Sudan University of Science and Technology

College of Graduate Studies

In Vitro Evaluation of Two Plants (Ginger and Cinnamon) Aqueous Extracts against the Bacteria *Streptomyces spp* of Potato Common Scab

تقويم استخدام المستخلصات المائية لنباتي الجنزبيد والقرفة علي البكتريا *Streptomyces spp* المسبب لمرض الجرب العادي في البطاطس معمليا

By:

Abrar Kheder Albadawi Mhamedahmed

B.SC.(Agric.) Honours (2014)

Sudan University of Science and Technology

A thesis submitted in partial of the requirements for the M. Sc in plant protection

Supervisor: Dr. Ekhlass Hussein Mohamed

Department of plant protection

College of Agricultural Studies-Shambat

Sudan University of Science and Technology

2019

الآية

قال تعالى:

(رَبَّنَا إِنَّنَا سَمِعْنَا مُنَادِيًا يُنَادِي لِلْإِيمَانِ أَنْ آمِنُوا بِرَبِّكُمْ فَآمَنَّا رَبَّنَا فَاغْفِرْ لَنَا ذُنُوبَنَا وَكَفِّرْ عَنَّا سَيِّئَاتِنَا وَتَوَفَّنَا مَعَ الْأَبْرَارِ).

صدق الله العظيم

سورة آل عمران الآية 193

Dedication

To my Mother and Father,

Who encourage me to study and

to those who assisted me to attain my goals.

Acknowledgement

First of all I want to render my praise to his almighty Allah, the most Gracious the most merciful who gave me life, health, knowledge and patience to complete this work.

Great thanks are for my supervisor Dr. Ekhlass Hussein Mohamed for help, good advice and guidance throughout their work.

Special thanks to staff members of the department of plant protection college of Agriculture Studies, Sudan University of Science and Technology Shambat, my thanks are extended to my colleagues in batch 10.

The Great help of the National Research Centre is also highly appreciated with special thanks to my teacher Alshafia Ali.

List of Content

LIST OF TABLES

LIST OF PLATES

ABSTRACT

This study was conducted at the plant pathology laboratory Sudan University of Science and technology of college of agricultural studies during the period (November 2019 – April 2019). The aim of this study is to evaluate the inhibitory effect of aqueous extracts of two plants Ginger (*Zingiber officinale*) and cinnamon (*Cinnamomheum*

verumis) on the growth of the bacterium Streptomyces spp *in vitro*. Different concentration s (5%, 10% and 20%) of each of the tested plant, in addition to penamox 2% (Amoxicillin) antibiotic were tested and compared to the untreated control H_2O. Penamox 2% recorded the highest inhibitory effect (3.07).The result showed that all concentrations (5%,10%and 20%) of aqueous extracts of both plants were found to be significantly different ($p \leq 0.05$) when compared to the untreated control (H_2O) and the Penamox 2% and reducing the inhibitory effect by 2.6, 2.6 and 2.6 for ginger and 2.5 ,2.6 and 2.6 for cinnamon, respectively. The study concluded the antibiotic (Penamox 2%) is the most effective (3.07) followed by the different concentration by 2.6, 2.6 and 2.6 ginger and cinnamon 2.5.2.6 and 2.6 respectively. We recommended further studies to evaluate the effect of these plants on the growth of the bacterium under field condition.

ملخص الاطروحة

أجريت هذه الدراسة في مختبر أمراض النبات بجامعة السودان للعلوم والتكنولوجيا بكلية

الدراسات الزراعية خلال الفترة (نوفمبر 2019 – أبريل 2019). الهدف من هذه الدراسة هو تقييم التأثير المثبط للمستخلصات المائية لنباتي الزنجبيل (*Zingiber officinale*) والقرفة (*Cinnamomheum verumis*) على نمو بكتيريا Streptomyces spp. تم اختبار تركيزات مختلفه 5%(، 10% و 20%) لكل من النباتات التي تم اختبارها ، بالإضافة إلى المضاد الحيوي2 %(Amoxicillin) Penamox ومقارنته مع الشاهد (untreated control) H20. سجل Penamox 2% أعلى تأثير تثبيطي (3.07). أظهرت النتائج أن جميع التركيزات (5% ، 10% و 20%) من المستخلصات المائية لكلا النباتين كانت مختلفة بشكل كبير ($P \leq 0.05$) بالمقارنة مع الشاهد (H20) و2% Penamox تقليل التأثير المثبط بنسبة 2.6 ، 2.6 و 2.6 للزنجبيل و 2.5 و 2.6 و 2.6 للقرفة ، على التوالي.اثبتت الدراسة ان المضاد الحيوي Penamox (2% هو الاكثر فعالية مقارنة ب بالتراكيز المختلفة للجنزبيل والقرفة (2.5 و2.6 و2.6) (2.6و 2.6 و2.6) علي التوالي .نوصي باجراء المزيد من الدراسات المستقبلية وتطبيقها علي نمو البكتريا تحت ظروف الحقل .

CHAPTER ONE

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanceae, which involves tomato, eggplant and other vegetables, This family contain 90 genera and 2000 species and named to the genera Solanum (Ahmed, 1999).

Potato is the only vegetable listed among the five principal world food crops (FAOSTAT, 2015). It comes in the forefront of tuber-crops and occupies the fourth position after wheat, sorghum and rice as the most edible and consumed crops in the world (Singh *et al.*, 2004).

Other researcher (Abdul *et al.*, 2013; Ali *et al.*, 2015) put the potato fourth most important food crop worldwide after maize, wheat and rice, with production of more than, 323 million tones. Moreover, its nutritional value is higher than most of the food crops. It is considered as the richest source of carbohydrates It is a very rich source of nutrient contents containing good amount of starch, carbohydrates, vitamins especially C and B1, minerals, protein, fat and amino acids (Buckenhuskes ,2005).

Potato was introduced to the Sudan sometimes before the second War11, since then it has been expanding in a rapid manner both horizontally and vertically, as the crop suits wide range of conditions in the Sudan (Alameen, 2003).

In Sudan, Potato is planted as a cash and food crop and plays an important role in the agricultural economy of the country. The area under potato is around 30 thousand hectares with an annual production of 400 000 tones and an average yield of 15 t/ha (Elraiah *et al.*, 2013).

Potato production in Sudan has increased in response to high demand due to urbanization and awareness of its nutritional value (Elraiah *et al.*, 2013).

In the Sudan several potato diseases can cause severe crop losses if not properly managed. These include early blight, late blight, scab, black leg, natural occurrence of Potato virus S (PVS), potato virus X (PVX) potato virus Y (PVY) and potato leaf roll virus (PLRV) were reported in important areas of production in the country. Rhizotonia, verticillum wilt, Fusarium dry rot, and bacterial soft rot (Christ, 1998).

In the Sudan, currently *S. scabies* has become very dangerous and a devastating disease on potato. All varieties are susceptible to this disease. However, common scab disease of potatoes caused by *S.*

scabies (bacteria), cause seed decay and reduce market value. Thus, the present study was undertaken with the following main objective

I) To evaluate the relative efficacies of selected botanical extracts *Ginger (Zingiber officinale) and* Cinnamon (*Cinnamomheum verumis*) against the potato common scab bacterial isolate *in vitro*.

CHAPTER TWO

LITERATURE REVIEW

2.1 Potato crop:

Potato, (*Solanum tuberosum* "L."), is the world's fourth most important crop after after maize, wheat and rice . It is grown chiefly in the temperate zone. Potato belongs to the family Solanaceae. This family also includes several plants which are of high food value. The genus Solanum that includes the potato comprises 2000 species (Hawkes, 1989).

The potato species can be found throughout the Americas, from the United States to Southern Chile (Hijmans and Spooner, 2001). The potato was originally believed to have been domesticated independently in multiple locations, but later genetic testing of the wide variety of cultivars and wild species traced a single origin for potatoes. In the area of present-day southern Peru and extreme northwestern Bolivia, from a species in the *Solanum brevicaule* complex, potatoes were domesticated approximately 7,000–10,000 years ago (Spooner ,2005).

Potato is one of the major vegetable crops grown worldwide following maize, wheat and rice with a production of 368 million tons (FAOSTAT, 2015).

Rich (1983) mentioned that it is one of humankind's most valuable foods, is produced in 130 countries where three –fourth of world's population lives. More than 90 of which are located in the tropical and subtropical zones. Although most of the production still comes from the temperate zone in the industrialized Countries, mainly in Asia (Vanderzaag, 1991).

In Sudan, potato is grown mainly as winter crop and the main area of production are along the Nile bank in both Khartoum and Northern states. Although potato cultivation in Sudan depends, mainly on exotic advanced cultivars but an old introduced material is still produced in Jabal Mara in the far west and it is locally known as Zalingei potato (Abdelgadir, 2005).

At Jebel Mara in Western Sudan the variety grown is of unknown origin. Some new other varieties with high yield include Diamond, Famoza, Ajax, Draga, Turbo, Akira, Maradona and Oblex, (Ali, 2000). The estimated total potatoes production in Sudan is about 616,000 tons in cultivated area of about 88,000 feddans (Hind and Mohamed, 2010).

2.2 Nutritional Value

A raw potato is 79% water, 17% carbohydrates (88% is starch), 2% protein, and contains negligible fat. In an amount measuring 100 grams (3.5 oz), raw potato provides 322 kilojoules (77 kilocalories) of

energy and is a rich source of vitamin B6 and vitamin C (23% and 24% of the Daily Value, respectively), with no other vitamins or minerals in significant amount The potato is rarely eaten raw because raw potato starch is poorly digested by humans (Beazell *et al*., 1939).

