the most consistent and economically appropriate management approach, but some studies indicate that clubroot resistance may not be robust. To build and deploy a different source of resistance constantly. The bait plants and soil modifications are not commercially practical. Crop data manipulation, soil fumigation, chemical fungicide application, and bio fungicides have much more ability to control *P. brassica*. The combinations of strategies that can minimize the pressure of disease in infested areas and enhance the resilience and number of the resistant gene versus *P. brassica* still need to be identified.
Keywords: *Plasmodiophora brassica*, clubroot, management, bio fungicides, soil modifications, crop data manipulation, soil fumigation, chemical fungicide application, disease pressure, resistant gene, infested areas, resilience.

INTRODUCTION

Clubroot, caused by the soil-borne pathogen *Plasmodiophora brassicae* Woronin, is a primary disease that leads to significant yield reductions in Brassica crops and has substantial economic implications (Ciaghi *et al.,* 2019). In areas where vegetable brassicas and canola (*Brassica napus* L.) are grown, there's a rise in particular diseases that affect the surrounding environment. These diseases have significant implications for developing economies (Hejna *et al.,* 2019). In China, clubroot epidemics have rarely been identified in recent years in areas producing cruciferous crops. China is one of the leading producers of cruciferous products consisting of 6,700,000 ha, of which 23,2600 ha of Cruciferae, 899,300 ha of cruciferous crops, 53,6900 ha, and 1,200500 ha of which canola is the seed of Chinese cabbage (*B. rapa* L. ssp. *pekinensis*), Pak choi (*B. rapa* L. ssp. *chinensis*). Since the 1910s, when infection was successively revealed in Taiwan and Fujian Provinces, *P. brassica* has been diseased by these crops (Ren *et al.,* 2016). Clubroot is sporadically found across the southwestern, northeast, and central regions of China, with the most significant outbreaks occurring in these areas. Clubroot disease is estimated to infect 3.2-4.0 million hectares per year of cruciferous crops. Chinese chocolate, Choi, radish, mouth-tail, stem mustard, and even medicinal crops such as Banlangen (*Isatis tinctoria* L.) are known to develop the disease. In recent years, it has expanded its presence in Anhui, Sichuan, Hubei, and the city

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of Chongqing (Ren *et al.*, 2016). *P. brassica* tries to invade vegetable fields in some areas very severely. It ends the cultivation of cruciferous plants. The clubroot increased impact led to comprehensive, coordinated research in China focusing on clubroot inspection knowledge.

Distribution of clubroot disease in China**:** Thin material on clubroot in China was published formerly in China's Freedom in 1949. However, in 1912, 1936, and 1947 in Fujian Province, clubroot's recorded findings were from Taiwan. The first National Conference on Plant Quarantine reported clubroot to be one of the essential quarantine objectives in 1953 (Wang, 1962). The influence of clubroots reports significantly increased in the 1950-60s as agricultural production increased to nurture the rising population that helped establish socialist industries. In 1950, in Nanchang County, Province of Jiangxi, after five years, the disease spread to almost all the areas in the Province of Zhejiang, including the districts of Zhuji, Huangyan, Yongjia, and Jinhua ranged between 55% and 70%. The turbo-ship club was registered to most cruciferous vegetable fields, approximately 10-42% at first, in Jiamusi City of Heilongjiang Province in 1956 and three years afterward. The 3.2-4.0 million hectares per year of cruciferous cultures affected by the disease account for more than a third of the region of cruciferous crops. The average return losses of 20-30% were recorded (Zhang *et al.*, 2023). These areas are usually alkaline in low rainfall. The current status of the clubroot in China (Figure 1).

Climate change is significant among the south and north, with clubroot taking place in various regions of China at different times. The disease occurs primarily in the Northwest between July and August while in the southwest between April-June and September-October. The club's source lies between April-June and October-November in the middle and lows of the Yellow River (Zhang *et al.*, 2022). It extended from July to August and then from October to November along the mid to lower sections of the Yangtze River. For the Southern and Northeast regions, the incidence periods range from January to March and then from October to December (Table 1).

