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Effect of Saponins of *Chenopodium quinoa* Applied as Seed or Foliar Treatments on Dry Rot, Common Scab and Black Scurf Diseases of Potato

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ABSTRACT

Dry rot, black scurf and common scab are three potato diseases of economic importance throughout the world. Field trials were conducted in 2005 and 2006 in New Brunswick, Canada to assess the efficacy of saponins extracted from *Chenopodium quinoa* (SCQ; HeadsUp®) applied as a seed treatment and foliarly in suppressing dry rot, black scurf and common scab diseases of potato. The trials consisted of four treatments for each disease, namely 1) untreated inoculated or infected control; 2) seed inoculated or infected and treated with SCQ; 3) seed inoculated or infected and the foliage treated with SCQ; and 4) seed inoculated or infected and treated with Maxim® PSP. After harvest, the tubers were assessed for the severity of dry rot, black scurf and common scab. The tubers were graded and assessed for total yield, tuber size, tuber number, and tuber weight. All of the treatments significantly reduced the severity of dry rot (32.4 to 46.7% reduction), common scab (~30% reduction) and black scurf (61.2 to 76.5% reduction) relative to the untreated, inoculated/infected controls. Seed and foliar treatments with SCQ increased both total yield and marketable yield compared to the untreated, inoculated/infected controls. Seed treatment with SCQ increased marketable yield by 23.8-26.2% while foliar treatment increased marketable yield by 16.8-23.8%. The results of this investigation indicate that saponins extracted from *Chenopodium quinoa* can be used as a potentially viable option for controlling dry rot, black scurf and common scab diseases of potato.

Keywords: biopesticides, *Fusarium* spp., *Rhizoctonia solani*, *Solanum tuberosum*, *Streptomyces scabiei*

INTRODUCTION

Potato is the most important vegetable crop in Canada, accounting for 35% of all vegetable farm cash receipts annually and about 75% of total area under potato cultivation in Canada comes from Prince Edward Island, New Brunswick, Alberta, and Manitoba (Statistics Canada 2009). The need for alternative and safe methods to control potato pests and pathogens has increased due to the development of fungicide resistance and to the negative effect of pesticides on the environment and humans (Bolkan and Reinert 1994; Urech *et al*. 1997; Rice *et al*. 1998).

Dry rot of potato caused by *Fusarium* spp. is responsible for yield losses worldwide ranging from 6 to 25% and in severe cases to the tune of 60% (Carnegie *et al*. 1990; Stevenson *et al*. 2001). Dry rot is caused by various *Fusarium* spp. which include *F. solani*, *F. sambucinum*, *F. avenaceum*, *F. culmorum*, and *F. oxysporum* (Wale *et al*. 2008). Although some infections may develop on tubers before harvest, most infections occur as the fungus enters tubers through wounds at and after harvest (Dean 1994). Extensive rotting causes the tissue to shrink and collapse while leaving a dark sunken area on the outside of the tuber showing internal cavities. Traditionally, management of dry rot has been achieved with the use of thiabendazole. However, over the years, resistance to thiabendazole in isolates of *F. sambucinum* has been recorded in Europe, the United States and Canada (Hanson *et al*. 1996; Platt 1997; Peters *et al*. 2001). None of the options available for management of dry rot have proven to be efficacious.

Common scab, caused by *Streptomyces scabiei*, is an important disease of potato and the economic losses due to this disease in the province of New Brunswick are estimated to exceed $1.2 million every year (Hill and Lazarovits 2005). Tubers infected with common scab show superficial, raised, or deep-pitted brownish lesions which ultimately reduce the quality and marketability of both fresh-market and processing potatoes. The majority of potato cultivars which are of commercial importance have become susceptible to common scab (Powelson *et al*. 1993; Waterer 2002). After getting established in the field, this pathogen can survive for over a decade (Kritzman and Grinstein 1991). It is a commonly found soil colonizer which thrives in the absence of potatoes. The recommended cultural practices do not always provide significant reductions in disease severity, especially in problematic fields. It is suggested that regulation of moisture at tuber set can suppress and control scab; however consistent results have not been achieved (Powelson *et al*. 1993). Once established in soils, common scab is difficult to eradicate or manage, as none of the registered pesticides can control the pathogen.

