A Review on Different Management Strategies to control Rhizoctonia Solani causing Black Scurf Disease Kuhn

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Abstract

Potato (*Solanum tuberosum* Lin.) is one of most important food crops and can be used in human nutrition as a low-cost energy source. It is an affordable food with significant content of starch, minerals, vitamin C and B, and amino acids. Potato is a very important vegetable crop throughout the world while in Africa total production in 201 9 was 26.5 million tons harvested from approximately 1.76 million hectares. Potassium is an important macro nutrient for vegetable crops including potato because plant requirements for K are higher than any other macro nutrient after nitrogen. However the production and output of potato have been threatened by black scurf disease caused by *Rhizoctonia solani*. Evidence of the negative effects of this fungal disease of potato is enormous in major potato growing zones in the world, particularly in temperate regions. The management of *R. solani* is difficult due to its soil-borne nature. The fungus is present in most of the soils. Once it becomes established in a field it remains viable there indefinitely. Dry sclerotia of the pathogen are reported to survive up to six years when stored at room temperature. Soil-borne inoculum of *R. solani* is the main cause of black scurf on potato tubers and also contributes to eyes germination inhibition, sprouts killing, stem, stolon and root damage. The developing tips of sprouts are attacked by the fungus prior to emergence and when sprout tips are killed plants will often make multiple attempts to emerge Light brown to black lesions of varying size form on sprouts, stolons, roots and each of these organs may be girdled or killed by such lesions. It is one of the most serious potato diseases. Marketable yield losses of up to 30% are often cited although losses of 10 to 15% are more common.

Black scurf disease is control by different method like cultural practices, chemical method, biocontrol method and bioformulation method. Cultural control like disease-free propagation material, crop rotation, soil management and irrigation, cultivar resistance, timing of harvest and haulm destruction are important in reducing as well as managing black scurf disease. Chemical control most common and predominant method of disease control is chemical method because of its diverse use and ease of synthesis. Synthetic fungicides bring about the prohibition of pathogens through destroying their cell membrane or its permeability or by inhibiting metabolic processes of the pathogens and hence are highly effective. Chemically synthesized fungicides cause serious environmental problems and also poisonous to non-target organisms like earthworms, microbes and humans leading imbalances in the ecosystems. Plant based agrochemical could be an alternative, environmentally safe and economically viable strategy for the control of disease. Plant based products do not leave any toxic residues in soil, hence led to an increased use in agriculture that can effectively replace synthetic fungicides. Nanotechnology method can also useful for management of *Rhizoctonia solani.*

Keywords: *Rhizoctonia*; Fungicides; Bioformulation; Control method

Introduction

Potato (*Solanum tuberosum* L.) is the fourth important crop that has high nutritive value. India ranks second in terms of potato production after China, where potato is cultivated in the year 2018-19 on an average over 2.18 million ha with annual production of 52.58 million tonnes and productivity of 24.07 tonnes/ha (Horticulture Statistics Division, 2019). In India, potato cultivation is mostly concentrated in northern hills and plains, eastern hills, plateau region and southern hills. Among the states of India, Uttar Pradesh tops the chart in terms of potato area and production which is followed by West Bengals, Karnataka, Orissa, Rajasthan and Maharashtra (Horticulture Statistics Division, 2019). Potato (*Solanum tuberosum* L.) is one of the most important food crops after wheat, maize and rice, contributing to food and nutritional security in the world. This tuber crop of the family solanaceae has about 200 wild species. It originated in the high Andean hills of South America, from where it was first introduced into Europe towards the end of 16th century through Spanish conquerors (ICAR-central potato research institute, Shimla, HP, India). Potato is an economical food and a source of low-cost energy to the human diet. It is also used for production of hig h-quality starch, alcohol, etc. and its starch is used in laundries for sizing yarn in textile mills. It is also used for the production of dextrin and glucose. Potato tubers contain about 77.8% water, 22.6% carbohydrates, 2.1 % protein, 0.3% fat, 1.1% crude fibre, 0.9% ash, 40 IU vitamin A, 12 mg ascorbic acid per 100 g of edible portion etc. Potato also contains minerals and some phytochemicals such as carotenoid, natural phenols etc. The potato is good source for carbohydrate content. The predominant form of carbohydrate is starch. A small but significant portion of this starch is resistant to digestion by enzymes in the stomach and small intestine, and so reaches the large intestine essentially intact. This resistant starch is considered to have similar physiological effects and health benefits as fibre. It provides bulk, offers protection against colon cancer, improves glucose tolerance and insulin sensitivity, lowers plasma cholesterol and triglyceride concentrations, increases satiety, and possibly even reduces fat storage. (Fernandes *et al.,* 2005). A medium-size 150 g potato has 27 mg of vitamin C with the skin, and it also provide 620 mg of potassium (18% of DV), 0.2 mg vitamin B6 (10% of DV) and trace amounts of thiamine, riboflavin, folate, niacin, magnesium, phosphorus, iron, and zinc (Englyst *et al.,* 1992). This crop is highly susceptible to black scruf diseases caused by *Rhizoctonia solani.* The standard disease symptoms comprise decay of pre-emerging sprouts, blister on underground stem parts and stolen, reduced root systems and sclerotia formation on progeny tubers (typical black scurf symptoms). Tuber-borne sclerotia is formed on potato so decline the quality of potato tuber, number of tubers decrease, size of tuber reduces and the development of deformed tubers (Anderson, 1982; Frank, 1978, 1981; Hide *et al.,* 1973; Carling *et al.,* 1989;