Disease Cycle: The disease cycle of *P. brassicae* encompasses two main phases: the primary stage affecting the host's root hair cells and the secondary stage targeting the cortical cells (Figure 2) (Jia *et al.*, 2017). Primary inoculum consists of spores that rest in the surrounding soil dispersed from rotted tissue (Botero *et al.*, 2019; Burki and Keeling, 2014). These restorative spores can survive up to 20 years in the soil and contaminate any nearby host. A secondary

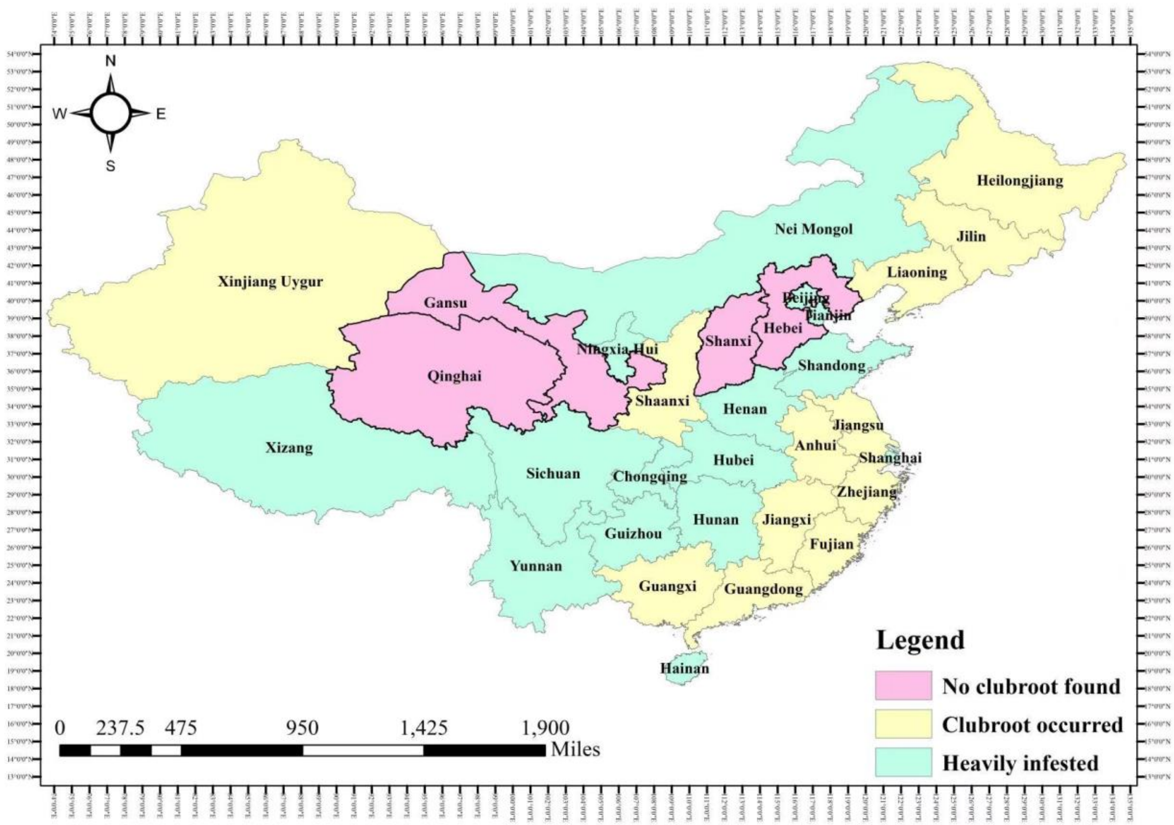

Figure 1. Disease distribution in China

Table 1. Geographical distribution and incidence seasons of disease in China.

Geographical regions	Province	Occurrence season
Northwest China	Xinjiang, Shanxi	July- August
Southwest China	Yunnan, Huizhou, Chongqing, Xizang, Sichuan	April-June, September-October
Middle and lower streams of the Yellow River	Henan, Shandong, Beijing	April-June, October-November

zoospore produced in the root hair from the zoosporangia causes cortical contamination. In the cortical tissue of the ventral roots, secondary zoospore joins. The pathogen has secondary plasmids within attacked root cells linked to cellular hypertrophy and is followed by tissue gall formation. The resting spores are released into the ground as the root tissue collapses and becomes the main inoculum for the following seasons.