2.3 Bacterial Diseases of potato

Anonymous (1960) listed approximately 160 diseases and disorders of *Solanum tuberosum*. About 50 of them are caused by fungi, 30 by viruses, 10 by bacteria, and another 50 or so are either non parasitic or due to unknown causes. Several others are due to nematodes or insect pests, in addition to parasitic weed dodder (Cuscuta spp).

Streptomyces was often classified with the fungi rather than with the bacteria (Anonymous, 1960)It produces rudimentary hyphae which produces spores by the formation of separations. It is also classified with the bacteria. It belongs to the order Actinomycetales and family Streptomycetaceae (Walker, 1969).

2.3.1 Streptomyces spp

Scab disease of potato and certain other root crops are caused by streptomycetes. Streptomyces spp are aerobic, filamentous, Gram-positive prokaryotes belonging to the order Actinomycetales, suborder Streptomycineae, family Streptomycetaceae and genus *Streptomyces* According to Kutzner (1981).

Thaxter (1892) reported that the causal agent of common scab is the

actinomycete Streptomyces spp Thaxter first identified and described the pathogen in 1890, calling it Oospora scabs.

The name was changed to Actinomyces scabs in (Gussow, 1914). Some writer classifies it as a bacterium (Walker, 1969).While others, including the United States Department of Agriculture, usually classify it as fungus (Anonymous, 1960; Drechsler, 1919; and Rich 1976). It produces a rudimentary, coiled hyaline mycelium characteristic of fungi, septations then it routed in one – celled hyaline spores 1 –2x0.6 – 0.7 μ resembling bacteria. These spores germinate by means of one or two germ tubes. Some systematists consider the actinomycetes a connecting link between the bacteria and true fungi, but Drechsler disagrees (Rich, 1983).

Deeper pitted scab usually produces distinct brown; corky, sunken lesions of variable size, they are roughly circular, and the majority of them 1–5 mm in diameter. Thin–skinned red or white cultivars are usually susceptible (Rich, 1983).

Robert (1955) mentioned that common scab, ordinary scab, brown scab, potato scab, and scab are some of the names applied to what it is undoubtedly, the most common malady affecting Potato, as this scab is known wherever potato are cultivated. The earliest mention of the disease appears to be that in London Encyclopedia of agriculture in 1825, but the causal agent was not described until

1890 when Thaxter published his paper on it. In addition to *S. scabies*, other Streptomyces species have been shown to or reported to cause common scab or other scab-like diseases of potato. Three of these (*S. acidiscabies*, *S. caviscabies* and *S. turgidiscabies*) have recently been described (Lambert, 1989; Goyer *et al.*, 1996, Miyajima *et al.*, 1998).

2.3.2 Distribution

Common scab of potato is one of the oldest known plant diseases and was first described in 1890 (Thaxter, 1891). Current information suggests that common scab is almost as widely distributed as the host itself (Loria *et al.*, 1997).

Common scab occurs most frequently on light, sandy, or gravelly soils, and it is most prevalent in dry seasons. It is rare on peaty and heavy soils (Brooks, 1928).

Bacterial growth is favored by worm, moist conditions. Bacteria thrive on medium containing starches and sugars. Thus potato tubers are a good medium for their growth. Some bacteria attack only tubers, while others attack both tubers and plants (Rich, 1983).

It is present in all the potato-growing areas of North America and Europe (Keinath and Loria 1989). Tashiro *et al.*(1983) reported the incidence of the disease in the Far East, whereas Mohanty *et al.* (1980) refer to a serious common scab problem in the coastal tracts of the Cuttack and Pure districts in India. A report by Pung and Cross (2000) confirmed the presence of the disease in Victoria,

Australia, and particularly the island of Tasmania. It was previously reported in South Australia. Common scab also occurs in Austria, Denmark, (Oestergaard and Nielsen,1979), France (Bouchek-Mechiche *et al*., 2000), Finland (Heinamies and Seppanen, 1971), Germany (Koronowski and Massfeller,1972), Greece (Alivizatos and Pantazis, 1992), Israel (Doering-Saad *et al*., 1992), Hungary (Elesawy and Szabo, 1979), Ireland (Dowley, 1972), the Netherlands (Janse, 1988), Sweden (Emilsson and Gustafsson, 1953), Norway (Bjor and Roer, 1980), Poland (Sadowski *et al*., 1996), Arabia (Ali,1987), Korea (Park *et al*., 2003), Japan (Miyajima *et al*., 1998) and the United Kingdom (Large and Honey, 1953; Read *et al*., 1995). The disease is present in all potato production regions of South Africa; albeit at varying levels (Marais and Visser, 1989).

Tarr (1955) reported that the distribution of any plant disease within the Sudan is governed largely by the presence or absence of suitable host plants and suitable climatic condition. However, other factors do undoubtedly play a part. Thus soil characteristics including pH composition, temperature and moisture content are important in root diseases. . The pathogen is soil-borne.

2.3.3 The Economic Importance

The disease is widespread in all the potato growing regions of the world and reduces the marketability of table, processing and seed potatoes and was ranked as the fourth most important disease in a

1999 survey of potato growers (Loria *et al*., 1997).

Wheeler (1972) noted common scab of potato caused by *S. scabies* unsightly pustules of the tubers reduce their market value and storage qualities.

2.3.4 Host range

Common scab pathogens not only cause disease in potato, but can attack the fleshy roots of radish, turnip, beet (*Beta vulgaris* L.), groundnut (*Arachis hypogaea* L.), carrot (*Daucus carota* L.), rutabaga (*Brassica napus* L.var. *napobrassica* (L.) Rchb.), parsnip (*Pastinaca sativa* L.), mangel (*Beta macrorrhiza* Steven) and (*Tragopogon porrifolius* L.) (Lutman and Johnson, 1915; Jones, 1953; Goth and Webb, 1986; Sherf and MacNab, 1986; De Klerk *et al*., 1997; Goyer and Beaulieu, 1997; Bouchek – Mechiche *et al*., 2000)

In addition, groundnuts grown in rotation with potato have exhibited want to like lesions and *S. scabies* was consistently isolated (De klerk et al; 1997). Various other monocotyledonous and dicotyledonous crops have also been reported to be negatively affected when artificially infected with *S. scabiei*

(Hooker and Kent, 1946; Hooker 1949; Leiner *et al*., 1996), probably due to toxic effects induced by thaxtomin A, a broad-spectrum phytotoxin produced by the scab pathogen (Leiner *et al*., 1996).

2.3.5 Description

Streptomyces spp is a Streptomycete bacteria which means it forms a mycelium made of hyphae, a growth form more usually associated with fungi. The hyphae of Streptomyces, are much smaller than those of fungi (0.5–2.0 μm) and form a heavily branched mycelium. They are Gram-positive and have a high proportion of the DNA bases guanine and cytosine (Loria *et al.*, 2003).

Paul Dyson (2011) Streptomyces spp, When cultured on agar the hyphae develop aerial fragments which bear chains of spores, giving the culture a fuzzy appearance. The chains of spores have the appearance of corkscrews and are grey in color (Loria *et al.*, 2003). These chains allow it to be differentiated from other species that are virulent on potatoes. Each chain contains 20 or more spores that are 0.5 by 0.9–1.0 μm, smooth and grey. Bacteria are often distinguished by their ability to grow on media containing different substances, which they either feed on or that inhibit their growth. Defining characteristics of strains of Streptomyces spp are that they grow on the sugar raffinose, are unable to degrade xanthine and when grown on media containing the amino acid tyrosine, they produce the pigment melanin, the same chemical that gives humans their skin colour. This trait is often associated with their ability to cause disease, but it is not always present and is considered a secondary trait.

2.3.6 Disease Cycle of *Streptomyces spp*

Streptomycin spp was the first to describe and isolate the causal agent of common scab in North America as *Oospora scabies* (Thaxter 1891). The change in name to *Streptomyces scabies* occurred in 1948, was revived in 1989, but then changed to *S. scabies* in 1997 to follow grammatical convention (Lambert and Loria 1989). A 2007 opinion paper published by Saddler *et al.* requests the approval of continued use of *S. scabies* in reference to the potato pathogenic *S. scabies*. While no final decision has been made on this taxonomic concern, a rebuttal to Saddler's paper was published in 2008.

Cylindrical spores (0.5 by 0.9–1.0 µm) are produced in mature spiral chains containing 20 or more spores (Lambert and Loria 1989). Spores are released from the tip of the hyphae. The bacterium is dispersed by spores and survives on seed, in soil, and in soil water (Agrios 2005). The hydrophobic characteristic of the spores allow's them to also be transported by arthropods and nematodes (Loria *et al.*,2006).

The spores germinate and enter plant tissues through wounds, larval feeding sites, stomata, and lenticels (Locci 1994; Agrios 2005). Penetration of tubers by streptomyces spp and other pathogenic Streptomyces species is thought to take place through young lenticels, probably because they have not yet formed a layer of protective suberin (loci 1994). Loria *et al.* (2003) demonstrated that penetration and growth occurs through the cell walls. Young tubers

are most susceptible up until three to four weeks from tuber initiation (Khatri *et al.*, 2011 and Agrios 2005).

Thaxtomin, a phytotoxin produced by Streptomyces genotypes that cause common scab, may aid penetration of rapidly growing plant cells, such as expanding internodes (Loria et al., 2003).