Black scurf is another important disease in potato caused by *Rhizoctonia solani*. The disease causes poor quality tubers and reduced yields (Carling *et al*. 1989; Powelson *et al*. 1993; Tsror *et al*. 1996; Stevenson *et al*. 2001). The formation of tuber-borne sclerotia reduces tuber quality and affects the size and number of tubers produced (Anderson 1982; Carling *et al*. 1989; Jeger *et al*. 1996). It is believed that the infection of underground plant parts of potato is caused by either soil borne inoculum or seed borne inoculum (Platt 1989; Platt *et al*. 1993; Powelson *et al*. 1993). The suggested means to reduce the losses caused by this pathogen include the use of disease free seed, soil treatment with chemicals, proper water management, crop rotation and the application of green manure (Platt 1989; Powelson *et al*. 1993; Singh 1995; Wale *et al*. 2008). Although crop rotation was suggested as a means to reduce black scurf infection, increased levels of black scurf infection was ob-

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served in potatoes following crop rotation (Celetti *et al*. 1990; Erampalli *et al*. 1999). The scarcity of fungicides effective against soil-borne fungal pathogens of potato including *R. solani* has compounded the matters (Powelson *et al*. 1993; Wicks *et al*. 1995; Johnston 1996). The limited availability of effective methods and fungicides to control dry rot, common scab and black scurf have prompted the need to search for new and efficient methods for their control.

HeadsUp® is an extract of *Chenopodium quinoa* which contains 49.65% quinoa saponins. The product was approved for organic grower use by OMRI and has received EPA registration as a reduced risk biological pesticide (Mariash 2007). It is a dry concentrated powder based on naturally occurring plant-extracted biochemicals which when mixed with water forms a protective solution. The potato plant inhibits the disease through its own defense mechanism after treated with HeadsUp® and although this product is not directly fungicidal, it is believed that the mode of action might be due to induction of systemic acquired resistance in plants. The present field study was conducted to evaluate the efficacy of saponins extracted from *C. quinoa* (HeadsUp®) applied as seed and foliar treatment in suppressing dry rot, common scab and black scurf disease of potatoes.

MATERIALS AND METHODS

Experimental set-up

Field trials were conducted in Wicklow, New Brunswick, Canada in 2005 and 2006. The trials were designed as completely randomized block consisting of eleven treatments (4 for dry rot, 4 for black scurf, and 3 for common scab) which were replicated three times (each replicate is a 4.5 m long row). Tubers of the potato cultivar Yukon Gold (Elite 1 class; Bon Accord Elite Seed Potato Centre, Bon Accord, New Brunswick, Canada) were used in both trials. The three diseases assessed were dry rot, common scab and black scurf. The trials consisted of four treatments for dry rot and black scurf diseases, namely, 1) untreated inoculated or infected control; 2) seed inoculated or infected and treated with saponins extracted from *Chenopodium quinoa* SCQ; 3) seed inoculated or infected and the foliage treated with SCQ; and 4) seed inoculated or infected and treated with Maxim® PSP. For common scab, the Maxim® PSP was not included.

Fertilizers were applied in bands at 327 kg acre^{-1} (N-P-K- 15-15-15). All seed pieces (~ 60 g each) were planted at 10 inch spacing within row and 1m between rows. For the Fusarium dry rot and common scab trial, seed pieces naturally infected with dry rot or common scab were used. For the black scurf trial, rye seed (20 g) inoculated with *R. solani* was added to each seed piece before covering with soil. Seed treatment was achieved by dipping seed tubers in HeadsUp® (SCQ; HeadsUp Plant Protectant, Kamsack, Saskatchewan, Canada; contains 49.65% quinoa saponins – approximately equimolar amounts of triterpene bidesmosidic glycosides of oleanolic acid, hederagenin, and phytolaccagenic acid) solution (1 g of product in 1 L of water) for 5 min. For foliar treatment, the same solution of SCQ was applied using a CO_2 sprayer at a spray angle of 90°and spray pressure of 300 KPa 30 days after planting. In the case of Maxim® PSP treatment, seed pieces were dusted at the rate of 500 g/100 kg of seed prior to planting.

Pesticide use

All pesticides used in this trial were applied according to the recommended label rates. Fludioxonil (Maxim® PSP, 4-(2,2-difluoro-1,3-benzodioxol-4-yl)-1H-pyrrole-3-carbonitrile, 0.5%; Syngenta Crop Protection Canada, Inc., Guelph, Ontario) was applied to the seed at the rate of 500 g/100 kg of cut seed. The insecticide imidacloprid (Admire®, 1-[(6-chloro-3-pyridinyl) methyl]-*N*-nitro-2-imidazolidinimine, 21.4%; Bayer Crop Science, Calgary, Alberta) was applied in-furrow using a backpack sprayer at the rate of 0.5 mL per 17 mL of water per 4.5 m row. Throughout the growing season, general agricultural practices commonly practiced by potato growers were followed (Bernard *et al*. 1993).