Jeger *et al.,* 1996). This disease is soil borne disease as fungus forming mycelia and sclerotia remain in soil and also on residual plant material (Frank and Leach, 1980). According to Sharma (2015) *Rhizoctonia solani* causes yield loss up to 25% in the hill area while in plain, it causes about 10% yield loss in potato crop. Various methods are used for control black scurf disease like using good cultural practices, applying chemical fungicides, cultural control, disease-free propagation material, crop rotation, soil management and irrigation, cultivar resistance, timing of harvest and haulm destruction are important in reducing as well as managing of black scurf disease. Nel *et al.,* (2003) investigated antifungal activity of six chemical fungicides *i.e.,* pencycuron, iprodione, azoxystrobin, benomyl, and fludioxonil against *R. solani*. Among these chemical fungicides, Azoxystrobin registered for control of stem canker and black scurf, pencycuron registered for seed tuber treatment and fludioxonil registered for stem canker and black scurf treatment. Black scurf disease is also managed through eye/bud treatment with fungicides such as organomercurials benomyl, thiabendazole, carboxin, pencycuron, azoxystrobin and fenpiclonil (Welsh and Callaghan, 1996; Virgin-Callerus *et al*., 2000). Fungicides exhibit high and specific activity against *Rhizoctonia solani* and effective for control of black scurf (Yamada, 1986; Kataria *et al*., 1991; Thind *et al*., 2002). Boric acid and pencycuron are the two chemicals which are frequently used by Indian farmers to control black scurf (Khurana *et al*., 2001). Chemical treatment is very effective to control disease but overuse of most of the synthetic fungicides has created various types of environmental and toxicological problems (Gurjar *et al.,* 2012. Hence there is a need to search for an environmentally safe and economically viable strategy for the control of diseases and to reduce the dependence on the synthetic agrochemicals. Therefore present time focus is shifting towards the biological control of plant diseases and biological control programs (Myers and Bazely, 2003, Seastedt, 2015). The natural plant products are sources of new agrochemicals which are useful for control of plant diseases (Kagale *et al.,* 2004, Maya and Thippanna, 2013). Plant based products could be an alternative, environmentally safe and economically viable strategy for the control of disease. Plant based products do not leave any toxic residues in soil, hence led to an increased use in agriculture that can effectively replace synthetic fungicides. The main aim of this review is to discuss economic importance of black scurf disease of potato and its management strategies.

Distribution of *R. solani* on Potato

This disease is reached up to 25% of the yield in western countries and almost 50% in developing countries (Bowyer, 1999). According to Sharma (2015) *Rhizoctonia solani* causes yield loss up to 25% in the hill area while in plain, it causes about 10% yield loss in potato crop. Black scurf disease of potato is becoming prominent in many potato growing districts of Gujarat state which reduce quality and market value of the produce, resulting in economic losses of potao by black scurf at Potato Research Station, S.D. Agricultural University, Deesa (Gujarat). Potato is grown in diverse environmental tropical and subtropical conditions in Brazil, most of them conducive to diseases due to continuous cropping, the potato is subject to attack by several fungal pathogens, including *Rhizoctonia* species (Dias *et al*., 2016). The pathogen is widespread in all potato growing countries around the world (Anderson, 1982; Powelson *et al*., 1993; Jeger *et al*., 1996). In recent years, it has become the most important potato disease in Israel resulting in considerable economic losses (Tsror *et al*., 1993).

