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Host range of *Plasmodiophora brassicae* in North Dakota

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Abstract

Plasmodiophora brassicae causes clubroot on brassica crops and is a new emerging disease on rapeseed in North Dakota. A two-year study was conducted to document the host range and symptomology on various brassica hosts to *P. brassicae* infections in field conditions. The results indicated that out of the 13 Brassica hosts tested, 12 of them developed ellipsoidal galls on roots exhibiting the clubroot symptomology with a disease index (DI) ranging from 41 to 100%. False flax/ camelina (*Camelina sativa*) showed the least susceptibility among the brassica hosts tested. Symptomology of clubroot on various brassica hosts will serve as a pictorial guide in the future to educate growers and in choosing non-brassica cover crops in clubroot infected fields.

Key words: *Clubroot, brassica hosts, Plasmodiophora brassicae*

Introduction

The plants of *Brassicaceae* family commonly referred as brassicas, mustards, crucifers or cole crops are prone to infections by several plant pathogens, out of which *Plasmodiophora brassicae* Woronin the causal agent of clubroot is one (Howard *et al*., 2010). The pathogen *P. brassicae* infects root hairs of susceptible Brassica hosts and induces developing roots to form large distorted galls (Colhoun, 1958). Severely infected plants are stunted, show premature ripening and often wilting. *P. brassicae*, forms resting spores within the root and makes it friable that eventually disintegrates into soil (Dixon 2009). The resting spores of *P. brassicae* prefer acidic soils and are viable in the soil for over 17 years (Wallenhammar 1996). Limiting the exposure of brassica hosts to clubroot infected soils is the primary recommended practice to manage clubroot (Donald *et al*., 2006). Several research reports indicate that certain fungicides and soil pH ameliorating products were effective in managing clubroot to an extent (Chapara, 2019, McDonald *et al*., 2004; Webster and Dixon, 1991). Theoretically, *P. brassicae* infects more than 300 members from the brassica family around the world in over 60 countries (Dixon, 2009; Hwang *et al*., 2012). However, a few non-cruciferous plants such as nasturtium (*Tropaeolum majus* L.), papaya (*Carica papaya* L.), corn poppy (*Papaver rhoeas* L.), and clover (*Trifolium repens* L.) were listed as hosts of *P. brassicae* (Muller *et al*., 1999). Several brassica crops grown in the United States were reported as potential hosts of clubroot (Tewari *et al*., 2005; Strelkov *et al*., 2005). Palm (1963) reported clubroot on an ornamental plant, stock and sweet alyssum (*Lobularia maritima* L.). Five Brassica weed species were linked to play a role in clubroot epidemics in China (Kim *et al*., 2011; Tanaka *et al*., 1993). Brassica host woodland bitter cress (*Cardamine flexuosa* L.) is in use as the indicator plant to know the distribution of clubroot in Japan (Tanaka *et al*., 1993). Under controlled conditions wild cabbage (*Brassica oleracea L.*), shepherd's purse (*Capsella bursa- pastoris* (L.) Medic.), wall rocket (*Diplotaxis muralis* L. (DC)), treacle mustard (*Elysium cheiranthoides* L.), white mustard (*Sinapis arvensis* L. Rabenh.), hedge mustard (*Sisymbrium officinale* (L.) Scop.), and field pennycress (*Thlaspi arvense* L.) were found to be the hosts of clubroot in Britain (Buczacki and Ockendon, 1979). Clubroot on rapeseed (*B. napus*) was reported in North Dakota, U.S.A., for the first time in 2013 (Chittem *et al*., 2014). Since then, it has been reported every year and has become a threat to the oilseed rapeseed production (Chapara *et al*., 2019a). Approximately 20 thousand acres of cropland is planted to cover crops in northeastern North Dakota annually (Knutson, 2018). Lately, use of *Brassica* species as individually or in mixtures of cover crops is gaining popularity among grower practices in North Dakota (Wick *et al*., 2018). Out of many brassicas, radish, turnip, kale and daikon radish are the prime choices for cover crops in North Dakota (Liebig and Johnson, 2015). False flax/ camelina (*Camelina sativa* (L.) Crantz), an emerging alternative oil seed crop in Canada, is a widely recommended cover crop around the world (Seguin-

Swartz *et al*., 2009) is being promoted in North Dakota lately along with radish (Marisol Berti, *personnel communication*). With clubroot being an emerging disease in North Dakota, not much information is available on the symptomology and susceptibility of various brassica hosts. The objective of this research is to study the host range, the authors determined the objective of this research was to study the host range, symptomology of Brassica hosts to *P. brassicae* infections under field condition.