Inoculum preparation

For Fusarium dry rot and common scab, seed tubers naturally infected with dry rot or common scab were used. For black scurf, the *R. solani* inoculum was prepared by subculturing surface-sterilized tuber piece infected with black scurf onto a Petri plate containing potato dextrose agar (PDA) using aseptic techniques. The culture was purified and multiplied on fresh PDA plates and allowed to grow for seven days at room temperature. Organically grown rye seeds were soaked in water for 24 hrs, drained, placed in transparent autoclave bags and autoclaved at 121°C for 15 min. Culture media of six plates containing fully grown *R. solani* culture were cut up into 2.5 cm cubes and mixed with 1 kg of autoclaved rye seed in transparent autoclaved bags under aseptic conditions. The bags were stored at room temperature for 60 days and were shaken weekly.

Data collection and statistical analysis

Tubers were harvested from each row using a potato digger and then picked manually. After harvest, the tubers were graded, and number and weight of healthy and diseased tubers were recorded for dry rot, common scab and black scurf. The number and weight of each tuber based on various size categories (in mm, < 47.6, 50.8, 57.2, 63.5, 69.8, 76.2, 88.9, > 88.9; and oversized potatoes weighing >280 g) were also recorded. Marketable yield includes all tubers that are ≥ 50.8 mm. The tubers were stored for 45 days in storage (set at 12°C and 95% RH) and then assessed for severity. For dry rot, disease severity was calculated based on the % tuber surface diseased and depth of internal necrosis (Ayer and Robinson 1954). For common scab and black scurf, tuber surface area infected was assessed on a scale of 0-100% (Cruickshank *et al*. 1982; Dorrance and Inglis 1997). Data analysis was done separately for each year by analysis of variance using CoStat (CoHort Software, Monterey, CA, USA). Since data generated in both years were similar, values were combined and averaged. The test of least significant difference (LSD, $P = 0.05$) was used to separate means when a significant treatment effect was found.

RESULTS

Disease severity

Foliar application of extract of *C. quinoa*, which contains 49.65% quinoa saponins (SCQ; HeadsUp®), and seed treatment with Maxim® PSP or with SCQ significantly reduced dry rot severity compared to the untreated control infected with dry rot (**Table 1**). The severity of dry rot was reduced by 46.7, 30.8 and 32.4% as a result of foliar treatment with SCQ, seed treatment with Maxim® PSP, and seed treatment with SCQ, respectively, relative to the untreated control infected with dry rot. Similarly, the severity of black scurf was significantly reduced due to the foliar treatment with SCQ, seed treatment with Maxim® PSP, and seed treatment with SCQ compared to the untreated control inoculated with *R. solani* (**Table 1**). The severity of black scurf was reduced by 76.5, 71.6 and 61.2% due to the foliar treatment with SCQ, seed treatment with Maxim® PSP, and seed treatment with SCQ, respectively, relative to the untreated control inoculated with *R. solani*. The severity of common scab was significantly reduced by seed and foliar treatments with SCQ compared to the untreated control infected with common scab (**Table 1**). The severity of common scab was reduced by 29.7 and 30.5% due to foliar and seed treatments with SCQ, respectively, relative to the untreated control infected with common scab. In all the cases the severity of dry rot, black scurf and common scab was reduced significantly compared to the inoculated/infected control treatments.

Table 1 Effect of saponins of *Chenopodium quinoa* (SCQ) applied as seed and foliar treatments on the severity of dry rot, common scab and black scurf of potatoes.