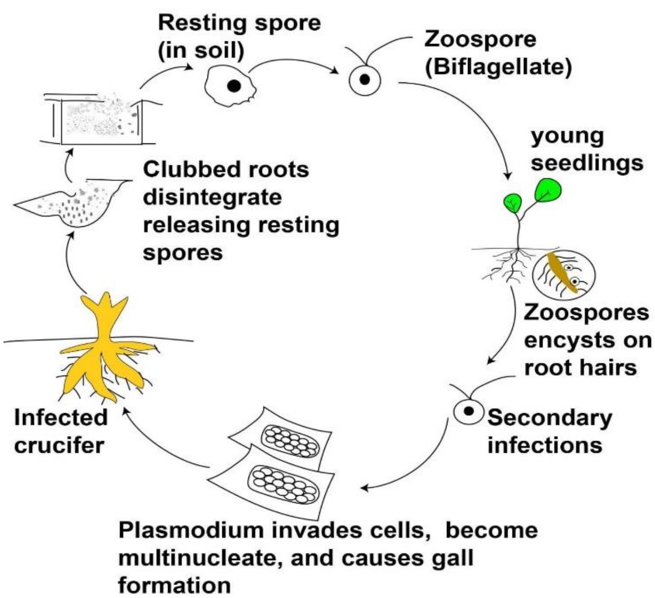

Figure 2. Disease cycle of clubroot caused by *Plasmodiophora brassicae.*

***Disease Control*:** Because of these complexities, those two microorganisms need to figure out effective disease control measures. Many management approaches have been used to contain club root disease of brassica (Figure 3).

***Chemical Approach*:** Usage of chemicals can reduce the *P. brassica* and *A. flavus*. Only a limited number of intense ingredients have been continuously tested on clubroot. Benzimidazole and its precursors containing benomyl, thiophanate, and thiophanate methyl are some of the most commonly estimated groups of chemicals for clubroot management. Several other substances are also effective against clubroots- particularly pentachloronitrobenzene (PCNB), trichllamide, flusulfamide, fluazinam, and cyazofamide. Fluazinam and cyazofamide mixtures are active in clubroot control and are commonly used in China (Ludwig-Müller, 2016). Their performance in management was higher than other chemical fungicides. Seeds treated with 10% cyazofamide SC were co-treated with 50% fluazinam SC before sowing. When these treated seeds were sown in seedbed soils and then the plants transferred, there was a notable increase in yield effectiveness at 85.7% and 42.3% respectively. These results suggest that fluazinam and cyazofamide could be useful tools in China to lessen the impacts of clubroot. There is currently only one fungicidal active in China (fluazinam) registered to control the brassicas' clubroot.

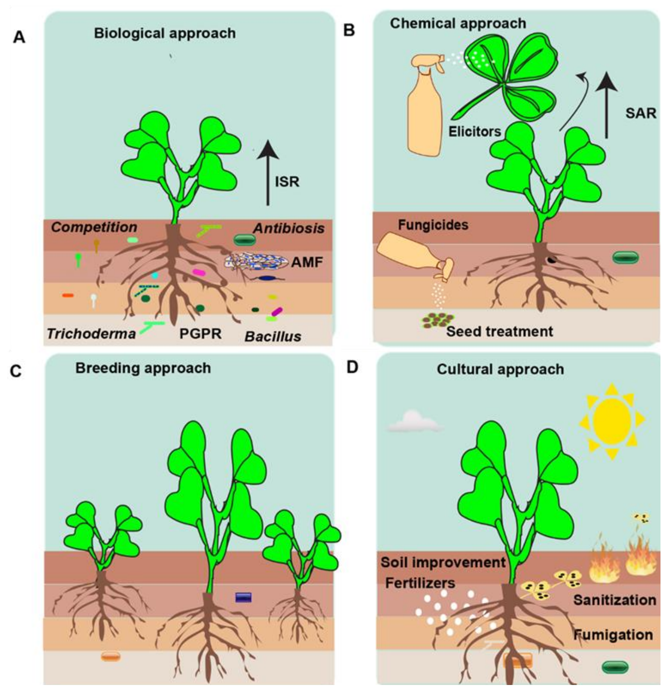

Figure 3. Critical management approaches to control club root disease.