Materials and Methods

The selected brassica hosts (Table 1) that were analyzed in this study were the most commonly grown vegetables and cover crop species as well as predominant weeds in North Dakota. A two-year field research was conducted in a growers field with *P. brassicae* base population of 13 million resting spores/g of soil (Chapara et al. 2019b) approximately two miles north (N 48.7752778; W -98.359444) of the Langdon Research Extension Center, Langdon, ND. Research plots were laid out in randomized complete block design (RCBD) with four replications. Brussels sprouts (*B. oleracea* L. var. *gemmifera* DC.), cabbage (*B. oleracea* L. var. *oleracea*), cauliflower (*B. oleracea* L. var. *botrytis*), chinese cabbage (*B. rapa* L. subsp. *pekinensis*) and kale *(B. oleracea* L. var. *acephala)* were planted as four-week seedlings, whereas, arugula (*Eruca sativa* Mill.), false flax/camelina (*C. sativa* (L.) Crantz), radish daikon (*Raphanus sativus* L. var. *longipinnatus*), radish round (*R. raphanistrum* subsp. *sativus* (L.) Domin), rutabaga *(B. napus L.* var. *napobrassica)*, shepherd's purse (*Capsella bursa-pastoris* (L) Medic.), turnip (*B. rapa* L. var. *rapifera*), and wild mustard (*Sinapis arvensis* (L.) Rabenh) were planted as seeds in deeply tilled soil at 1.27cm depth. Clubroot disease evaluation was conducted on 10 plants per plot, 55 days after planting. Clubroot incidence (percent plants infected with clubroot) and disease severity were rated using a clubroot disease rating scale of 0-3 (Kuginuki *et al*., 1999). The plants were uprooted in each treatment and were rated as 0 = no galling; 1 = a few small galls (small galls on less than 1/3 of roots), 2 = moderate galling (small to medium-sized galls on 1/3 to 2/3 of roots), 3 = severe galling (medium to large galls on more than 2/3 of roots). A clubroot disease index (DI) was calculated based on the incidence and severity ratings observed in each treatment (Horiuchi and Hori, 1980; Strelkov *et al*., 2006).

Table 1: List of Brassica hosts in North Dakota selected for clubroot symptomology study

Brassica Host	Scientific name	Cultivar
Arugula	*Eruca sativa* Mill.	Heirloom
Brussels Sprouts	*Brassica oleracea* L. var. *gemmifera* DC.	Jade E
Cabbage	*B. oleracea* L. var. *oleracea*	Stone head
Cauliflower	*B. oleracea* L. var. *botrytis*	Super snowball
Chinese Cabbage	*B. rapa* L. subsp. *pekinensis*	Blues
False flax	*Camelina sativa* (L.) Crantz	Joelle
Kale	*B. oleracea* L. var. *acephala*	Poscano
Radish Daikon	*Raphanus sativus* L. *var. longipinnatus*	White Icicle
Radish Round	*R. raphanistrum* subsp. *sativus* (L.) Domin	Cherry Belle
Rutabaga	*B. napus* L. *var. napobrassica*	Laurentian
Shepherd's purse	*Capsella bursa- pastoris* (L.) Medic.	Collected in the wild
Turnip	*B. rapa* L. var. *rapifera*	Purple top white globe
Wild Mustard	*Sinapis arvensis* (L.) Rabenh	Collected in the wild

Analysis of variance (AGROBASE® Generation II version 10 statistical software) was used to analyze the observed clubroot DI on each brassica species. Mean separation was conducted based on Fisher's least significant difference test (P = 0.05).

Results and Discussion

Plasmodiophora brassicae infected plants were yellow and severely stunted, when uprooted showed spindle shaped mass of small to large clubs. In radish, rutabaga and turnip, galls were observed on the extreme end of taproot and on secondary roots as well. Whereas, the entire root system of the infected plants showed clubbed and spindle-shaped galls (Plates I, II and III) on the rest of the hosts tested. Chinese cabbage showed severe stunting and rotted earlier than other hosts tested. The Disease Index (DI) rating ranged from 41-100% with significant differences ($p = < 0.05$) among the twelve brassica hosts (Figure I). Arugula, Chinese cabbage, cabbage, and cauliflower showed the highest DI and camelina had the lowest DI compared to the rest of the hosts tested (Figure 1).

The current study confirms the susceptibility of tested brassica hosts to clubroot and the host range. The symptoms and DI ratings indicate that these brassica species can host and add inoculum loads of *P. brassicae* to the soil in the form of resting spores. This is the first study to document the symptomology of clubroot on brassica hosts in North Dakota, USA. Similar results were reported in field trials with brassica crops in China that

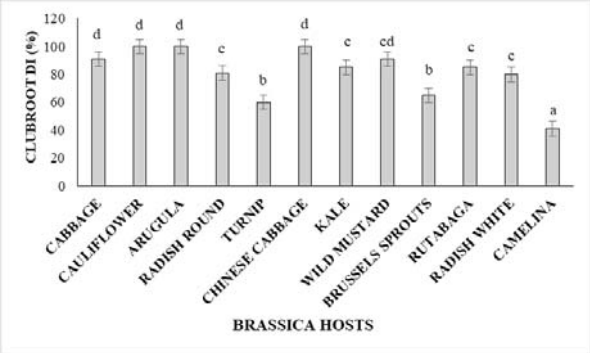

Figure 1: Data shown are percent clubroot disease index (DI (0-100)) observed on various brassica hosts. Means followed by same letter are not significantly different from each other (Fisher's LSD (13.7), P = ≤ 0.05). Bars show ± one standard error of the mean (N=10 plants in each plot).