Treatment	Disease severity (%)	% Reduction in disease severity[1]
Dry rot		
FUCD	44.1 b[2]	
FUF	23.5 b	46.7
FUP	30.5 b	30.8
FUS	29.8 b	32.4
Black scurf		
RZCD	55.7 a	
RZF	13.1 b	76.5
RZP	15.8 b	71.6
RZS	21.6 b	61.2
Common scab		
SBCD	38.1 a	
SBF	26.8 b	29.7
SBS	26.5 b	30.5

[1]Relative to the untreated, inoculated/infected control treatment.
[2]Average values of 2 experiments. Each value is the mean of three replicates. Within each column, means followed by same letter are not significantly different from each other at P=0.05. FUCD: Untreated control infected with dry rot; FUF: Seed infected with dry rot and SCQ applied foliarly; FUP: Seed infected with dry rot and treated with Maxim® PSP; FUS: Seed infected with dry rot and treated with SCQ; RZCD: Untreated control inoculated with *Rhizoctonia solani*; RZF: Seed inoculated with *R. solani* and SCQ applied foliarly; RZP: Seed inoculated with *R. solani* and treated with Maxim® PSP; RZS: Seed inoculated with *R. solani* and treated with SCQ. SBCD: Untreated control infected with common scab; SBF: Seed infected with common scab and SCQ applied foliarly; SBS: Seed infected with common scab and treated with SCQ.

Table 2 Effect of saponins of *Chenopodium quinoa* (SCQ) applied as seed and foliar treatments on total and marketable yields of potato.

Disease/ Treatment	Total yield (Kg/ha)	% Increase in total yield[1]	Marketable yield (Kg/ha)	% Increase in marketable yield[2]
Dry rot				
FUCD	30.38 b[3]		28.46 b	
FUF	34.68 ab	14.2	33.25 ab	16.8
FUP	33.73 ab	11.0	32.05 ab	12.6
FUS	37.08 a	22.1	35.64 a	25.2
Black scurf				
RZCD	30.14 b		29.18 b	
RZF	37.08 ab	22.6	36.12 ab	23.8
RZP	36.12 ab	19.9	34.92 ab	19.7
RZS	38.03 a	26.2	36.84 a	26.2
Common scab				
SBCD	32.05 b		30.14 b	
SBF	37.08 a	15.7	35.40 a	17.5
SBS	38.75 a	20.9	37.31 a	23.8

[1&2]Relative to the untreated, inoculated/infected control treatment.
[3]Average values of 2 experiments. Each value is the mean of three replicates. Within each column, means followed by same letter are not significantly different from each other at P=0.05. FUCD: Untreated control infected with dry rot; FUF: Seed infected with dry rot and SCQ applied foliarly; FUP: Seed infected with dry rot and treated with Maxim® PSP; FUS: Seed infected with dry rot and treated with SCQ; RZCD: Untreated control inoculated with *Rhizoctonia solani*; RZF: Seed inoculated with *R. solani* and SCQ applied foliarly; RZP: Seed inoculated with *R. solani* and treated with Maxim® PSP; RZS: Seed inoculated with *R. solani* and treated with SCQ. SBCD: Untreated control infected with common scab; SBF: Seed infected with common scab and SCQ applied foliarly; SBS: Seed infected with common scab and treated with SCQ.

Yield parameters

1. Total and marketable yields

Among all treatments, treating seed tubers with SCQ produced higher total yield and marketable yield. Total tuber yield produced from SCQ-treated seed was significantly increased for each of the three tuber diseases relative to untreated infected controls, with yield increased by 22.1, 26.2, and 20.9% for dry rot, black scurf, and common scab, respectively. Similarly, marketable yield produced from the same treated seed increased by 25.2, 26.2, and 23.8% for dry rot, black scurf, and common scab diseases, respectively (**Table 2**). Foliar application of SCQ had also resulted in an increase of both total and marketable tuber yields. Total tuber yield was increased by 14.2, 22.6, and 15.7% for dry rot, black scurf, and common scab diseases, respectively. Similarly, marketable tuber yield increased by 16.8, 23.8, and 17.5% for the same three diseases (**Table 2**). Seed treatment with Maxim® PSP had the least effect on yield compared to other treatments. Treatment increased total yield by 11.0 and 19.9% for dry rot and black scurf diseases, respectively. Marketable yield was increased by 12.6 and 19.7% both diseases as a result of seed treatment with Maxim® PSP (**Table 2**). This treatment was not tested against common scab.