Breeding Approach: The most successful approach to minimize crop loss caused by *P. brassica* is a resistant cultivar (Strelkov *et al.*, 2016). Genetically resistant, the dynamic inconsistency of several other species or pathotypes of *B. thuringiensis* may range from broad-spectrum resistance to particular active resistance to just a specific strain of the pathologist. Therefore, the opposition's stability is predisposed by the composition in the region of pathotypes planned for the use of this resistance base (Strelkov *et al.*, 2011). As described earlier, an analysis of Chinese populations of *P. brassica* has shown a pathogenic diversity in parasite virulence, which has at least eight different pathotypes (1, 2, 4, 7, 9, 10, 11, and 13) which were recognized by the differential collection (Jia *et al.,* 2017). Clubroot resistance breeding (CR) is currently based in China on Chinese cod, European cold, and canola. The plants are reproducing resistant cultivars of more than ten private enterprises and 20 government agencies. Recently several cultivars have been published (CR589, DEgapo 'CR117,' 'Kanggen 39', 'Kanggen 51', 'CR Weimin', 'CR Huimin' and 'CR Aimin'), 'Shennong 106','Kangda No. 3', 'CR Huimin', 'Xiyuan 6', 'Huayou 7', 'A 35', and 'Yunyouhuang 1' of canola) to the market. The result is intense attempts to grow resistant hybrids. The production of these varieties is an essential step towards clubroot management in China. The virulence composition of P. brassica changes quickly when resistant varieties are cultivated. Observations from various countries have indicated that genomic resistance can be diminished (LeBoldus *et al.,* 2012). In Canada, a three-year difference among resistant canola cultivars grown in club-inferred fields is recommended. Still, the lack of information about the use of resistance sources as commercial hybrids complicates resistance management (Strelkov *et al.,* 2011).

***Cultural approach disease avoidance*:** Cultural management for clubroot management is most successful in ensuring the fields stay pathogen-free. Any operation leading to the carriage from one point to another of dirt or crop residues contaminated with *P. brassica* could spread the pathogen (Strelkov *et al.,* 2011). An analysis of club-infested crops shows that the infected plants are most prevalent at field entrances and lower at 150 m and 300 m from the entry stage. A study shows that there is no problem with infected crops. Seeds and tubers from fields with infestations revealed detectable levels of spores, suggesting another potential method for the long-distance spread of *P. brassica* (Rennie *et al.,* 2011). It is important to note that the transport of agricultural machinery, mechanisms, and automobiles of infested soil and agricultural waste is a much more systematic and reliable propagation process than the spread of seed. The transmission of essential spores through roots and tubers might enable *P. brassica* to spread over greater distances than typically linked to the movement of farm machinery. This may also lead to new races or pathotypes being introduced in a field where they have not been present before. The following evaluation outlines several strains or pathotypes of *P. brassica* (Strelkov *et al.,* 2016). The irrigation water pumped by rivers, streams, and reservoirs polluted by club-based runoff from infesting fields is essential for *P. brassica* dispersal. Contaminated water can invade large areas of non-infested fields and should not be used on cruciferous plantings or other susceptible crops, such as canola. Similarly, the passage through cattle of residual spores will survive so that raw mist is avoided from animals fed or grazed by club-infected foods on clean fields. The temperature and humidity content of the *P. metal* residue spores from composted residues infested with club roots were necessary for the effective removal. The effects of composting have been modest, though, and it has been questioned how temperatures could be reached that would eliminate all *P. brassica* resting spores.