Host range

Rhizoctonia solani attacks members of the Poaceae (e.g., maize, rice, wheat, barley, oat), Fabaceae (e.g., soybean, peanut, dry bean, alfalfa, chickpea, lentil, field pea), Solanaceae (e.g., tobacco, potato), Amaranthaceae (e.g., sugar beet), Brassicaceae (e.g canola), Rubiaceae (e.g., coffee), Malvaceae (e.g. cotton), Asteraceae (e.g., lettuce), Araceae (e.g. pothos), Moraceae (e.g. ficus) and Linaceae (e.g. flax) family. Symptoms on diverse hosts include seed rot, root rot, hypocotyl rot, crown rot, stem rot, limb rot, pod rot, stem canker, black scurf, seedling blight, and pre- and post-emergence damping off. Seedling disease symptoms on soybean range from seed rot and preemergence damping off, especially under high inoculum density, to root or hypocotyl rot, depending on which anastomosis group is present at the time of infection

Alternative hosts can support the long survival of *R. solani* in plots where potatoes are grown. *R. solani* AG-3 has been isolated from the roots of barley (Murray, 1981), flax (Anderson, 1977) and sugar beet (Windels and Nabben, 1989). In pathogenicity trials, many other crops were susceptible to AG-3 isolates including buckwheat, carrot, cauliflower, lucerne, oats, radish, clover, tobacco, tomato, wheat, bean, lettuce, maize, onion, sweet clover and sunflower (Carling *et al.,* 1986). In addition, *R. solani* AG-3 has been isolated from the roots and stems of many weeds prevailing in potato fields in Spain (*Chenopodium album, Diplotaxis eurocoides*, *Solanum nigrum,* and *Sorghum halepense*) (Bakali *et al.*, 2000) and from additional wild plants in the Netherlands (*Capsella bursa-pastoris*, *Cirisum arvense*, *Elytrichia repens*, *Fumaria officinalis*, *Matricaria recutita*) (Jager *et al.,* 1982). In a survey in Colorado Oshima *et al.,* (1963) found the weeds *Amaranthus retroflexus, Chenopodium* spp. and *Portulaca olerecea* collected from potato fields to be frequently colonized by *Rhizoctonia* spp.

The large spectrum of alternative hosts that can be either *R. solani* infected with symptoms or latently infected has to be considered in the integrated management of the disease e.g., by crop rotation and sanitation.

Table-1: List of various diseases caused by *Rhizoctonia Solani*

S.No.	Fungus Name	Host	Disease	References
1.	*Rhizoctonia Solani*	Rice	Sheath blight disease	Lee, & Dai, 2009
2.	*Rhizoctonia Solani*	Cucumber	Damping-off diseases	Decurtis *et al.,* 2010

3.	*Rhizoctonia Solani*	Tobacco	Damping-off diseases	Miniagri, 2016
4.	*Rhizoctonia Solani*	Soybean	Damping-off, root and hypocotyl rot, and foliar blight	Embrapa, 1999
5.	*Rhizoctonia Solani*	Tomato	Damping off and/or root rot	Montealegre *et al.*,2003
6	*Rhizoctonia Solani*	Maize	Sheath blight disease	Madhavi *et al.*, 2018
7.	*Rhizoctonia Solani*	Okra plant	Seed rot disease	Asmaa *et al.*, 2020
8.	*Rhizoctonia Solani*	Sugar beet	Seed rot, Seedling death and Root rot	Baldawy *et al.*, 2021
9.	*Rhizoctonia Solani*	Cotton	Damping off	Matloob *et al.*, 2021
10.	*Rhizoctonia Solani*	Snap bean	Root and hypocotyl diseases	Sumner *et al.*,1992