2. Tuber number and weight

Dry rot: Potato seed tubers treated with Maxim® PSP produced significantly higher number (13 tubers) of tubers measuring 88.9 mm in size category compared to the untreated control infected with dry rot (9 tubers), seed treatment with SCQ (8 tubers) and foliar application of SCQ (6 tubers) (**Table 3**). Although higher number of tubers under the size categories < 47.6, 50.8 and 57.2 mm were produced where SCQ was applied foliarly, none of the treatments differed significantly. The weight of tubers less than 47.6 mm in size produced from untreated seed tubers infected with dry rot was significantly higher than tubers treated with SCQ (**Table 4**). Similarly, the weight of tubers 76.2 mm in size produced from seed treated with Maxim® PSP was significantly higher than the untreated control infected with dry rot. The weight of tubers greater than 88.9mm in size was significantly higher for the Maxim® PSP and foliar treatments with SCQ compared to the untreated control infected with dry rot (**Table 4**).

Black scurf: Foliar treatment with SCQ resulted in a significantly higher number of tubers measuring less than 47.6 mm in size compared to the untreated control inoculated with *R. solani*, seed treated with Maxim® PSP and SCQ. Tubers treated with Maxim® PSP produced significantly higher number of tubers measuring 57.2 mm in size compared to the untreated control inoculated with *R. solani* (**Table 3**). Higher number of tubers measuring 63.5 mm in size was produced from seed treated with SCQ which differed significantly from the untreated control inoculated with *R. solani*, seed treatment with Maxim® PSP and foliar application of SCQ. Similarly, the highest number of tubers measuring 69.8 mm in size was produced by seed tubers treated with SCQ and higher number of tubers measuring 76.2 mm in size was produced from seed tubers treated with Maxim® PSP. Both treatments differed significantly from the untreated control inoculated with *R. solani* (**Table 3**).

Tubers treated with Maxim® PSP (544 g) produced higher weight of tubers measuring less than 47.6 mm in size than the untreated control inoculated with *R. solani* (482 g) but did not differ significantly from it (**Table 4**). Similarly, seed tubers treated with SCQ produced significantly higher weight of tubers measuring 57.2 mm compared to the untreated control inoculated with *R. solani* (**Table 4**). Although the weight of tubers measuring 63.5mm in size produced from plants foliarly treated with SCQ and seed tubers treated with SCQ was higher than that of the untreated control inoculated with *R. solani*, they did not differ significantly from it. Higher weight of tubers measuring 69.8mm in size was produced from seed treated with SCQ, Maxim® PSP and plants foliarly treated with SCQ which was significantly higher than untreated control inoculated with *R. solani* (**Table 4**). Higher weight of tubers measuring 76.2 mm in size was produced from seed tubers treated with SCQ which differed significantly from the untreated control inoculated with *R. solani* (**Table 4**).

Table 3 Effect of saponins of *Chenopodium quinoa* (SCQ) applied as seed and foliar treatments on number of tubers of different size categories.

Disease/	Tuber size (in mm)								Oversized
Treatment	<47.6	50.8	57.2	63.5	69.8	76.2	88.9	> 88.9	> 280 g
Dry rot									
FUCD	22 a	10 a	21 a	25 a	16 a	13 a	9 b	0 b	5 a
FUF	26 a	14 a	22 a	24 a	22 a	9 a	6 c	2 a	2 a
FUP	23 a	13 a	18 a	22 a	17 a	12 a	13 a	2 a	5 a
FUS	24 a	13 a	22 a	22 a	23 a	12 a	8 bc	1 a	4 a
Black scurf									
RZCD	18 b	10 a	14 b	23 b	15 b	10 c	9 a	2 a	6 a
RZF	25 a	11 a	18 ab	23 b	21 a	16 ab	11 a	2 a	7 a
RZP	19 b	9 a	23 a	23 b	20 a	17 a	11 a	2 a	5 a
RZS	20 b	14 a	19 ab	30 a	23 a	15 b	10 a	2 a	4 a
Common scab									
SBCD	26 a	16 a	26 a	31 a	22 a	8 b	4 b	1 a	1 a
SBF	26 a	19 a	21 a	19 a	22 a	15 a	11 a	1 a	3 a
SBS	21 a	13 a	21 a	29 a	24 a	14 a	14 a	1 a	3 a

[1] Average values of 2 experiments. Each value is the mean of three replicates. Within each column, means followed by same letter are not significantly different from each other at P=0.05. FUCD: Untreated control infected with dry rot; FUF: Seed infected with dry rot and SCQ applied foliarly; FUP: Seed infected with dry rot and treated with Maxim® PSP; FUS: Seed infected with dry rot and treated with SCQ; RZCD: Untreated control inoculated with *Rhizoctonia solani*; RZF: Seed inoculated with *R. solani* and SCQ applied foliarly; RZP: Seed inoculated with *R. solani* and treated with Maxim® PSP; RZS: Seed inoculated with *R. solani* and treated with SCQ. SBCD: Untreated control infected with common scab; SBF: Seed infected with common scab and SCQ applied foliarly; SBS: Seed infected with common scab and treated with SCQ.