Tegg *et al.* (2005) demonstrated that thaxtomin is more effective in young, physiologically active tissues, which would include expanding internodes. Studies suggest that thaxtomin results in a compromised cell wall (Scheible *et al.*, 2003) allowing for penetration.

The tuber is the only known tissue type displaying symptoms on potato (Powelson and Rowe 2008). However, Han *et al.*, (2008) demonstrated that *S. scabies* affects the emergence and growth of roots at early stages of development. When exposed to a tuber, the pathogen grows through the outer few cell layers symplastically and apoplastically (Loria 2001 and Agrios 2005). As host cells die, they provide nutrients for the bacterium. Subsequently, the living host cells around the area of the infection divide and produce layers of cork cells that eventually push outward and form a scab lesion on the tuber. Surface (russet scab), raised (erumpent scab), and pitted (pitted scab) lesions may be observed on the same tuber, and can vary in size; lesions may also coalese to form large scab-by areas on a tuber.

2.3.7 Conditions favorite to Disease

Streptomyces species that are pathogenic on potato can potentially cause lesions on the tubers of susceptible genotypes given the occurrence of favorable conditions including a pH higher than 5.2, temperatures of 20–22 °C, and soil moisture below field capacity during early tuberization (Archuleta and Easton 1981). Water develops a microfilm around the developing tuber to limit infection (Gudmestad 2008). Streptomyces spp will generally cause disease in soils with less than 65–70% soil moisture (Gudmestad 2008. Environmental conditions may further influence the types of lesions observed (shallow, raised, or pitted) (Goyer *et al.*1996).However, lesion type has also been associated with pathogen species and/or the presence of one or more virulence factors (Boucheck-Mechiche *et al.* 2000). Multiple species and/or strains of Streptomyces may be present within the tuber spheremicrobial community, making it difficult to discern tight associations among these factors. Environmental factors that are conducive to common scab caused by Streptomyces spp include low soil moisture during tuber initiation, daytime temperatures above 70 °F, and a soil pH range of 5.5 to 7.5. The severity of scab lesions increases as the soil pH increases from pH 5.2 to 8.0. Above pH 8.0, scab severity decreases again (Agrios 2005).

2.3.8 Diagnostic Methods

Lambert and Loria (1989) explained that *S. scabies* can be

distinguished from other scab causing Streptomycetes by their use of raffinose as a sole carbon source, production of melanin, in ability to degrade xanthine and grow below pH 5, and susceptibility to Streptomcin and crystal violet. Using DNA hybridization techniques the distinctiveness of *S. scabies*
strains from other scab forming Streptomycetes was confirmed, through a high degree of diversity that exists within the species (Healy and Lambert, 1991). These findings were confirmed by (Paradis *et al.*, 1994), studying fatty acid composition, protein profiling and DNA – DNA hybridization of 31 pathogenic and non pathogenic strains from potato. They found that *S. scabies* strains, whilst highly diverse, could be distinguished from other pathogenic Streptomycetes.

2.3.9 Control of the Disease

2.3.9.1 Use of irrigation

Lapwood (1966) confirmed that scab is most sever when the soil is dry soon after tubers begin to develop.

In the United Kingdom and Europe, common scab is controlled largely by specified irrigation schedules (Lapwood, 1966; Lapwood *et al.*, 1970, 1971, 1973; Wellings and Lapwood 1971; Davis *et al.*, 1976; Adams *et al.*, 1987).

Western (1971) pointed out that supplementing rainfall by irrigation

were practicable to keep the soil moist for perhaps 4-6 weeks after tuber initiation seems a promising way to control scab even on the most affected land.

High soil moisture and low soil temperature after tuber initiation reduce the disease. Tubers become infected while still very young and if they can survive this period without infection they escape the disease (Lapwood and Hering, 1970).

Various theories have been proposed to explain the mechanism of scab control by irrigation (Lapwood and Adams, 1975; Adams and Lapwood, 1987). Firstly, there is a direct influence on tuber susceptibility, e.g.lenticel proliferation. Soil moisture is necessary for the development of lenticels from stomata. With adequate soil moisture, susceptible stomata rapidly develop into resistant lenticels and are therefore protected from infection (Labruyère, 1971; Adams, 1975). Secondly, there are direct effects on the growth of the pathogen due to lowering of the soil temperature and reduced oxygen availability. Thirdly, irrigation indirectly affects disease by providing an environment conducive to antagonism (Lewis, 1971). Antagonistic bacteria move faster than scab-causing Streptomyces spp in the water films in wet soil. The antagonistic bacteria colonies the lenticels first and compete with the pathogen for the niche. Fourthly, high moisture levels have been associated with a decrease

in calcium levels in tuber tissue and it has been implied that increased calcium leads to increased scab susceptibility (Horsfall *et al*., 1954; Davis et al, 1976).

2.3.9.2 Resistant varieties

Walker (1957) reported that resistant varieties are the ultimate solution for control of this disease. The tolerant varieties are useful in this regard, but they are not successful under conditions extremely favorable for scab. Western (1971) pointed that the resistance occurs on a big number of russetted skin varieties. Pent land crown is more resistant than Majestic, but there is no acceptable replacement for King Edward). Somewhat resistant varieties include Menonimee, Ontario, Cayuga and Seneca (Kenneth, 1969).

2.3.9.3 Crop rotation

Bollen *et al* (1989) found that when cropped once every six years potatoes yield 7% less than a first cropping with potatoes, and when grown once every three years this reduction can be as much as 20 %. Soil borne diseases such as *Verticillium dahlia*, *Rhizoctonia solani* and Streptomyces spp appeared to be the main organisms responsible for the decline in yields.

2.3.9.4 Use of Fertilizers

Vanloon and Houwing (1989) mentioned that in integrated farming the amounts of N, P and K applied should be adjusted to meet needs revealed by soil or tissue analysis. It is better to use organic manure rather than artificial fertilizer, provided that the losses of No_3 and NH_3 to the environment can be minimized. The advantages of organic manure are its relative cheapness, its beneficial effect on soil structure, its stimulating effect on soil fauna, and the extra yield increase that cannot be reached by artificial fertilizer. Organic manure is best applied in spring when the leaching of nitrate is minimum.

Adisadvantage of organic manure is that it does not allow precise fertilization with N, since the proportion of the organically bound N that mineralizes during the growing season cannot be predicted. This may lead to shortage or excess of N in the crop. This problem can partly be overcomed by a split application of N, provided the second application is based on the nitrogen status of the plant or the soil. Petiole nitrate content has proved to be a useful indicator of the crop nitrogen status.

2.3.9.6 Chemical Control

2.3.9.6 .1 Tuber Treatments

Relatively little research has been conducted on the effect of tuber treatments on common scab. Kulikova (1982), Singh and Soni (1987),

Somani (1988) and Fulton (1994) reported the use of copper sulphate, formaldehyde, mercuric chloride, borax, boric acid, tetracycline, plantomycin and quintozene. Fluazinam, flusulfamide, fludioxonil and mancozeb have provided control in Australia (Wilson *et al.*, 1999; Pung and Cross, 2000).

2.3.9.6. 2 Soil Treatments

Specht (1985) reported that in integrated farming, soil cultivation should be directed to improving soil structure and controlling weeds, while using the minimum of energy.

The most widely used chemical method of controlling potato common scab is soil treatment with quintozene (PCNB) before planting (Erickson, 1960; Vashisth *et al.*, 1990). However, quintozene is persistent, could be carcinogenic, and may decrease yield or impart off-flavours to tubers .

The recommendation for potato growers is to reduce soil pH to 5.2 or below (Locci 1994). Sulfur, acid-forming fertilizers, and gypsum applied before or at planting reduces the soil pH to between 5.0 and 5. 2, which helps to suppress CS caused by *S. scabies* (Locci 1994; Powelson and Rowe 2008). Further, growers are encouraged to carefully monitor and manage soil moistureto field capacity during early tuberization in fields with a history of common scab or in fields planted to highly susceptible potato cultivars with the potential for carrying seed- introduced inoculums.

2.3.9.6.3 Foliar applications

McIntosh and Burrell (1980) reported that foliar sprays with ethionine (a protein synthesis-inhibiting amino acid) decreased the incidence of common scab caused by soil borne *S. scabiei* in greenhouse and field trials.

2.3.9.7 Biological control

Biological control such as the utilisation of suppressive soils (Anderson and Lorang, 1988; Wilson, 1994), antibiotic-producing Streptomyces strains antagonistic to potato scab pathogens (Wood & Tveit, 1955; Wilson, 1994) and biofumigation (Gouws and Wehner, 2004), offers an environmentally acceptable means of controlling common scab. It is important to realise that these methods can only be effective when applied as part of an integrated disease management system.

In further experiments 93 streptomycetes were isolated from lenticels of potato tubers grown in naturally disease - suppressive and disease -conductive soils (Liu *et al.*, 1996). Of these 22 strains showed greater antibiotic activity against virulent *S. scabies*RB 311 than pon R and pon ss II. These strains were non - pathogenic on leaf - bud tubers in green house testing and significantly reduced scab without affecting tuber yield in field-pots tests. Other

bioactive compounds have also been studied as possible control agents, antibiotic substances from a red alga, Laurencia okamurae .

2.3.9.7.1 Control with Natural "Pesticide

Medical plants have a long history of use and their use is widespread in over world countries. According to the report of the World Health Organization 80% of the worlds population rely mainly on traditional therapies which involve the use of plant extracts or their active substances (Sofowora,1999). The herbal medicines may be in form of powders, liquids, or mixtures, which may be raw, or boiled, ointments, liniments, and incisions (Malu *et al.*, 2009).