Disease symptoms

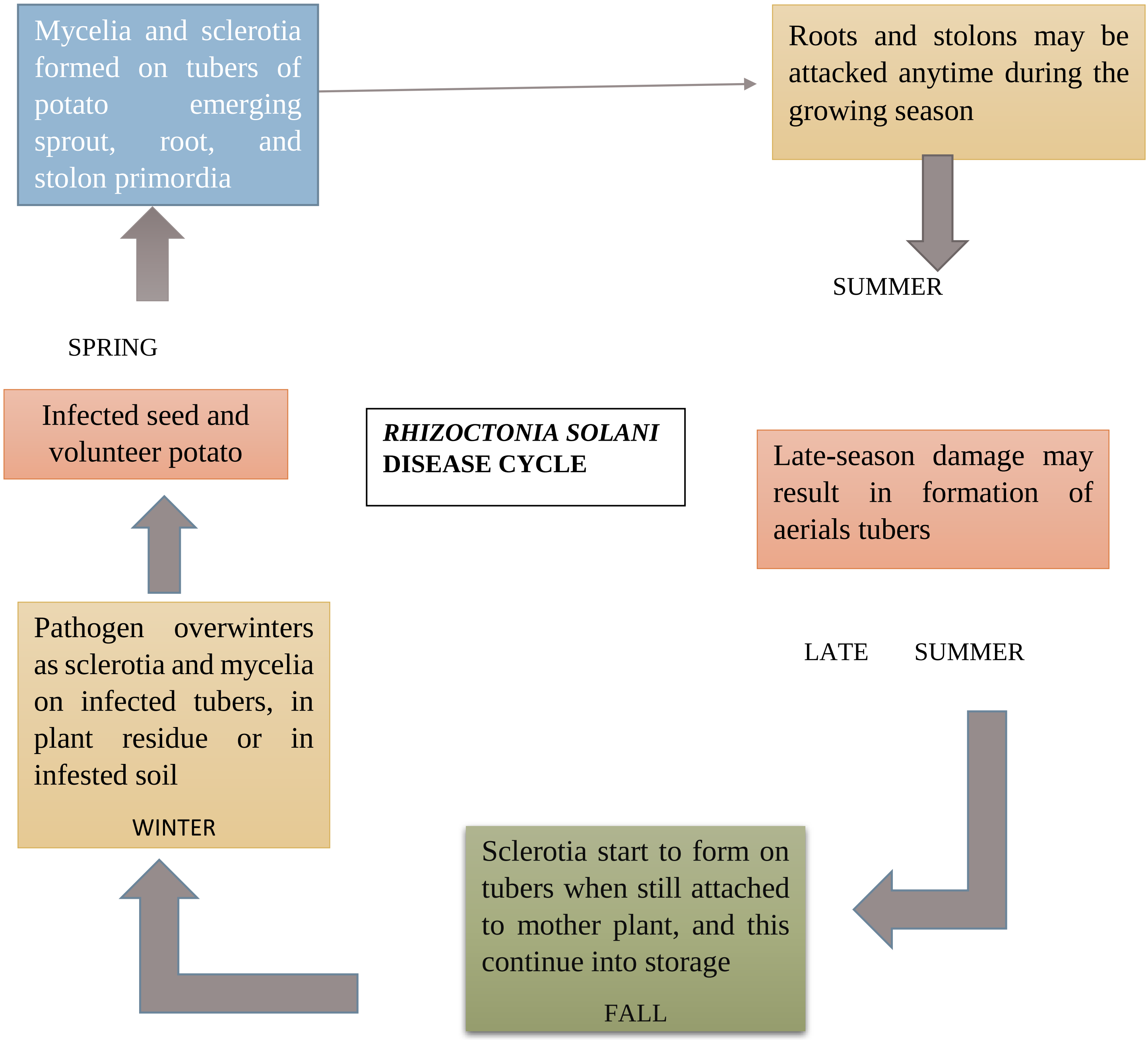
Symptoms of *Rhizoctonia* disease complex are observed on below- and aboveground plant parts in two phases: infection of growing plants (stem canker) and infection of tubers with the formation of sclerotia (black scurf). Black scurf, which is the most conspicuous sign of *Rhizoctonia* disease develops later in the growing season and is characterized by the formation of black, irregular sclerotia of various sizes on the tuber. An alteration in the lesion area size and number of infected tubers can occur, and in severe infections, tubers can be malformed and cracked (Hide *et al.,* 1973; Frank and Leach, 1980; Anderson, 1982; Banville, 1989; Carling *et al.,*1989; Jeger *et al.,* 1996). Symptoms of stem canker, occurring early in the season, include necrotic lesions on sprout tips that may inhibit or delay emergence, causing poor and uneven stands with weakened plants. Brown, dry and usually sunken lesions may also develop on stems, stolons and roots (Baker, 1970; Banville 1978). Brown cankers formed on stem bases, girdle the stems and cause stunting. Aboveground symptoms include chlorosis and purpling of leaves (Hartill ,1989). In severe infection, small, green aerial tubers may be formed on the stem above the soil. The stems become resistant to infection after emergence (Van Emden, 1965). Another symptom of the *Rhizoctonia* disease complex is white collar, caused by the teleomorph *T. cucumeris* (Banville and Carling, 2001). A superficial white-grey powdery collar may develop at the stem base near the soil line. The role of the sexual form of the fungus in the disease epidemiology is unclear (Jeger *et al.,* 1996).