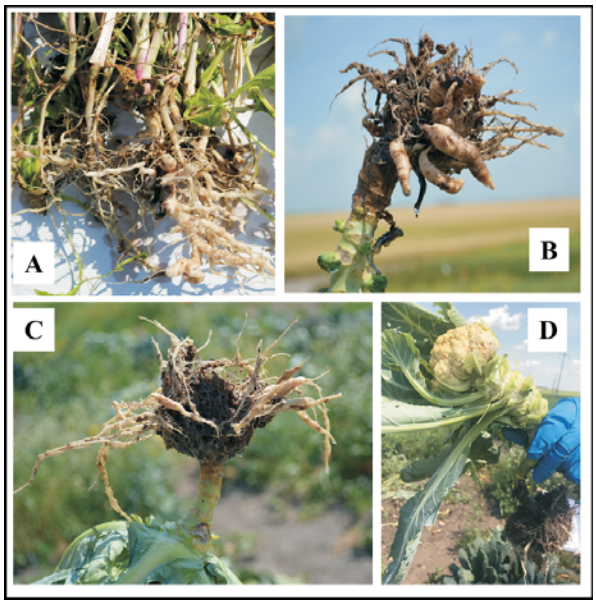

Plate I). Symptomology of clubroot (*Plasmodiophora brassicae* Woronin) showing galls on roots of various brassica hosts documented under field conditions: A) Arugula (*Eruca sativa Mill.*); B) Brussels sprouts (*Brassica oleracea L. var. gemmifera DC.*); C) Cabbage (*B. oleracea L. var. oleracea*); D) Cauliflower (*B. oleracea L. var. botrytis*).

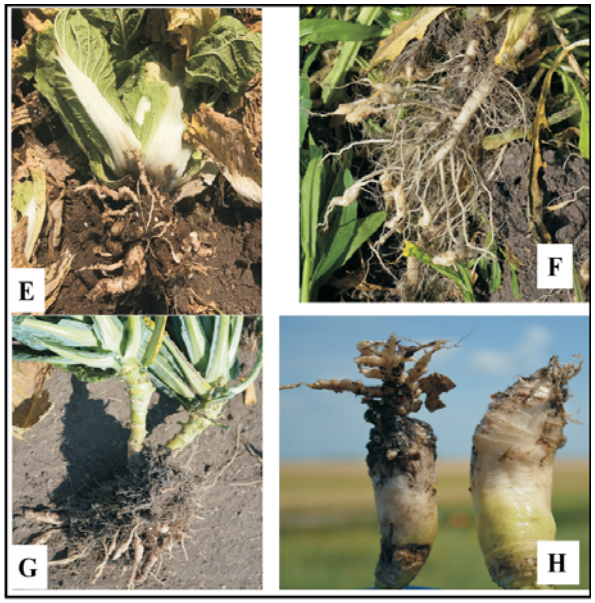

Plate II). Symptomology of clubroot (*P. brassicae*) showing galls on roots of various brassica hosts documented under field conditions: E) Chinese cabbage (*B. rapa L. subsp. pekinensis*); F) False flax/ Camelina (*Camelina sativa* (L.) Crantz); G) Kale (*B. oleracea L. var. acephala*); H) Radish Daikon (*R. sativus L. var. longipinnatus*).

Plate III). Symptomology of clubroot (*P. brassicae*) showing galls on roots of various brassica hosts documented under field conditions: I) Radish round (*R. raphanistrum subsp. sativus* (L.) Domin); J) Rutabaga (*B. napus L. var. napobrassica*); K) Turnip (*B. rapa* L. *var. rapifera*); L) Wild Mustard (*Sinapis arvensis* (L.) Rabenh).

indicated 17 species from five genera produced visible galls on radish, shepherd's purse, wild mustard and 13 other brassica crops (Ren *et al*., 2016). Symptomology on shepherd's purse was earlier recorded in controlled conditions (Buczacki and Ockendon, 1979) could be the reason for not observing clubroot symptoms in the current study. The current documentation of clubroot symptomology on various brassica hosts will aid as a pictorial guide to researchers and growers in the future. Further, the results of this study will be useful to growers' in choosing cover crops, managing voluntary rapeseed, brassica weeds and in determining the effective length of

crop rotation with brassica crops to manage clubroot.

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