Ginger (Zingiber officinale) belongs to Zingiberaceae family. The part of the plant used is rhizome (Onyeagba *et al.*, 2004).

Nutrient Composition Fresh ginger contains 80.9% moisture, 2.3% protein, 0.9% fat, 1.2% minerals, 2.4% fiber and 12.3% carbohydrates. The minerals present in ginger are iron, calcium and phosphorous. It also contains vitamins such as thiamine, riboflavin, niacin and vitamin C (Govindarajan, 1992).

In the fresh ginger rhizome, the gingerols were identified as the major active components and gingerol [5-hydroxy-1-(4-hydroxy-3-methoxy phenyl) decan-3-one is the most abundant constituent in the gingerolseries. The powdered

rhizome contains 3-6% fatty oil, 9% protein, 60-70% carbohydrates, 3-8% crude fiber, about 8% ash, 9-12% water and 2-3% volatile oil (Ali *et al.*, 2008)

In dried ginger powder, shogaol a dehydrated product of gingerol, is a predominant pungent constituent up to biosynthesis3-5. Oleoresin, which is isolated by acetone and ethanol extraction, contains 4-7.5% of dried powder, pungent substances namely gingerol, shogaol, zingerone and paradol (Hoffman, 2007).

In vitro studies have shown that active constituents of ginger inhibit multiplication of colon bacteria. These bacteria ferment undigested carbohydrates causing flatulence, this can be counteracted with ginger (Gupta and Ravishankar, 2005). It inhibits the growth of *Escherichia coli*, Proteus sp, Staphylococci, Streptococci and Salmonella (Ernst and Pittler, 2000 and White, 2007).

Ginger has strong antibacterial activity and to some extent antifungal properties (Nielsen and Rios, 2000).

Cinnamon (*Cinnamomheum verumis)* is the name for several species of trees and the commercial spice products that some of them produce. All are members of the genus cinnamomum in the family lauraceae .

only a few cinnamomum species are grown commercially for spice. *Cinnamomheum verumis* sometimes considered to be (true cinnamon),

but most cinnamon in international commerce is derived from related species, also referred to as "cassia".(Iqbal, 1993 and Bell,2009). In 2016, Indonesia and china produced 75% of the world's supply of cinnamon.

A number of species are often sold as cinnamon (Chen et al., 2014). Ground cinnamon is composed of around 11% water,81% carbohydrates(including 53%dietary fiber),4% protein, and 1%fat (US National Nutrient Database2016). In a100 gram reference amount, ground cinnamon is rich source of calcium (100% of the daily value, DV), iron (64%DV), and vitamin K (30%DV).

2.3.9.7.5 Penamox (Amoxicillin)

Composition :

Each capsule contains: Amoxicilline trihydrate B.P. equivalent t Amoxicillin anhydrous 250 mg and Amoxicillin anhydrous 500mg. Each 5ml of reconstituted suspension contains: Amoxicillin trihydrate B.P. equivalent to Amoxicillin anhydrous125 mg and Amoxicillin anhydrous 250mg.

Action:

Amoxicillin is semi synthetic penicillin with a broad spectrum antibacterial activity against wide range of gram positive and gram negative pathogens.

Manufactured by: pharmaland pharmaceuticals, Building 71\1 , block 2,

Al-bagair industrial area , gazeera state- Sudan.

CHAPTER THREE

MATERIALS AND METHODS

This study was conducted in the laboratory of plant pathology, Department of Plant Protection, College of Agricultural Studies, Sudan University of Science and Technology during the period (November 2019 – April 2019). The aim of this study is to evaluate the effect of some plant aqueous extracts Cinnamon (*Cinnamomum verum*) and Ginger (*Zingiber officinale*) against the growth of the bacterium *streptomyces scabies* under laboratory conditions.

3.1 Isolation and Purification of the Bacteria from Infected potato tubers

Potato tubers showing symptoms of common scab were obtained from potato market, Nutrient agar Media (NA) was prepared for the bacteria isolation according to the of method used by Lambert and Loria (1989).

Symptoms on the scabby potato tubers (Plate1) were recorded before the tubers were surface-disinfected in 70% ethanol for 20 seconds and then rinsed several times in sterile distilled water (SDW). Thereafter, from each tuber, a small piece of potato tissue was cut from under the surface of a single lesion, at the border between healthy and infected tissue and put on NA plate.

Plates were incubated at 28C° and checked for bacterial growth after 24h (Plate 3). Sterile loop was used to sterilely streak the plate. Then the plates were incubated at 25 – 28C°. Then the bacterial growth was checked for bacterial growth after 24 hours for further use. Colonies of bacteria were streaked several times, respectively onto the same medium until a pure culture was obtained (Plate 4) and kept in refrigerator for further use.

Plate 1 Symptoms of ***Streptomyces scabies*** on potato tubers

Plate 3: Growth of Streptomyces spp Nutrient Agar

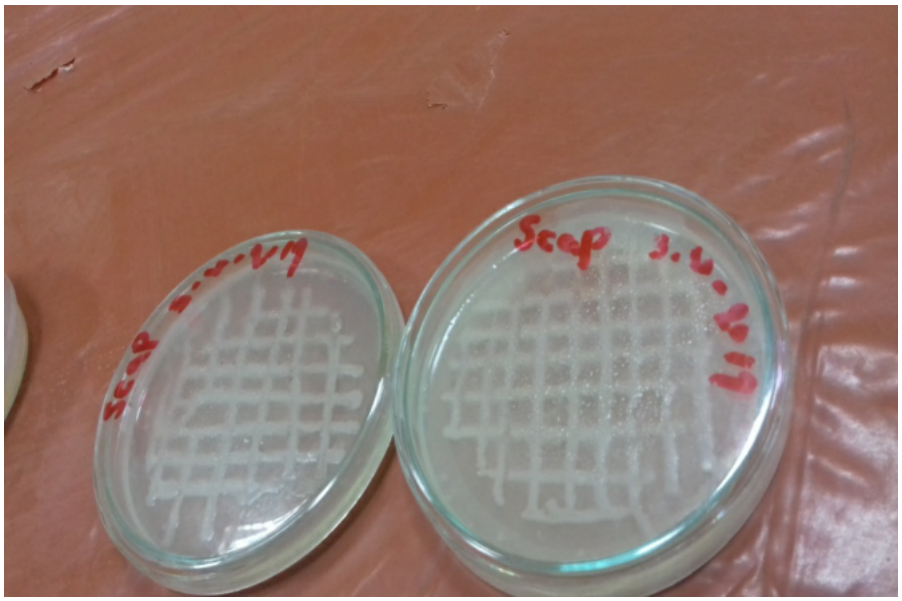

Plate4 Pure culture of Streptomyces spp the causal agent of potato plant

3.2 Inoculums Preparation

Pure isolates of Bacterial cell were harvested in sterile distilled water by using sterile glass rod. Control of bacteria using selected botanicals: Plant materials, equipment, tools and reagents:

3.3 Effects of botanicals

The aim of this experiment was to study the antibactrial activities of plant extracts on the growth of streptomyces spp invitro. The plants used were Cinnamon (*Cinnamomum verum*) and Ginger (*Zingiber officinale)* , in addition to penamox 2% which obtained from pharmacy.

Two plant materials were used *Zingiber officinale* and *Cinnamomum verum* , the following were prepared :Penamox was buy from pharmacy Sterile distilled H2OPure bacterial culture Sterile beaker , glass rod, sterile filter paper discs, scalpel and cotton swabs.

3.3 Preparation of plant extracts

Zingiber officinale (Ginger) and *Cinnamomum verum* (Cinnamon) were obtained from Shambat local marked.

Twenty gram of dried material of each plant species were placed in a 250 ml conical flask , then 80 ml of sterile distilled water were added to each flask . The mixture was placed on a shaker (orbital incubators 1500 and left to extract for 24 h at a speed of about 133rpm at room temperature 25C.

Extracts are expressed through 2 layers of cheesecloth. Filtered extracts were the collected in 50 ml round bottom flasks.

Hundred ml of bacterial suspension (1.0 x CFU/) were spread on to

the surface of the NA plate using sterile cotton swabs (Casimiri and Burstein,1998). Sterile filter paper disc were dipped briefly in the respective plant extracts and were then applied on to surface of the NA plate .Discs fattened with Penamox (2%) were used as positive controls, while sterile distilled water – treated discs were use as a negative control. The treated plates were incubated at 28 c° for 48 h and the developing inhibition zones were observed and measured to determine the relative efficacy of the plant extracts against streptomyces spp.

Table1. Plant extracts used for the control of Streptomyces spp.

Common name	Botanicals name	Family	Plant parts used
Ginger	*Zingiber officinale*	Zingiberaceae	Rhizome
Cinnamon	*Cinnamomum verum* J. presl	Lauraceae	Inner bark

3.4. Statistical Analysis Procedure

The data was collected statistically analyzed using the soft ware to Statistix 8 in a one-way Completely Randomized design .

Data were transformed using the equation .

CHAPTER FOUR
RESULTS

4.1 Isolation and Purification of the Bacteria from Infected potato tubers

The pathogenic bacteria that were isolated from infected potato tuber plants showing symptoms. The results showed that the bacteria were identified based on morphological and cultural characters as Streptomyces spp (Plate 2).