***BAIT CROPS*:** It has been suggested that eliminating the host plants' ability to germination of resting spores is one way to contain the clubroot (Ernst *et al.,* 2019). *P. brassica* resting spores can live in the soil environment for several years. However, to maintain their life, they have to infect a host after germination rapidly. The levels of viable restorative spores in the soil are essential in further producing *P. brassica* epidemics. For the clubroot disease Index to decrease to 50% of that seen in 108 ML-1 spores, viable spore density was reduced to about 104-105 mL-1 spores (Hwang *et al.,* 2014). However, high inoculum concentrations can decrease below the disease threshold, especially in long rotations (Ernst *et al.,* 2019). Various non-brassica plants, such as common velvet-grass (*Holcus lanatus* L.), perennial ryegrass (*Lolium perenne* L.), and Indian cress (*Tropaeolum majus* L), have been found to have root hair infections with *P. brassica*. In a single sample, permanent ryegrass decreased the remaining spore numbers (Hwang *et al.,* 2015). Although studies in northern Europe with bait plants to induce sprouts when they were at rest were not feasible, they were typically successful with club roots (Hwang *et al.,* 2015). The bait evaluation in two different field in Alberta had minimal impact on spores populations. The resting spores were about 1 to 106 spores per g of soil at those locations, so it was not easy to detect a reduced spore load and not impact the clubroot's intensity. Although cultivars also encourage the germination of residual spores, the production of few or no viable spores can lower inoculum pressure (Hwang *et al.,* 2015). Long-term studies are essential for detecting substantial decreases in clubroot inoculum and severity at highly infected sites and assessing the effectiveness of bait crops in locations with low to moderate inoculum levels. The findings (Hwang *et al.,* 2015) tend to support Canadian findings that bait crops' effect on the potential and severity of inoculums and clubroot crop disease is too limited and not reliable for the commercial management of bait disease.

Seeding date: High soil humidity and temperatures near 25-30°C are strongly promoted for clubroot production. Therefore, the seeding timing to mitigate infection can be a crucial way of preventing disease in canola and other long-term brassicas (He *et al.,* 2019). Cold field temperatures are being demonstrated to avoid pathogens' production; older plants are shown to be less contagious and less likely to affect output from the infection occurring. Early dates of seeding decreased clubroot severity by 10-5% and boosted the production by 30-58% (only statistically relevant in two locations. The same results were achieved over several years in central Canada by manipulating club root minimis in Shanghai pak choy (*Brassica rapa* subsp. *chinensis*). An early seedling of canola has reduced club severeness and increased production, although it is also decreased in a study. Younger canola planting plants are more contagious than older planting plants, according to earlier study (Hwang *et al.,* 2017). Some plants were inoculated within five sowing days, however a resistant cultivar showed little to no clubroot signs when inoculated 10-25 days after the seeding. With increased age, susceptibility of canola roots to infection by *P. brassica* may decrease as cell walls are thickened or other barriers that restrict the colonization of pathogenic substances are developed (He *et al.,* 2019). However, the management of the clubroot is not adequate to handle the seed dates alone. Further research is still needed in this area, however. Early sowing could be a useful technique for clubroot control of canola, in addition to other crop management strategies such host plant tolerance, soil modification, and fungicide use.