The *Rhizoctonia* disease complex can cause both quantitative and qualitative damage to potato crops. Quantitative losses occur due to infection of the stems, stolons and roots which affects tuber size and number (Carling *et al.,* 1989; Platt, 1989), whereas qualitative losses occur mainly through the production of misshapen tubers and the development of sclerotia on the tuber surface (James and McKenzie, 1972). *Rhizoctonia* potato has been reported to cause marketable yield losses of up to 30% (Weinhold *et al.,* 1982; Banville, 1989; Platt *et al.,* 1993). Disease severity is not always associated with yield reduction; however, formation of tuber-borne sclerotia downgrades tuber quality, causing the development of malformed tubers and an alteration in their target size and number (Hide *et al.,* 1973; Frank and Leach ,1980; Anderson,1982; Carling *et al.,* 1989; Jager *et al.,* 1991; Jeger *et al.,* 1996; Tsror and Peretz, 2005). Initial infection of sprouts prior to emergence causes lesions and may be lethal to the sprout or sprout tip. As a result, it is possible that new compensatory sprouts emerge successfully with no significant damage (Lehtonen *et al.,* 2008b). Late in the growing season during periods of cool wet weather during midseason under a dense canopy of foliage, the teleomorph stage of the fungus may develop a white, powdery mould growth on stems, extending just above the soil line. Potato plants affected at this stage are characterized by a lack of vigour because much of their energy has been used to produce secondary or tertiary sprouts before a plant emerges. Sometimes, heavily infested seed will not produce an above ground plant. Instead, it will produce a stolon with several small tubers. Stolons and roots, like sprouts can be killed by the pathogen. The root system is reduced when this occurs. The number, shape and size of tubers produced are also affected when the roots and stolons are attacked. However, the health of these plants can be severely compromised and they can frequently become more susceptible to other diseases, particularly early blight. Tubers are affected in many ways by this pathogen. The main symptom observed is the black sclerotia on the surface, thus the name black scurf. These sclerotia are not easily removed with water and are often referred to as the ‘‘dirt that won’t wash off’’. They do not affect the interior of the tuber. Other tuber symptoms include necrosis in stem apex, russeting, cracking, knobbiness, infected lenticels and malformed tubers. Both phases of this disease result in the reduction of marketable yield. Seed tubers infested with sclerotia and mycelium are major sources of inoculum for future crops. Disease development on emerging sprouts is favoured by cold, wet soil conditions.

These conditions slow sprout development but favour germination of sclerotia and infection causing cankers to develop on young, under-developed tissues. Tuber-borne inoculum is very important in this phase of the disease while soil-borne inoculum is believed to be generally more important in stem and stolon infections. When stolons become pruned, the secondary stolons are generally weaker and much shorter in length. Tubers produced on these shorter stolons are generally the ones that become misshapen because they tend to grow around the plant stem.

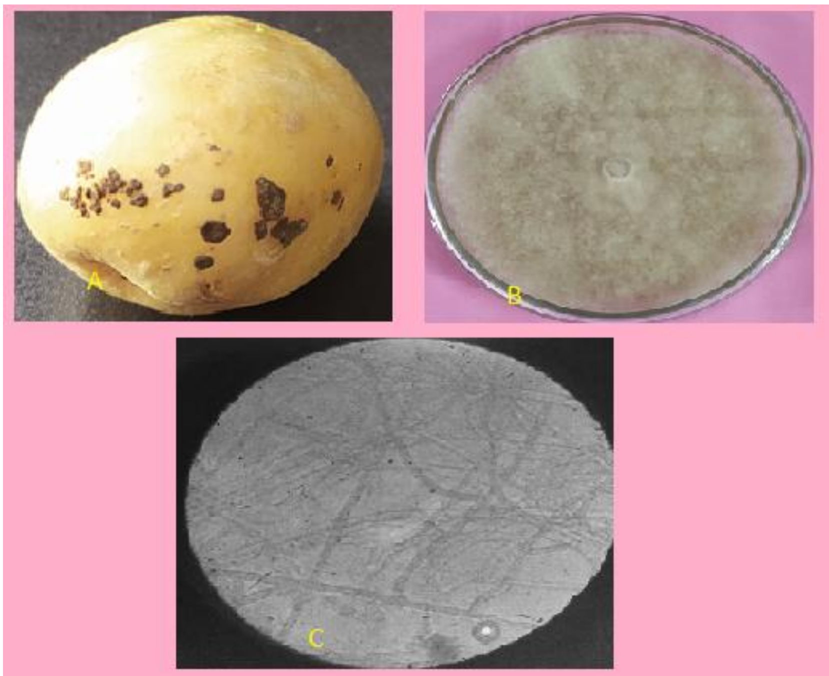
Mode of transmission and establishment of disease