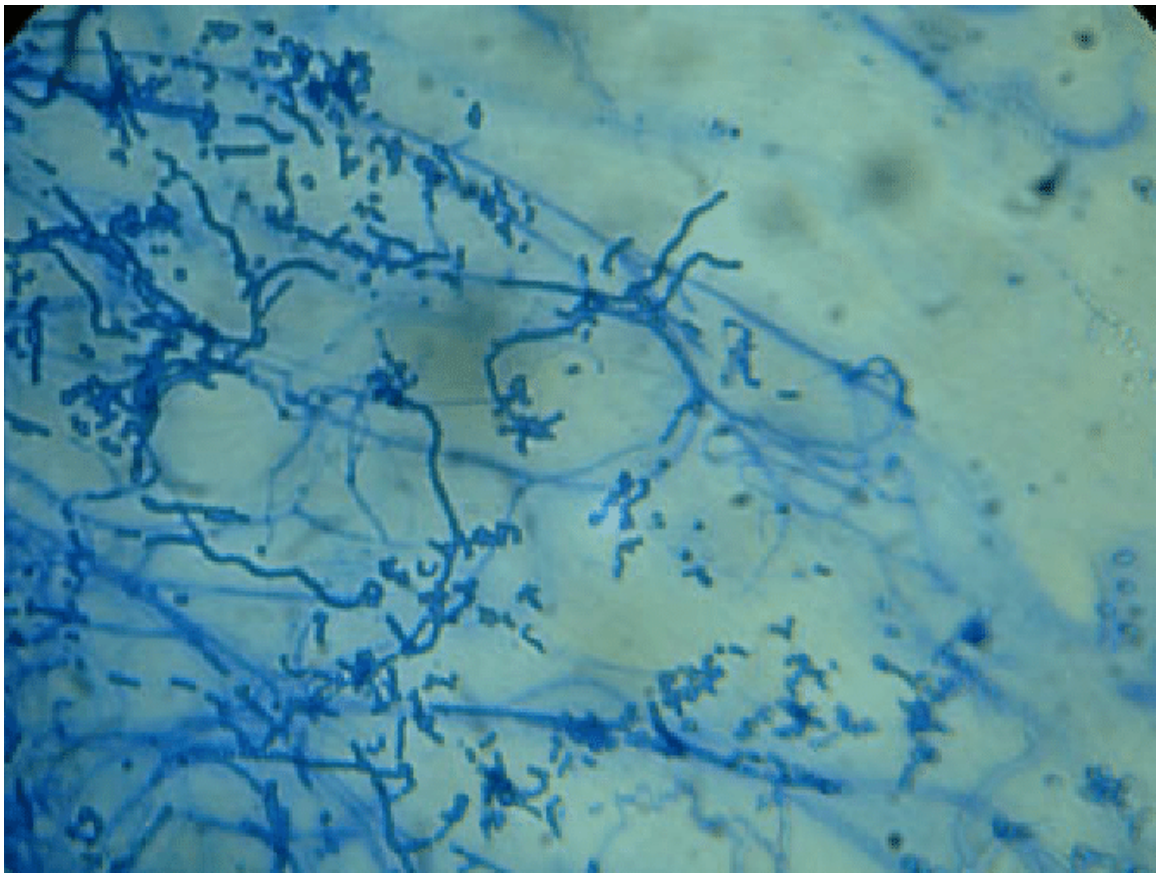

Plate 2 the isolated Streptomyces spp under microscope

4.2 Effects of aqueous extracts of Ginger and the antibiotic Penamox 2% against Streptomyces spp two days after inoculation *in vitro*

The results presented in Table (2) tow days after inoculation, showed that all concentrations (5% ,10% and 20%) of aqueous extracts in addition to the penamox 2% tested were found to be significantly ($p \geq 0.05$) inhibited the growth of Streptomyces spp compared to the untreated control (H_2O) by (2.6.2.6.2.6) of 3.7 inhibitory effect respectively .

There is no significant different between the different concentration

Table 2 Effects of Ginger aqueous extracts and the antibiotic Penamox 2% against Streptomyces spp two days after inoculation *in vitro*

Treatments	Mean (mm)
Penamox 2%	**3.07** [a]
Ginger 20%	**2.6** [b]
Ginger 10%	**2.6** [b]
Ginger 5%	**2.6** [b]

Untreated control (H_2O)	0.2 ^{c}

LSD 0.1
CV 3.6
SE± 0.06

Dissimilar letters on the" mean" showing significant differences data transformed using the equation

Plate 5 **Effects of Ginger queous extracts and the antibiotic**

Penamox 2% against Streptomyces spp **in potato two days after inoculation *in vitro***

A: Ginger 20%
B: Ginger 10 %
C: Ginger 5 %
D: H_2O
E: Penamox 2%

Effects of Cinnamon aqueous extracts and the antibiotic Penamox 2% against Streptomyces spp two days after inoculation *in vitro*

The result in Table (3) sohowed that the different concentrations of Cinnamon aqueous extracts (5% ,10% and 20%) effected the growth of the bacteria Streptomyces spp significantly ($p \geq 0.05$) when compared to the untreated control (H_2O) inhibited the growth by (2.6.2.6.2.5) respectively .

On the other hand no significant ($p \geq .05$) difference recorded between the different concentrations one to another .

Penamox 2% followed the same trend as in ginger experiment by recording the highest inhibitory effect (3.7).

Our results revealed that both tested plants aqueous extracts were significant ($p \geq .05$) retarded the growth of the bacteria

Streptomyces spp in vitro.

Table 3 Effects of Cinnamon aqueous extracts and the antibiotic Penamox 2% against Streptomyces spp two days after inoculation *in vitro*

Treatments/concentration	Mean(mm)
Penamox 2% (+control)	3.07[a]
Cinnamon 20%	2.5 [b]
Cinnamon 10%	2.6 [b]
Cinnamon 5%	2.6 [b]
Untreated control (H_2O)	0.2 [C]

Dissimilar letters on the" mean" showing significant differences data transformed using the equation .

LSD 0.01

CV 3.02

SE± 0.05

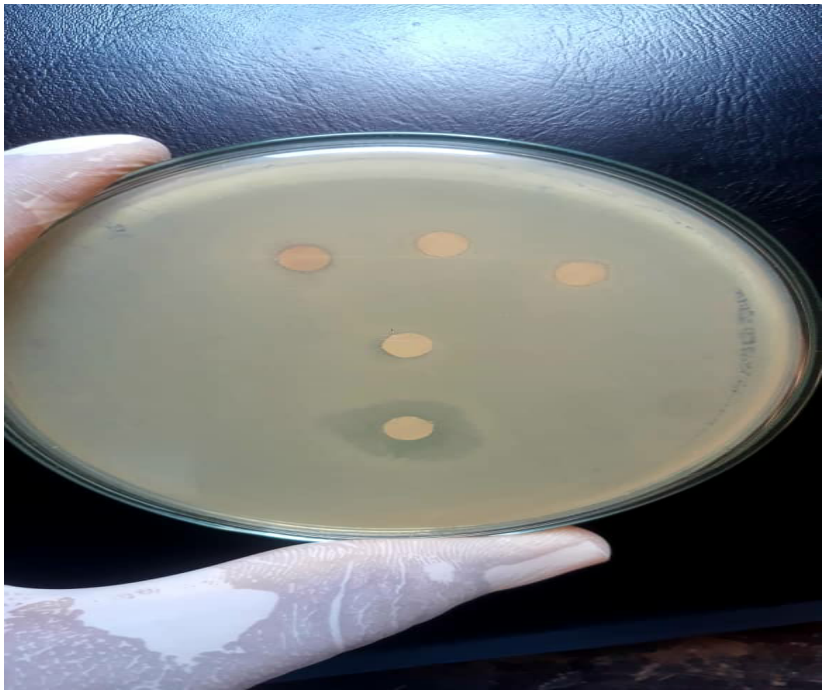

Plate 6 **Effects of Cinnamon aqueous extracts and the antibiotic Penamox 2% against** Streptomyces spp **in potato two days after inoculation** ***in vitro***

A: Cinnamon 20%
B: Cinnamon 10 %
C: Cinnamon5 %
D: H_2O
E: Penamox 2%

CHAPTER FIVE
DISCUSSION

The present study revealed that the scab bacterial disease has become established and attained epidemic status in Khartoum state. The use of plant extracts for controlling scab of potato granted some favorable results that might give more options for controlling the disease.

Relatively, Ginger *(Zingiber officinale*) expounds higher inhibitory effects with inhibition zone of 2.6 mm. However the effectiveness of, *Zingiber officinal* was previously reported by (Suhad *et al.*, 2012), aqueous extract of ginger roots were used for antibacterial activity against various Gram negative and Gram positive bacteria.

*Cinnamomum verum (*cinnamon) showed an inhibitory effect with inhibition zone of 2.5mm, while when used to control Citrus Bacteria Canker on Lime showed inhibition zone 6.50 mm (Elshafia, 2017).

On the other hand (Elrasheed, 2007) reported similar effect of the other plant extract (Neem seed extraction) , when his results showed a significantly positive effect on controlling the common scab disease as compared to check treatment. The concentration 10 % was significantly higher in inhibiting the causal organism, followed by 5 % concentration. Also the study showed that the inhibition of Streptomyces spp was significantly decreased with the time .

The variation in the inhibitory effect may be due to qualitative and quantitative differences between the selected plant materials or due to the diffusion of bacteria on plate .