Sanitization**:** *P. brassica* Soils infested or crop residues invaded by *P. brassica* will spread from one field to another (Strelkov *et al.,* 2011). The sanitation method consists of the purifying of, or otherwise decontaminating, hard surfaces of the crops, plants, water, and soil infesting with pathogens (machinery, appliances, cars, tools, and footwood). These agricultural practices aim to get rid of pathogens, reduce the chance of bringing them in, or slow their spread from contaminated to uninfested fields or outside of restricted zones of already-infested fields. To avoid transfusion to new sites, field equipment, machines, vehicles, and similar club-infested soils and contaminated crop residues should be washed as far as possible before they are transported to club-free areas. Sadly, many farmers consider extreme sanitization protocols to take too long and work hard as field facilities usually have many internal and external soil and spore-bearing dust surfaces and contaminated crop residues that can. Simulation protocols are too long. Rough and fine cleaning should eliminate up to 99% of the club's emissions and be an essential step in sanitizing the machinery, equipment, and vehicles polluted with clubs (Geddes *et al.,* 2022). Free of visible soil and materials should be on the surfaces. Using a disinfectant on pre-cleaned surfaces, such as 1-2 % active sodium hypochlorite solution, can destroy or inactivate the rest's remaining spores. To achieve adequate spore mortality, a contact time of 20-30 minutes is required. It took at least 2 h to clean up and disinfect a 12 m prominent farm farmer and up to 4 h for a big tractor for demonstration tests on the farm in Southern Alberta (R.J. Howard unpublished data). This was carried out using a mobile sanitary system that included an air compressor, a commercial press washer, and other equipment that farmers usually use for machinery, field equipment, and vehicles like farm trucks. In such situations, brushes or compressed air should be used to eliminate loose dust and waste (Geddes *et al.,* 2022). Some experiments measured the relative effectiveness of chemical disinfectants against the residual *P. brassica* spores. Hwang et al. (2014) confirmed that neither of the nine commercial désinfectants was wholly inactivated, and most were inactive club resting spores. The only treatment with Hypochlorite that led to a substantial reduction in club seriousness when treated spores were used inoculating Broccoli seedlings (Hwang *et al.,* 2014) recorded significant changes in their pathogenic activity and caused the decrease of broccoli disease (121°C, 20 min) or dry heat (80°C, 12h). Neither procedure resulted in 100% resting spores being inactivated. All treatments shortened the exposure times by 30 min to 72h in increments of 0.5 or 1.0 h. All treatments reduced their infectivity. The sharpest declines occurred at 80, 90, and 100°C, and after just 30 minutes of treatment, many spores were reduced to nonviable. After 48 hours of thermal therapy, spores at 40 and 50°C remained contagious. UV light sensitivity has contributed to lower pathogens. This was associated with reductions in galling root intensity (r= 0.80) in vegetable seedlings inoculated by treated spores. By comparison, ion therapy decreased pathogenic activity by relatively small amounts, and the degree of symptom expression was not correlated.

Soil improvement Fumigation**:** Calcium cyanamide is another modification used for a long to ease clubroot in brassica vegetables (Dixon, 2017). Calcium cyanamide is broken down to create cyanamide, urea, ammonia, and nitrate. The soil has increased pH and acts as the nitrogen source in the crop with calcium cyanamide and its disintegrating products. Soil humidity facilitates cyanamide to dicyandiamide dimerization (Dixon, 2017; Liu *et al.,* 2016). Dicyandiamide is an inhibitor of nitrification that delays soil nitrification and decreases nitrates' leaching into groundwater (Di and Cameron, 2016). Calcium cyanamide degradation to ammonium continues for a long time (Kishida *et al.,* 2020). Zhengfeidan TM is a granulating SLR fertilizer that is used in most parts of China. The fertilizer consists of calcium cyanamide (alternatively, 50% calcium oxide, a total of 19% nitrogen, and 0.3% calcium carbide). The suppression of the clubroot of cruciferous plants has been demonstrated (Dixon, 2017). The use of industrial granular calcium cyanamide types Zhengfeidan and Perlka is also associated with reduced clubroot severity of stem mustard. The club management results with a combination of dazomet and calcium cyanamide were most successful (Hwang *et al.,* 2017). Also, the application of calcium cyanamide to strengthen the control of *P. brassica* was suggested after studies. For more than 70 years, Boron has been advised to minimize clubroot intensity on vegetable plants. In addition to promoting the growth of numerous Brassica species that require high boron levels, it prevents the transition of developing plasmodium to sporangium during root hair infection (Ludwig-Müller, 2016). The decline in clubroot intensity was more consistently noted in soils with a high organic content compared to the typical mineral soils of the Canadian prairie regions, as observed from field evaluations across various landscapes and ecosystems.

liming**:** Liming is also a part of the integrated mechanism of the club infection. Infield trials on cruciferous crops over several evolving periods in China, the impact of the limitation on severity and disease yield was calculated. Lime usage in the Lichen region, Hubei Province, increased soil pH by one unit for three years at 150-200 kg/667m2, decreased the clubroot prevalence by 13.3%, increasing yield by 14.3%. Long-term use is also effective in harming crop nutrition (da Costa and Crusciol, 2016).