Table 4 Effect of saponins of *Chenopodium quinoa* (SCQ) applied as seed and foliar treatments on weight of tubers (kg) of different size categories.

Disease/	Tuber size (in mm)								Oversized
Treatment	<47.6	50.8	57.2	63.5	69.8	76.2	88.9	> 88.9	> 280 g
Dry rot									
FUCD	0.78 a[1]	0.81 a	1.87 a	2.76 a	3.37 a	1.70 b	1.42 a	0 b	0.69 a
FUF	0.67 ab	0.79 a	1.55 a	2.58 a	2.78 a	2.35 ab	3.07 a	0.76 a	1.56 a
FUP	0.67 ab	0.61 a	1.81 a	2.90 a	2.44 a	2.66 a	2.18 a	0.76 a	1.69 a
FUS	0.58 b	0.74 a	1.83 a	2.63 a	3.37 a	2.21 ab	3.71 a	0.41 ab	1.17 a
Black scurf									
RZCD	0.48 ab	0.53 a	1.21 b	2.75 ab	2.23 b	1.87 c	2.49 a	1.07 a	2.42 a
RZF	0.44 b	0.79 a	1.58 ab	3.28 a	3.35 a	2.82 b	2.46 a	0.82 a	1.43 a
RZP	0.54 a	0.67 a	1.48 ab	2.58 b	3.18 a	3.08 ab	2.95 a	0.64 a	2.27 a
RZS	0.48 ab	0.56 a	1.79 a	2.77 ab	3.07 a	3.42 a	3.07 a	0.69 a	2.05 a
Common scab									
SBCD	0.76 a	0.92 ab	2.26 a	3.57 a	3.26 a	1.57 b	0.94 b	0.10 a	0.28 b
SBF	0.66 a	1.29 a	2.03 a	2.16 a	3.28 a	2.90 a	2.63 ab	0.52 a	0.98 a
SBS	0.59 a	0.79 b	1.70 a	3.33 a	3.61 a	2.61 a	3.39 a	0.18 a	0.92 a

[1] Average values of 2 experiments. Each value is the mean of three replicates. Within each column, means followed by same letter are not significantly different from each other at P=0.05. FUCD: Untreated control infected with dry rot; FUF: Seed infected with dry rot and SCQ applied foliarly; FUP: Seed infected with dry rot and treated with Maxim® PSP; FUS: Seed infected with dry rot and treated with SCQ; RZCD: Untreated control inoculated with *Rhizoctonia solani*; RZF: Seed inoculated with *R. solani* and SCQ applied foliarly; RZP: Seed inoculated with *R. solani* and treated with Maxim® PSP; RZS: Seed inoculated with *R. solani* and treated with SCQ. SBCD: Untreated control infected with common scab; SBF: Seed infected with common scab and SCQ applied foliarly; SBS: Seed infected with common scab and treated with SCQ.

Common scab: Seed treatment with SCQ and foliar treatment with resulted in a significantly higher number of tubers measuring 76.2 and 88.9 mm in size compared to the untreated control infected with common scab (**Table 3**). Foliar application of SCQ yielded significantly higher weight of tubers measuring 50.8 mm in size compared to tubers treated with SCQ (**Table 4**). Similarly, the weight of tubers measuring 76.2 mm in size was significantly higher for plants foliarly treated with SCQ and seed treated with SCQ compared to the untreated control infected with common scab. Similarly, higher weight of tubers measuring 88.9 mm in size was produced from seed treated with SCQ which differed significantly from the untreated control infected with common scab (**Table 4**).

DISCUSSION

The development of resistance to fungicides by some potato pathogens has hindered the process of managing potato diseases in the field and storage. In addition, the incessant and indiscriminate use of fungicides has caused health hazards to animals and humans due to their residual toxicity (Ambridge and Haines 1987; Anonymous 1998). Biopesticides are suitable alternatives to chemicals for pathogen control as they are environmentally friendly and can reduce the use of synthetic pesticides. The present study was undertaken to test the efficacy of extract of *C. quinoa* which contains 49.65% quinoa saponins (SCQ; HeadsUp®) applied as seed treatment and foliarly in suppressing dry rot, common scab and black scurf diseases in potatoes.