During the cycle of disease the perfect and imperfect form of fungi co-exist. The anamorphic *Rhizoctonia* form emerges from germination of sclerotia or mycelium on the seed tuber producing the hyphae attacking sprouts, stolons and new daughter tubers. When the temperature and moisture conditions are optimal the teleomorph appears on stems under the foliage. The mycelia form a conglomerate with basidia and basidiospores. This phase is short, approximately 2 weeks. *R. solani* can be either a soil-borne or a seed-borne pathogen. The fungus survives in soil as mycelium in decomposing plant tissues. It also survives as sclerotia on tuber surfaces (seed-borne) or in the soil for extended periods. Populations of *R. solani* decline in the absence of a susceptible host although the rate of decline is affected by soil type, rotational crops and possibly the amount of organic matter present in the soil. Black scurf is the most noticeable sign of *Rhizoctonia.* But the most damaging phase of the disease occurs underground and often goes unnoticed. The fungus attacks underground sprouts before they emerge from the soil. Stolons that grow later in the season can also be attacked. The damage varies the fungal lesions, or canker, can be limited toa superficial brown area that has no discernible effect on plant growth. Severe lesions are large and sunken, as well as necrotic. They interfere with the normal functioning of stems and stolons in translocating starch from leaves to storage in tubers. If the fungal lesion expands quickly, relative to the growth of the plant, the stolons or stem can be girdle and killed. Damage is most severe at cold temperatures, when emergence and growth of stem and stolons from the tubers are slow relative to the growth of the pathogen. Soils also contribute to damage because they warm up more slowly than dry soils and excessive soil moisture slows plant development and favours fungal growth. If Rhizoctonia damage is severe and lesions partially or completely girdle the shoots, Sprouts may be stunted or not emerge above the soil. Tubers forming on diseased stolons may be deformed. If stolons and underground stems are severely infected with Rhizoctonia canker, they can not carry the starch produced in the leaves to the developing tubers. In this case, small, green tubers, called aerials tubers may form on the stem above the soil. Formation of aerial tuber may indicate that the plant has no tubers of marketable quality below ground. The *Rhizoctonia* fungus overwinters in propagules and in the soil as mycelia and/or sclerotia, which serve as inoculum for the subsequent crop (Tsror *et al.*, 2010). When *Rhizoctonia* sclerotia and/or mycelia are present on seed tubers, they serve as a primary inoculum source for disease epidemics and act as a mechanism for long-distance dispersal of the pathogen to other potato growing regions (Tsror *et al.*, 2010).



Identification

The defining characteristics of *Rhizoctonia solani* include septate hyphae, multinucleate cells in young hyphae, brown colouration of mature hyphae, right-angled hyphal branching, constriction at the point of branching, dolipore septa that permits unrestricted cell-to-cell movement of cytoplasm, mitochondria and nuclei, production of monilioid cells, sclerotia of uniform texture, Conidia, clamp connections, rhizomorphs, hyphal pigmentations other than brown, and sexual states. Identification is based mostly on vegetative characters (Moni *et al*.,2016; Desvani *et al*., 2018; Duggar, 1915 and Parmeter & Whitney, 1970). Septate multinucleate hyphae appear hyaline when young, but turn brown with age. Hyphal branch originates from distal dolipore septum with a characteristic constriction at the branching point. Desvani *et al*., 2018 was reported that Monilioid cells and sclerotia of uniform texture are usually produced by most but not all members of the species. Conidia, clamp connections, rhizomorphs, and cultural pigmentations other than brown are never observed. Basidiomal structure of sexual state is characterized by a vertically branching hymenium succeeded by layers of elongated basidia slightly wider than basal hyphae.



(A)Infected tuber
(B)*Rhizotonia solani* on Potato Dextrose Agar
(C)Mycelium of *Rhizotonia solani*

Management strategies for *R. Solani*

Effective management of this disease requires implementation of an integrated disease management approach and knowledge of each of its stages. Inoculum source and its impact on progeny tubers play an important part in strategies for controlling *R. solani* on potato. *R. solani* is a tuber- and soilborne pathogen (Frank and Leach 1980; Powelson *et al*., 1993). The ability to detect the presence of the pathogen in the crop or the soil, to determine threshold levels of inoculum and to investigate the relative importance of seed- and soilborne inoculum provides information on which disease management decisions can be based (Lees *et al*., 2002; Brierley *et al*., 2009). Although the most important measures are cultural, chemical controls can be utilized in some cases (Harrison *et al.,* 1970; Powelson *et al*., 1993; Wicks *et al*., 1995; Johnston, 1995; Loria *et al*., 1997).

1. **Cultural Methods**

The importance of cropping practices in the control of soilborne diseases has long been recognized. Disease-free propagation material, disease-free soil, crop rotation, haulm destruction, timing of harvest, soil management, irrigation and plant residues all have an influence on the *Rhizoctonia* disease development and crop quality and yield.

1) **Disease-free propagation material**

One of the keys to minimizing the *Rhizoctonia* disease complex is to use certified seed free of sclerotia. Planting clean seed tubers or tubers treated with antagonists or fungicides can be helpful in some situations. Therefore monitoring black scurf incidence on seed tubers can be the first stage in preventing the disease. To illustrate the problem black scurf was detected in most of the seed lots imported to Israel from northern Europe. On average 1% of the lots were contaminated at low moderate and high levels respectively and only 7% were disease free. Most of the domestic seed lots produced in Israel for the fall-winter crop were either disease free (45%) or had a low incidence of disease (37%). Only 17% of the lots were moderately infected and only 0.2% were highly contaminated (Tsror *et al*., 1999).