Gaining Control Through Combination Of Suppressiveness And Molecular Biology**:** Research prospects now exist, providing ways to deepen the understanding of *P. brassica*'s connection to its environment and enhanced potential for club disease control. Before Woronin, it was successfully realized that a high concentration in soil of hydrogen ions (acidic pH) favored *P. brassica* and clubroot disease. Grounds with pH>7.0 and high calcium antagonism with pathogen and disease. Mainly, Plamodiophorus members respond pretty differently (*S. subterranean*, which causes powdery scab of potatoes). In early studies, the optimum pH was about 6.0 (slightly acidic) for clubroot infection (Huan *et al.,* 2017). Alkaline soils were thought to mitigate the production of symptoms, and it was suggested that the pH of soils be increased between 7.3-7.5 for reasonable clubroot control. The question is whether the soil's alkalinity is responsible or part of the rise in calcium ions for a decreased infection (Gahatraj *et al.,* 2019). Thalli that produced zoospores were deformed, and the development of clubs was terminated at a ground pH greater than 8.0. This supports the argument that gall production requires secondary zoospores. Whether the pH of soil rising is responsible for a reduction in the infection of *P. brassica* or the existence of calcium ions was addressed. Organic pumps were found to be used for elegant experiments, which found that the effects on calcium and pH in the promotion and decreased growth of the pathogens are different but complementary (McGrann *et al.,* 2016). Nitrogen levels may also influence the outcome of host-pathogen interactions. Dixon, (2014) reported that calcium cyanamide fertilizer is considered to promote soil microbes' growth antagonistic to *P. brassica*, in parallel to these studies. These experiments have shown the synergistic effect of calcium, boron, and nitrate nitrogen. This evidence provides a theoretical basis for long-term soil liming and soil chemistry practice, which results in a decrease in the hydrogen ion levels and an increases in the amount of calcium and other rhizosphere components. Changing the soil's chemistry is a tried-and-true farming technique, and its effectiveness now has some strong biological reasons. Research has concentrated in the last decade on direct biological control opportunities for *P. brassica*. A new range of agrochemicals could pave the way for epoxy research (5-hydroxy-3-(hydroxymethyl)- 7-oxolate bicyclo [4.1.0] hepta 3-en-2-one). Bacillus subtilis recently demonstrated its potential as a biocontrol agent in commercial preparations (Liu *et al.,* 2016). In a few cases, the soil was not suppressive after sterilization, suggesting that a biological agent could be responsible. Still, the soil's physical and chemical properties could also minimize the disease's severity (McGrann *et al.,* 2016). A combination of microbial activity based on the soil's physical and chemical environment will probably result in suppression. Soil texture, pH, moisture content, the content of organic matter, and mineral or nutrient composition affect the suppressiveness of soil and compost. The suppression of these factors can, therefore, be promoted by changing (Dixon, 2017). The behavior of physical and chemical elements that boost soil suppression will also likely increase microorganisms' biological control ability (Bhering *et al.,* 2017). The incorporation of organically derived factors such as chitin and marine extracts into the soil environment can alter its suppressive properties and minimize the development of a disease. These results indicate the most promising approach to the management of club diseases. Dixon, (2014) work goes some way to understand the existence of soils that inhibit *P. brassica* but not biotic factors. In Taiwan, soils like this were found. These soils were more than 7.4 pH, and 1210 ppm were calcium. The latter used repressive soil samples of 7.3 pH and 1460 ppm of calcium. The pH was altered to 6.7 and the calcium level to 1210 ppm when the suppressive field was diluted with conducive soil. The soil suppressiveness was lost when acidified with sulphuric acid, but it came back after applying sodium carbonate. Soil acidification raises the calcium level by dissolving the compounds of calcium. As a result of higher hydrogen ion concentrations, the supply of calcium decreased. A classic example of how soil replacement of *P. brassica* may be promoted through a process of manipulation of soil chemistry is found in the fertilizer calcium cyanamide, which promotes the production of microbial flora antagonistic to the pathogen. This fertilizer is environmentally friendly and well-known (Dixon, 2014). In Australia since the 90s, clubroot became a major flag of brassica, especially cauliflower in Victoria and Western Australia in Perth. This approach has been continuing and growing. During this time, resistant cultivars of vegetable brassica or oilseed rape arose and formed a significant part of the integrated control program (Pandolfo *et al.,* 2016). Indeed, using a variety of clubroot disease control techniques is vital to sustain and protect resistant cultivars from degradation because of changes in the virulence spectrum that dominate *P. brassica* populations. To quantify the inoculum (sensu garrett) potential and monitor the efficacy or otherwise of remedial mitigation agriculture, robust diagnostic instruments are required. Molecular biology provides methods for studying soil, tissue, and water samples based on polymerase chain reaction (PCR). They reported that serological tests could give a simple field test method. The largest adequately financed program of the Robuste Diagnostic Tools (Rennie *et al.*, 2012) program has been developed and commissioned to assess and propagate disease production in Canada (*B. napus*) plants. In addition to all the work, there are also more fundamental studies on the relationship between host and pathogens. Actually, in both brassica vegetables and petroleum grains in China, clubroot is of great importance. The problem is so enormous that certain steps are taken to promote the study and obtain control methods. The method that maintains and strengthens soil integrity has the potential for improved farm productivity and profitability. This includes a thorough knowledge of the soil ecosystem dynamics in which *P. brassica* hosts grow and club diseases evolve. Over the last one and a half centuries, the pathogen *P. brassica* and its hosts have undergone a few comprehensive scientific studies. This leads to a better understanding of some of the biological challenges and reduces some agricultural challenges. The interaction between *P. brassica* and clubroot disease continues to be an area warranting intensive research. This biologically intrinsic microbial pathogen exhibits a novel life cycle, adeptly colonizing its hosts and using them as a resource bank for its subsequent generations. Delving deeper into the biology of this host-pathogen dynamic could pave the way for a more profound understanding of cellular metabolic processes, potentially revealing how to modulate them for either beneficial or detrimental outcomes. Despite advancements in research, there remain gaps in our comprehension of the soil environment interactions between *P. brassica* and its host plants, especially over the past two decades. Addressing these gaps could provide invaluable insights into sustainable agriculture, disease management, and potentially uncover new biological mechanisms. A fundamental insight into how soil chemistry affects the primary invasion and growth of root hairs has been achieved. There are opportunities to gain much more knowledge of the genetic resistance mechanisms in agriculture and how plant breeding products can be incorporated into other controls. Studies of how the rotational crop changes the microbial plant to antagonize *P. brassica* are more attractive. The concept of suppression is now scientifically recognized as a legitimate field of science and engineering to establish this as a key to sustainable and integrated control strategies. The most effective and cost-effective agriculture strategy is likely to be potential interwoven crop resistance, rotational cultivation, resulting biological and agricultural suppressiveness that modifies soil properties to restrict diseases that can cause *P. brassica*'s potential. As one of Canada's primary trading commodities is now infiltrated by this disease and is known as a flagging flag in China, the country with the largest population globally, there are excellent grounds for anticipating the continuation of this study.