CONCLUSION

- The two plant extracts, Gengir (*Zingiber officinale)* and Cinnamon (*Cinnamomum verum*) were expound positive inhibitory effect against the bacteria streptomyces spp of potato .

RECOMMENDATIONS

- Further investigations on plant extracts ginger (*Zingiber officinale*) and Cinnamon (*Cinnamomum verum*) because they have proved highly effective against bacteria streptomyces spp of potato.
- Fractioning of the extracts into different substances for both tested plants is essential to determined the most effective substance responsible for the suppression of the bacterial growth.
- The selected plant species need more investigation to be considered as a promising option to IPM component to shorten the spread of disease.
- Further studies in recommended to test the effect of both tested plant under field conditions.

APPENDICES

Equipment ,tools and reagents:

Equipment ,tools and reagents used in the isolation of the bacteria from field Samples were :

- Autoclave
- Laminar flow cabinet
- Light microscope
- Cover slips
- Microscope glass slide
- Scalpel
- Tissues paper
- Sterile inoculation loop
- Petri dishes
- Flame
- Nutrient agar
- Ethanol (70-90%)
- 0.1% sodium hypochlorite (Naclo)
- 0.85% saline or sterile water.

origin data		
treatment/CONCENTRATIION	R1(Cinnamon)	R2(Ginger)
20%	6.5	7
20%	7	7.5
20%	6	7.5
20%	6	6
10%	6.5	7
10%	6.5	6.5
10%	6	7
10%	6	6
5%	6.5	7
5%	6.5	6.5
5%	6	7
5%	6	6
Penamox 2%	9	10
Penamox 2%	10	9.5
Penamox 2%	9	9
Penamox 2%	9.5	9
H_2O	0	0
H_2O	0	0
H_2O	0	0
H_2O	0	0

REFERENCE

Abdelgader, H.S.M. (2015). Pathogenicity of two seed born fungi isolation from *Cicer arietinum* L. MSC Thesis. College of Agricultural Studies, Universities. Scual.

Abdul, A. M., Yasin, M. A., Randhawa, A., Yasmin, M. A., Jahangir and Sohail, M. (2013). Nutritional and antioxidant profile of some selected Pakistani potato cultivars. *Pakistan Journal of Food Sciences*, 23(2): 87-93, 2013.

Adams, M. J. (1975). Potato tuber lenticels: development and structure. *Annals of Applied Biology* 79: 265-273.

Adams, M. J., Read, P. J., Lapwood, D. H., Cayley, G. R. & Hide, G. (1987). The effect of irrigation on powdery scab and other tuber diseases of potatoes. *Annals of Applied Biology* 110: 287-294.

Agrios, G.N. (2005). Plant pathology. 4th ed. London: Academic. Alam, Z. 1972. Inheritance of scab resistance in 24-chromosome

pota-toes. Ph.D., University of Wisconsin-Madison, 58 pp.

Ahmed.A.S.

(2012). Study the Antibacterial Activity of *Zingiber officinale* roots against Some of Pathogenic Bacteria. Biotechnology Branch-Applied Science-University of Technology 23,No 3.

Al-Ameen, S.M. (2003). Present and future prospective of potato crop inthe Susan. A paper presented at the Faculty of Agricultural Studies, Sudan University of Science and Technology.

Ali, B.H; Blunden, G.; Tanira, M.O. and Nemmar, A.(2008). Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): a review of recent research. Food Chem Toxicol.46(2):409-20.

Ali, F. I. (1987). Identification and variability among different isolates of the bacteria causing potato scab disease. *Arabian Journal of Plant Protection* 5: 74-77.

Ali,K. Mohammed., (2000). Potato (Solanum tuberosum)and sweet potato (Ipomea batata) production in Sudan vegetable research .

Alivizatos, A. S. and Pantazis, S. (1992). Preliminary studies on biological control of potato common scab caused by Streptomyces sp. Pages 85-92 In: E. S. Tjamos (ed.) Biological

control of plant diseases. Plenum Press, New York.

Anderson, N. A. & Lorang, J. M. (1988). Potato scab: An old disease presents new control opportunities. *Valley Potato Grower*. 88: 14-17.

Anonymous., (1960). Index of plant disease in the United States, Agr. Hand book, No 165. U.S. Dept of Agriculture, Washington, D.C.

Archuleta, J.G., and G.D. Easton. (1981). The cause of deep-pitted scab ofpotatoes. *American Potato Journal*. 58: 385-392.

Beazell, JM; Schmidt, CR; Ivy, AC (January 1939). "On the Digestibility of Raw Potato Starch in Man". *The Journal of Nutrition*. Volume 17, Issue 1: Pages 77-83 – via Oxford University Press.

Bell, M.T.S Toussaint -Anthea (2009). A history of food (New expanded) ed. Chichester, West Sussex:Wiley-Blackwell.ISBN 978-1405181198."Cassia,also known as cinnamon or Chinese cinnamon is a tree that has bark similar to that of cinnamon but with a rather pungent odour "

Bjor, T. and Roer, L. (1980). Testing the resistance of potato varieties to common scab. *Potato Research* 23: 33-47.

Bollen G. J. (Eds), Effects of crop rotation on potato production in the temperate zones, Kluwer Academic publishers, Dordrecht, P. 203-322.

Bollen, G. J., Hoekstra, O., Scholte, K., Hofman, T.W., Caletti, M. J. & Schirring, A., (1989). Incidence of soil borne pathogens in potato related to the frquency of potato growing on a clayloam. In: Vos. J., Vanloon, C.D.

Bouchek-Mechiche, K., Pasco, C., Andrivon, D. and Jouan, B. (2000). Differences in host range, pathogenicity to potato cultivars and response to soil temperature among Streptomyces species causing common and netted scab in France. *Plant Pathology* 49: 3-10.

Brooks, F.T., (1928). Plant Diseases. London Oxford University press.

Buckenhuskes, H.J. (2005). Nutritionally relevant aspects of potatoes and potato constituents. In Haverkort, A.J. and Struik, P.C. (editors) potato in progress: science and meets practice. Wageningen Academic Publishers.

Chen P, Sun J, Ford P (2014). "Differentiation of the four major species of cinnamons (C. *burmannii*, C. *verum*, C. *cassia*, and C. *loureiroi*) using a flow injection mass spectrometric (FIMS) fingerprinting method". *J. Agric. Food Chem.* 62 (12): 2516–2521. doi:10.1021/jf405580c. PMC 3983393. PMID 24628250

Christ, B.J., (1998). Potato Diseases in Pennsylvaina. College of

Agricultural Sciences , University Park, PA.

Davis, J.R., G.M. McMaster, R.H. Callihan, F.H. Nissley, and J.J. Pavek. (1976). Influence of soil moisture and fungicide treatments on com-mon scab and mineral content of potatoes. *Phytopathology* 66: 228–233.

De Klerk A, Mcleod A, Faurie R,Van Wyk P.S., (1997a). Net blotch and necrotic warts caused by Streptomyces scabieson pods of peanut (Arachis hypogaea) . *Plant Disease*, 81:958.

De Klerk, A. D. K., Mcleod, A., Faurie, R. & Van Wyk, P. S. (1997b). Groundnuts as alternative host for Streptomyces scabies, the common scab pathogen of potatoes. *African Plant Protection* 3: 77–79.

Dees, M., A. Sletten, and A. Hermansen. (2013). Isolation and characterization of streptomyces species from potato common scab lesion in Norway. *Plant Pathology* 62: 217–225.

Doering-Saad, C., Kämpfer, P., Manulis, S., Kritzman, G., Schneider, J., Zakrzewska-Czerwinska, J., Schrempf, H. & BARASH, I. (1992). Diversity among Streptomyces strains causing potato scab. Applied and Environmental Microbiology 58: 3932–3940.

Dowley, L. J. (1972). Reliability of methods of assessing the degree of tuber attack by common scab of potatoes. *Potato Research* 15:

263-265.

Elesaway, A. A. & Szabo, I. M. (1979). Isolation and characterization of Streptomyces scabies strains from scab lesions on potato tubers. Designation of the neotype strain of Streptomyces scabies. Acta Microbiologica Academiae Scientiarum Hungaricae **26**: 311-320.

Elraiah, A. E.; Mohamed, A. K.; Elfahal A. M.; Bedry K. A, M.;Mahadi A. A. And Yousif, K.S. (2013). Performance of introduced Dutch potato varieties under the arid conditions of Northern Sudan. A paper submitted to the Variety Release Committee. Agricultural Research Corporation. Khartoum, Sudan, Sec. Meeting (2013).

Elrasheed S.L.I. (2007). The Scab of Potato (*Solanum tuberosum*) caused by *Streptomyces scabies* and its Control. Thesis Submitted for the Fulfillment of the Requirements for Ph.D. (Agric) Plant Pathology Dep. Of Crop Protection, Faculty of Agriculture University of Khartoum, Sudan.

Elshafia A. H. M. (2017). Citrus Bacterial Canker on Lime (*Citrus aurantifolia Swingle*) in Kassal and Khartoum States and Evaluation of Some Plant Extracts for the Disease Control. A Dissertation Submitted to the University of Khartoum in Partial Fulfillment of the Requirements for the Degree Master

of Science in Plant Pathology.

Emilsson, B. and Gustafsson, N. (1953). Scab resistance in potato cultivars. *Acta Agricultura Scandinavica* 3: 33-52.

Erickson, H. T. (1960). Potato scab control in organic soils. I. Initial response to PCNB. *American Potato Journal* 37: 18-22.