Inoculum density levels in soil can be used to as criteria in a risk-prediction system to decide control actions of *Rhizoctonia* diseases. Earlier specific primers had been developed for detecting *R. solani* AG-3 in soil by Lees *et al*., 2002). Recently improved DNA extraction techniques have become available for quantifying the pathogen level in soil (Brierley *et al.,* 2009). This advanced method enables our ability to study the relation between inoculum levels and disease expression which may result in a better management of the disease in the future.

2) **Crop rotation**

It is well recognized that monoculture should be avoided. Ideally three-year rotations or longer are often required to reduce damage caused by *R. solani* (Banville *et al.,*1996). The frequency with which potato is grown has a greater effect on *Rhizoctonia* diseases than crop rotation. An increased number of potato cropping cycles enhanced the incidence and severity of stem canker due to the increase in soilborne inoculum density (Scholte, 1992; Honeycutt *et al.,* 1996). Despite the fact that crop rotation is practiced to manage *Rhizoctonia* diseases an increase in the disease has been observed in potato fields (Celetti *et al.,* 1990; Errampalli *et al.,* 1999). In different 3-year cropping systems (soybean-canola, soybean-barley, sweet corn-canola, sweet corn-soybean, green bean-sweet corn, canola-sweet corn, barley-clover) followed by potato, compared with continuous potato growing, both rotation and cropping sequence were important in the microbial characteristics, soilborne disease and tuber quality (Larkin and Honeycutt ,2006). *Rhizoctonia* disease incidence and severity were reduced in most rotations, compared with the continuous potato, where canola, barley or sweet corn prior to potato had the lowest levels of *Rhizoctonia* disease and the best tuber quality (Larkin and Honeycutt ,2006). *Rhizoctonia* disease was aggravated by rotation with certain legumes, sugar beet and broccoli (Baker and Martinson,1970). Results from different crop-rotation programs vary greatly with respect to their effect on *Rhizoctonia* incidence (Carter *et al.,* 2003; Peters *et al.,* 2003). Economical rotation systems should be developed according to particular growing conditions.

3) **Timing of harvest and haulm destruction**

The harvesting methods used in potato production can affect the level of black scurf (Dijst *et al.,* 1986). The incidence of infested tubers increased with the length of interval between haulm destruction and harvest. Sclerotia production was stimulated similarly with individual practices of cutting off shoots, chemical haulm destruction and cutting off roots (Dijst, 1985). Fewer sclerotia were produced when roots were cut in combination with haulm destruction compared to haulm destruction alone. Green-crop harvesting (harvesting the immature crop mechanically and returning the tubers to the soil for a curing period of at least 10 days before final harvesting) and immature-crop harvesting (pulling haulms and collecting the tubers by hand) often result in a low level of black scurf (Mulder *et al.,* 1992; Lootsma and Scholte, 1996). Green-crop harvesting has the advantage of involving the application of fungicides or antagonistic organisms with the first lifting of the tubers resulting in effective control of black scurf (Mulder *et al.,* 1992). The accelerated development of black scurf after haulm destruction is due mainly to changes in the tubers' exudation of volatiles. Sclerotia production is directly affected by the tuber and probably by physiological changes in the tuber caused by elimination of the shoot (Dijst, 1985). Volatile products from decomposing potato roots and stolons and probably unstable substances in the tuber exudate as well further promote sclerotium formation (Dijst, 1990). Carbon dioxide (CO_2) might be an inhibitor based on a negative correlation between tuber respiration and black scurf formation. Quick separation of tubers from plant residues thus prevented accumulation of CO_2 may prevent the increase in black scurf development after haulm destruction (Dijst ,1990).

4) **Soil management and irrigation**

Practices that favour rapid emergence such as shallow planting and avoiding planting in cold, wet, heavy poorly drained soil, that increase the rate of emergence and reduce the risk of root and stem cankers (Jeger *et al*., 1996). High nitrogen and phosphorus levels in soil enhance black scurf incidence whereas low levels of potassium, sodium and calcium increased disease symptoms (Jeger *et al*., 1996). In areas where potatoes are irrigated pre irrigation of dry soils before planting is a recommended practice (Banville *et al*., 1996).

5) **Cultivar resistance**

The use of resistant cultivars would obviously improve the control of *R. solani* disease in the field. Although differences in susceptibility can be seen among cultivars, no resistant cultivars have been identified or developed (Jeger *et al*., 1996). Systemic induction of resistance in sprouts upon infection with virulent *R. solani* was recently demonstrated (Lehtonen *et al*., 2008b). The apical portion of the sprout also expressed resistance that inhibited secondary infection of the sprouts. These novel observations of pathogen defence in potato referred to the period before the plant emerges and becomes photosynthetically active (Lehtonen *et al*., 2008b).