***Conclusions, Issues, And Future Perspectives*:** Managing *Plasmodiophora brassica* is no small task. This pathogen is a primary cause of root rot across various regions in China. Though some brassica lines exhibit partial resistance to the disease, these resistance traits are often complex and controlled by multiple genes. Furthermore, assessing the actual impact on yield is difficult since roots are seldom inspected unless visible symptoms emerge on the foliage. Many current studies on this pathogen occur under controlled conditions, which may not perfectly replicate field scenarios. Furthermore, there's a notable gap in the research on club root resistance QTLs. A more standardized approach to evaluating disease resistance across different pathogenic species is imperative. It would also be beneficial to delve deeper into the mechanisms underlying resistance to different pathogenic strains. Future endeavors should prioritize genome sequencing and detailed comparative analyses across various strains of the pathogen responsible for club roots. Understanding the gene expressions of these strains could provide valuable insights. Presently, while farmers depend primarily on fungicides, the pathogen has shown an alarming ability to develop resistance against them. Some have started using biological control agents like arbuscular fungi, Bacillus, and Trichoderma spp. However, these agents face their own set of challenges, especially when it comes to longevity and adaptability in the field. Looking ahead, emerging technologies such as high-throughput phenotyping, genomics, transcriptomics, and advanced sequencing will be instrumental. These will not only assist in identifying club root-resistant cultivars but also enhance our understanding of the pathogen's pathogenesis. In addition, they'll play a key role in identifying genes that influence a plant's resistance or susceptibility to club root pathogens.

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