Ernst, E. and Pittler, M.H.(2000). Efficacy of ginger for nausea and vomiting. A systematic review of randomised clinical trials. *Br. J. Anaesth* 84: 367.

FAOSTAT(2015). faostat.fao.org.Retrieved 25 January.

Fernandes G, Velangi A, Wolever TM (2005). "Glycemic index of potatoes commonly consumed in North America". Journal of the American Dietetic Association. 105 (4): 557–62. doi:10.1016/j.jada.2005.01.003. PMID 15800557.

Florse-Gonzalez, R., I. Velasco, and F . Montes. (2008). Detection and characterization of streptomyces causing potato common scab in Western Europe. *Plant Pathology* 57: 162-169.

Fulton, D. (1994). Control of common scab via irrigation. Pages 48-58 In: Integrated control of common scab: A compilation of working documents by C. Wilson, D. Fulton and B. Pemberton.

Goth, R. W. and Webb, R. E. (1986). Rapid method to assess virulence of

potato scab isolates of Streptomyces scabies. *American Potato Journal* **63**: 427.

Gouws, R. and Wehner, F. C. (2004). Biofumigation as alternative control measure for common scab on seed potatoes in South Africa. *Agroindustria* 3: 5-8.

Govindarajan, V.S. (1992). Ginger: Chemistry, technology and quality evaluation (Part I). Crit Rev Food Sci Nutr 17: 1.

Goyer, C. and Beaulieu, C. (1997). Host range of streptomycete strains causing common scab. *Plant Disease* 81:901-904.

Gudmestad, N. (2008). Potato health from sprouting to harvest. In Potato health management, ed. D. Johnson, 2nd ed., 67-77. St. Paul: APSPress.

Gupta, S. and Ravishankar, S. (2005). A comparison of the antimicrobial activity of garlic, ginger, carrot, and turmeric pastes against *Escherichia coli* O157:H7 in laboratory buffer and ground beef. *Food borne Pathogen Dis* .2(4):330-40.

Gussow, H.T., (1914). The systematic position of the organism of the common potato scab . Science , 39 : 431 – 433 .

Han, L., P. Dutilleul, S. Prahser, C. Beaulieu, and D. Smith. (2008). Asessment of common scab-inducing pathogen effects on potato underground organs via computed tomography scanning.

Phytopathology 98: 1118-1125.

Hawkes, J.G., (1989). The potato evaluation, biodiversity and genetic resources. 1sted London Belhvan Press.

Healy, F.G,, Lambert DH., (1991). Relationships among Streptomyces spp. Causing potato scab. *International Journal of systematic Bacteriology*, 41(4): 479 – 482 .

Heinamies, H. and Seppanen, E. (1971). Morphological, physiological and pathogenic properties of potato scab organism in Finland. *Annales Agriculturae* Fenniae10:174-180.

Hijmans, RJ; and Spooner,DM(2001). "Geographic distribution of wild potato species" .American Journal of Botany. Btanical Society of America. 88(11):2010-12. doi:10.2307/3558435. JSTOR 3558435.

Hind, A.E; and Mohamed.A.I.(2010). Status Report on Fruits and Vegatables Production and Processing Industry in Sudan. Tech. R.Post.Pp.168-179.

Hoffman, T. (2007). Antimicrobial activity of some medicinal plants from *India.Hawaii Med. J.*, 66: 326-327.

Hooker, W. J. and Kent, G. C.(1946). Infection studies with Actinomyces scabies.Phytopathology36: 388-389.

Hooker, W. J. (1949). Parasitic action of Streptomyces scabieson roots of seedlings. *Phytopathology* 39: 442–462.

Horsfall, J. G., Hollis, J. P. & Jacobson, H. G. M. (1954). Calcium and potato scab. *Phytopathology* 44: 19–24.

Iqbal, Mohammed (1993). "International trade in non-wood forest products: An overview". FO: Misc/93/11 – Working Paper. Food and Agriculture Organization of the United Nations. Retrieved 12 November 2012.

John M. F. (2005). Iberia and the Americas: Culture, Politics, and History : a Multidisciplinary Encyclopedia. ABC-CLIO. p. 867. ISBN 978-1-85109-421-9.

Jones, A. P. (1953). Parsnip canker. *Nature* 171: 574.

Keinath, A. P. and Loria, R.(1989). Management of common scab of potato with plant nutrients. 152–166 In: W. A. Engelhard (ed.). Soilborne plant pathogens: Management of diseases with macroelements. Scientific Publishers, New York.

Khatri, B.B., R.S. Tegg, P.H. Brown, and C.R. Wilson. (2011). Temporalassociation of potato tuber development with susceptibility to common scab and *Streptomyces scabiei*-induced responses in the potatoperiderm. *Plant Pathology* 60: 776–786.

Koronowski, P. and Massfeller, D. (1972). Anactinomycosis of Radish.

Nachrichtenblatt Des Deutschen *Pflanzenschutzdienstes* 24: 152-154.

Kulikova, G. A. (1982). Borax against common scab. Potato Abstracts vol. 7 no.1

Kutzner, H. J. (1981). The Family Streptomycetaceae.

Labruyère, R. E. (1971). Common scab and its control in seed-potato crops. Center for Agricultural Publishing and Documentation, Wageningen. Agricultural Research Report 767: 1-72.

Lambert, D. H.; Loria, R. (1989a). "Streptomyces scabies sp. nov., nom. rev". International Journal of Systematic Bacteriology. 39 (4): 387. doi:10.1099/00207713-39-4-387

Lambert, D., and R. Loria. (1989b). Streptomyces scabies SP-Nov, nom-rev. International Journal of Systematic and EvolutionaryMicrobiology 39: 387-392.

Lapwood D. H. & Hering, T.F. (1970). Soil moisture and the infection of young potato tubers by *Streptomyces scabies.*

Lapwood, D. H. & Adams, M. J. (1975). Mechanisms of control of common scab by irrigation. Pages 123-129 In: G. W. Bruehl (ed.). Biology and control of soil-borne plant pathogens. American *Phytopathological Society*, St. Paul, MN.

Lapwood, D. H. & Dyson, P. W. (1966). Aneffect of nitrogen on the formation of potato tubers and the incidence of common scab (Streptomyces scabies). Plant Pathology 15: 9–14.

Lapwood, D. H. (1966). The effects of soil moisture at the time potato tubers are forming on the incidence of common scab (Streptomyces scabies). Annals of Applied Biology 58: 447–454.

Lapwood, D. H., Wellings, L. W. and Hawkins, J. H. (1971). Irrigation as a practical means to control potato common scab (Streptomyces scabies). *Plant Pathology* **20**: 157–163.

Lapwood, D. H., Wellings, L. W. and Hawkins, J. H. (1973). Irrigation as a practical means to control potato common scab (Streptomyces scabies): Final experiment and conclusions. *Plant Pathology* 22: 35–41.

Lapwood, D. H., Wellings, L. W. and Rosser, W. R. (1970). The control of common scab of potatoes by irrigation. *Annals of Applied Biology* 66: 397–405.

Large, E. C. and Honey, J. K. (1953). Survey of Common Scab of Potatoes in Great Britain, 1952 and 1953. *Plant Pathology* 4: 1–8.

Lawrence, C.H., M.C. Clark, and R.R. King. (1990). Induction of common scab symptoms in aseptically cultured potato tubers by the

vivotoxin, thaxtomin. Phytopathology 80:606-608.

Lehtonen, M., H. Rantala, J. Kreuze, h. Bang, L. Kuisma, P. Koski, E. Virtanen, K. Vihlman, and J. Valkonen. (2004). Occurrence and survival of potato scab pathogens (Streptomyces species) on tuber lesions: quick diagnosis based on a PCR - based assay. *Plant Pathology* 53:280-287.

Leiner, R. H., Fry, B. A., Carling, D. E. & Loria, R.(1996). Probable involvement of thaxtomin A in pathogenicity of Streptomyces scabies on seedlings. *Phytopathology* **86**: 709-713.

Lewis, B. G. (1971). Effects of water potential on the infection of potato tubers by Streptomyces scabies in soils. *Annals of Applied Biology* 66: 83-88.

Liu, D., Anderson N.A., Kinkel L.L., (1996). Selection and characterization of strains of Streptomyces suppressive to the potato scab pathogen . *Canadian Journal of Microbiology* , 42: 487- 502 .

Locci, R. (1994). Actinomycetes as a plant pathogen. European *Journal of Plant Pathology* 100: 179-200.

Loria, R. (2001). Common scab. In Compendium of potato diseases, ed. W. R. Stevenson, R. Loria, G.D. Franc, and D.P. Weingartner, 2nde d., 14-15. St. Paul: *The American Phytopathological Society.*

Loria, R., Bukhalid, R. A., Fry, B. A. & King, R. R. (1997). Plant pathogenicity in the genus Streptomyces. *Plant Disease* 81: 836-846.

Loria, R., J. Coombs, M. Yoshida, J. Kers, and R. Bukhalid. (2003). A paucity of bacterial root diseases: Streptomyces succeeds where others fail. Physiological and Molecular Plant Pathology 62: 65-72.

Loria, R., J. Kers, and M. Joshi. (2006). Evolution of plant pathogenicity in Streptomyces. *Annual Review of Phytopathology* 44: 469-487.

Lutman, B. F. and Johnson, H. F. (1915). Some observations on ordinary beet scab. *Phytopathology* 5: 30-34.

Malu, S. P.; Obochi, G. O.; Tawo, E. N. and Nyong, B. E. (2009). Antibacterial activity and medical properties of ginger (*zingiber officinale*).*Global J. of pure and applied sciences vol.* 15 No. 3:65-368.