The use of SCQ as seed treatment and foliar spray has resulted in reduction of severity of dry rot, black scurf and common scab. The reduction in the severity of these diseases is suspected to be due to activation of specific systemic plant defense pathways which causes the plant to develop systemic protection against fungal diseases. SCQ is also considered as a natural source plant defense activator (Pernezny *et al*. 2005; Mariash 2007). Saponins also possess some insecticidal activities and exert a strong and rapid-working action against a broad range of insects (De Geyter *et al.* 2007; Joshi *et al*. 2008). The major mechanism of antifungal activity of saponins is associated with their ability to complex with sterols present in fungal membranes and to cause loss of membrane integrity with formation of transmembrane pores (Keukens *et al*. 1995; Armah *et al*. 1999). In our experiments, producing healthier plants has resulted in an increase in yield and marketable yield and also impacted the size and weight of tubers produced.

In addition, pathogen suppression is believed to be influenced by the induction of systemic acquired response in plants. Systemic acquired resistance (SAR) is an important component in a plant's defense arsenal and is characterized by an increase in endogenous salicylic acid, transcriptional activation of the pathogenesis related genes, and enhanced resistance to a broad spectrum of virulent pathogens (Uknes *et al*. 1993; Ryals *et al*. 1996; Sticher *et al*. 1997). Activation of SAR prevents infection from a wide range of pathogens (Coquoz *et al*. 1995; Lawton *et al*.

1996) and is also associated with the induction of a suite of pathogenesis-related (PR) genes and a wide array of other genes of unknown function (Linthorst 1991; Ward *et al*. 1991; Delaney 2000). It is not completely clear how SAR leads to resistance in plants but there are reports which state that the majority of pathogenesis related genes expressed during the development of resistance are antagonistic to pathogens (Alexander *et al*. 1993; Sticher *et al*. 1997). Plants protected by SAR show several morphological and biochemical changes after pathogen attack. These changes include faster lignification, increase in peroxidase activity, increase in glucose and fructose concentrations in systemic tissue, accumulation of fungitoxic β-ionone derivatives, induction of lipoxygenase, antimicrobial fatty acid derivatives, phenylalanine ammonialysase, phytoalexins and hydroxyproline-rich glycoprotein activity (Elliston *et al*. 1977; Ajilan and Potter 1992; Staub *et al*. 1992; Wyatt and Kuc 1992; Namai *et al*. 1993; Chandra and Bhatt 1998; Raggi 1998).

In an earlier study, a single early season foliar application of SCQ significantly reduced the severity of early blight in tomato compared to the untreated control (Pernezny *et al*. 2005). The total weight of tomatoes per plot was higher in SCQ treated plants compared to the untreated control but there was no significant difference between the two treatments. Similarly, the use of composted pine bark in combination with *Trichoderma hamatum* – 382 reduced the severity of bacterial leaf spot on radish, lettuce and tomato under controlled environmental conditions (Al-Dahmani *et al*. 2003). In another study, plots amended with composted cannery wastes reduced the incidence of anthracnose fruit rot in tomatoes compared to non amended plots and resulted in a 33% increase in marketable yield (Abbasi *et al*. 2002). Similarly, the treatment of potato tubers with naturally extracted S-carvone inhibited the growth of *Helminthosporium solani*, *Fusarium sulphureum* and *Phoma exigua* var. *foveata* (Hartmans *et al*. 1995). The extracts from oregano, thyme and thyme borneal also exhibited moderate to strong inhibition activity against the late blight pathogen *P. infestans* in laboratory studies (Olanya and Larkin 2006).

SCQ is easy to use and safe for the user and the environment. It is an economical tool for growers and can be applied as a onetime seed treatment or spray. In addition, this product can be used on its own or in conjunction with other fungicidal products. It is suggested that SCQ increases the efficacy of other products in addition to being effective all by itself (Mariash 2007). Since SCQ is organically derived, there is reduced risk of resistance development. SCQ is natural in origin, safe to humans and environment, biodegradable, multifunctional, non-persistent in the environment and do not leave any residues (Mariash 2007). These characteristics make it a potential candidate for use in managing potato diseases. Currently it is registered for commercial use in the USA and is also approved by the Organic Materials Review Institute. The results from these studies indicate that SCQ can be used for control of dry rot, black scurf and common scab in potato. However some more work needs to be done before it can be recommended for commercial use in Canada.

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