Marais, L. and Visser, A. F. (1989). Progress with breeding for resistance of potatoes to common scab and future strategy. Pages 32-40 In: Proceedings of the Potato Research Symposium, Warmbaths, South Africa, 1-2 August '89.

Mcintosh, A. H. and BURRELL, M. M. (1980). Movement Of Ethionine In

potato plants after foliar application against common scab. *Physiological Plant Pathology*,17: 205–212.

Miyajima, K., Tanaka, F., Takeuchi, T. and Kuninaga,S. (1998). *Streptomyces turgidiscabies* sp. nov. International Journal of Systemic Bacteriology 48: 495–502.

Mohanty, N. N., Pattanayak, B. K., Mohapatra, K.C., Lenka, M. K., Dash S. C. & Chotray, P. K.(1980). Notes on varietal reaction of some potato cultivars to common scab disease. *Indian Journal of Agricultural Science* **50**: 189–190.

Nielsen, .PV.; Rios, R.(2000). Inhibiti on of fungal growth on bread by volatile compounds from spices and herbs and mustard essential oil. *Inter J Food Microbiol* **60**: 219–229.

Nutritiondata.com, Conde Nast for the US National Nutrient Database, SR-21. 2014. Retrieved 7 May 2017. "Nutrient contents of potato, baked, flesh and skin, without salt per 100 grams".

Oestergaard, S. P. & Nielsen, S.(1979). Control of potato scab (Streptomyces scabies) by irrigation. Tidsskrift fur Planteavl 83: 201–204.

Office of International Affairs (1989). Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide

Cultivation. nap.edu. p. 92. ISBN 030904264X.

Onyeagba, R.; Ugbogu, A.; Okeke, O.C. and Iroakasi, O. (2004). Studies on the antimicrobial effects of garlic (*Allium sativumLinn*)|, ginger (*Zingiber officinal* Roscoe) and Lime (*Citrus aurantifoliaL inn*) Short communication Afr. *Journ. Biotech.* 3(10): 552-554.

Paradis, E., Goyer, C., Hodge, N.C., Hogur, R., Stall, R.E., Beaulieu C., (1994). Fatty acid and protein profiles of *Streptomyces scabies* strains isolated in eastern Canada. *International Journal of systematic Bacteriology* , 44(3): 561- 564 ; 22 .

Park, D., Soon Kim, J., Wo Kwon, S., Wilson, C., Man Yu, Y., Hyun Hur, J. and Keun Lim, C. (2003). *Streptomyces Luridiscabiei* sp. nov., *Streptomyces puniciscabiei* sp. nov. and *Streptomyces niveiscabiei* sp. nov., which cause potato common scab disease in Korea. *International Journal of Systematic and Evolutionary Microbiology* 53: 2049-2054.

Paul D.(2011). Streptomyces: Molecular Biology and Biotechnology. Horizon Scientific Press. p. 15. ISBN 978-1-904455-77-6. Retrieved 16 January 2012.Sanger Institute. Retrieved 2001-02-26. "Streptomyces scabies".

Powelson, M., and R. Rowe. (2008). Managing diseases caused by

seedborne and soilborne fungi and fungus-like pathogens. In potato health management, ed. D. Johnson, 2nd ed., 183-195. St. Paul, MN: PAS Press.

Pung, H. and Cross, S. (2000). Common scab – Incidence on seed potatoes and seed-borne disease control. Pages 81-84 In: C. M. Williams and L. J. Walters (eds). Potatoes 2000 " Linking research to practice".Australian Potato Research, Development and Technology Transfer Conference, 31 July – 3 August 2000, Adelaide, South Australia.

Qu, X.S., L.A. Wanner, and B.J. Christ. (2008). Using the txtAB operon to quantify pathogenic streptomyces in potato tubers and soil. *Phytopathology* 98: 405-412.

Qu, X.S., L.A. Wanner, and B.J. Christ. (2011). Multiplex real-time PCR (TaqMan) assay for the simultaneous detectionand discrimination of potato powdery and common scab diseases and pathogens. *Journal of Applied Microbiology* 110: 769-777.

Read, P. J., Storey, R. M. J. and Hudson, D. R. (1995). A Survey Of black dot and other fungal tuber blemishing diseases in British potato crops at harvest. *Annals of Applied Biology* 126: 249-258.

Rich, A.E., (1983). Potato Disease, NewYork – London.

Robert ,M. (1955). Potato diseases. Irish potato Marketing, LTD., Dublin.

Sadowski, C., Peszek, J., Rzekanowski, C. & Sobkowiak, S. (1996). Effect of irrigation and different nitrogen fertilization rates on the occurrence of *Streptomyces scabies*(Thaxter) on potato cultivated on very light soil. *Plant Breeding and Seed Science* 40: 45–49.

Scheible, W.W., B. Fry, A. Kochevenko, D. Schindelasch, L. Zimmerli, S. Somerville, R. Loria, and C.R. Somerville. (2003). An Arabidopsis mutant resistant to thaxtomin A, a cellulose synthesis inhibitor from Streptomyces species. *The plant cell*15: 1781–1794.

Sherf, A. F. and MacNAB, A. A. (1986). Other fungus diseases. Pages 256–260 In: Vegetable diseases and their control. Wiley, New York.

Singh, H. & Soni, P. S. (1987). Chemical control of common scab of potato. *Plant Disease Research* 2: 77–79.

Singh, N.P., Bhardway, A.K., Kumar, A. and Singh, K.M. (2004). Modern Technology on Vegetable production. International book distributing co. India

Sofowora, A. (1999). Introduction to medical plants and traditional medicine. Spectrum books limited, 2: 8–76.

Somani, A. K. (1988). Control of black scurf (*Rhizoctonia solani*) and common scab (*Streptomyces scabies*) on potato (*Solanum*

tuberosum) with boric acid. *Indian Journal of Agricultural Science* 58: 693–698.

Specht, A., (1985). Anbautchnikim integrierten Kartoffelanbau, Der Kartoffelbau 36: 128- 413.

Spooner, D.M.; McLean, Karen; Ramsay, Gavin; Waugh, Robbie; Bryan, Glenn J. (2005). "A single domestication for potato based on multilocus amplified fragment length polymorphism genotyping". PNAS. 102 (41): 14694–99. doi:10.1073/pnas.0507400102.

Tarr, S.A.J., (1955). The Fungi and plant diseases of the Sudan.

Tegg, R.S., L. Melian, C.R. Wilson, and S. Shabala. (2005). Plant cell growth and ion fiux responses to the *Streptomycete phytotoxin* thaxtomin a:calcium and hydrogen flux patterns revealed by the non-invasive MIFE technique. *Plant Cell Physiology* 46: 638–648.

Thaxter, R. (1891). The potato "scab." Connecticut Agricultural Experiment Station Annual Report,PP. 81–95.

Thaxter, R., (1892). Potato scab. Annual Reoprt, the connecticut Agricultural Experiment station for 1891. Connecticut, USA: connecticut Agricultural Expriment station, 153- 160.

University of Wisconsion-Madison,Finding rewrites the evolutionary history of the origin of potatoes (2005).

US National Nutrient Database, Release 28, United States Department of Agriculture.May 2016. Retrieved 18 September 2017. "Cinnamon, spice , ground, per 100g"

Vanderzaag, D.E., (1991). The potato crop in Saudia Arabia. Saudi potato development program. Ministry of Agriculture and water, Riyadh.

VanLoon, C.D., and Houwing, J.F., (1989). Optimization of nitrogen nutrition of ware potatoes . *Pub likatie nr.* 42. PAGV.

Vashisth, K. S., Sharma, V. C. and Sekhawat, G. S. (1990). Chemical soil treatment for the control of common scab of potato. *Journal of the Indian Potato Association* 17: 212-213.

Walker, J.C., (1957). Plant Pathology. Second Edition. Mc Grow. Hill Book Company, INC- London.

Walker, J.C., (1969). "*Plant Pathology" Third Edition* . Mc Grow. Hill, New York.

Wanner, L. (2006). A survey of genetic variation in Streptomyces isolatescausing potato common scab in the United States. *Phytopathology* 96: 1363-1371.

Wanner, L. (2007). High proportions of nonpathogenic Streptomyces areassociated with common scab-resistant potato lines and less severedisease. *Canadian Journal of Microbiology* 53: 1062-1075.

Wastern, J.H., (1971). Disease of crop plants – Macmillan press LTD . London and Basingstok.

Wellings, L. W. and Lapwood, D. H. (1971). Control of common scab by the use of irrigation. National Association of Agricultural Science Review 91: 128-137.

Wheeler,M.R.(1972). The Drosophila melanogaster species group. Univ. Texes publs Stud. Genet. 7(7213):1—102.

White, B. (2007). Antimicrobial activity of ginger against different microorganisms: *Physician*, 75: 1689-1691.

Wilson, C. R. (1994). Biological control. Page 28 In: Integrated control of common scab: A compilation of working documents by C. Wilson, D. Fulton & B. Pemberton.

Wilson, C.R., Ransum, L.M. & Pemberton, B. M.(1999). The relative importance of seed borne inoculum to common scab disease of potato and the efficiency of seed tuber and soil treatments for disease control. *Journal of Phytopathology* 147: 13-18.

Wood, R. K. S. and Tveit, M.(1955). Control of plant diseases by use of antagonistic organisms. *Botanical Review* 21: 441-492.