2. **Chemical control**

The fungitoxic potential of different anti-*R. solani* fungicides against AGs is crucial for a successful disease control. *Rhizoctonia* diseases of potato are controlled by seed tuber or soil treatments. Because of different influence of fungicides on *R. solani* AGs a careful selection should be performed to obtain efficient control of the disease (Kataria and Gisi 1996, 1999). Fungicide treatments applied either on seed tubers or in the soil (as an in-furrow spray) may not provide effective control against soilborne inoculum especially when its initial levels are high (Jager and Velvis 1988; Wicks *et al*., 1995; Brewer and Larkin, 2005; Tsror and Peretz, 2005. Tube r borne *R. solani* is relatively easy to control compared with its soil borne counterpart because of its accessibility to control agents (Frank and Leach ,1980; Jeger *et al*., 1996). Seed treatments are applied by dressing (dusting) (Jager *et al*., 1991) or by spraying at low volume (Tsror and Peretz, 2005). Thus seed treatments may not provide complete control due to the presence of soilborne inoculum. In-furrow application of fungicide at planting resulted in significantly improved control of the disease. However on some occasions both seed treatments and in-furrow applications resulted in poor control. Conditions conducive to disease such as extensive periods of wet and cold soil shortly after planting may contribute to sporadic failures in control but the major constraints are the initial levels of the fungus on the seed tubers and in the soil. Various fungicides have been evaluated against black scurf and stem canker (Kataria and Gisi, 1996), e.g. pencycuron, fludioxonil, tolclofos-methyl, flutolanil, azoxystrobin, mancozeb, iprodione and imazalil. A preplanting combination of seed treatment with sodium hypochlorite and thiophanate-methyl reduced black scurf on progeny tubers (Errampalli and Johnston, 2001). Dusting tubers with tolclofos-methyl or spraying them with fenpiclonil or pencycuron gave control equal to that achieved by dipping in formaldehyde whereas a sodium hypochlorite dip was ineffective (Wicks *et al*., 1995). Soil treatment at planting with pencycuron resulted in lowest disease severity the following year (Lootsma and Scholte, 1996). Application of pencycuron combined with captan in furrow or as a seed dressing decreased the incidence and severity of black scurf and also significantly increased the yield whereas dip treatment of seed tubers was less effective (Tsror *et al*., 1996). Soil fumigation is prohibited in many countries and is usually not common in countries in which such fumigation is performed against other soilborne pathogens (e.g. *Verticillium dahliae* Tsror *et al*., 2005). Moreover growing concern over the risks of chemical pest control for human health and the environment emphasize the need for alternative disease-control strategies. For the control of *R. solani* on potato, soil fumigation is not commercially implemented. However methyl bromide was effective and alternatives which have been evaluated since its ban include methyl iodide, metham sodium, dazomet and chloropicrin: all were found to be equally effective (Ohr *et al*., 1996; Csinos *et al*., 1997). The management of *Rhizoctonia* disease requires an integrated approach and knowledge of each stage of the disease, because no single tactic is totally effective (Banville *et al*., 1997). Some potato varieties differ in their susceptibility to *Rhizoctonia* however, no resistant varieties are currently available. To date no variety has been found with immunity to the sprout nipping and stem lesion phase, although some varieties show varying degrees of resistance to formation of sclerotia on tubers. The sexual stage of *Rhizoctonia solani* seen as a white mycelium (around) on lower parts of the stems' inoculum is more important than the soil inoculum as the primary cause of disease. Seed growers should certainly plant only sclerotia-free seed. Research performed at our institution has shown that sclerotia coverage of as little as 5% can significantly increase disease incidence and severity (unpublished data). *Rhizoctonia* stem canker can be reduced by practices that favour rapid emergence such as warming seed tubers before planting, avoiding planting in cold, wet, heavy, and poorly drained soils, which reduces the rate of sprout growth and encourages disease. Early irrigation, prior to emergence, should be kept to a minimum. However a fungicide seed treatment will usually not be beneficial if the soil is infested with high levels of the *Rhizoctonia* fungus. No seed treatment will compensate for poor quality seed. Crop rotation with corn, grasses, cereals, and non-susceptible crops for *Rhizoctonia* is helpful as is good rotation. At a minimum two consecutive seasons of potatoes on the same land should be avoided. If the disease has been severe, 3-5 years should elapse between potato crops this reduces both the incidence and severity of the disease. Increasing the rate of crop residue decomposition and the amount of organic matter in the soil decreases the growth rate of *Rhizoctonia* which does not compete well with other microbes in the soil. Since young developing potato crops are more susceptible to injury by *Rhizoctonia* all practices that encourage rapid emergence and plant development will reduce disease severity. Potatoes planted into soils with excessive amounts of residue from a previous crop such as corn tend to have serious *Rhizoctonia* problems.

The overuse of most of the synthetic fungicides has created various types of environmental and toxicological problems (Gurjar *et al.,* 2012). Hence there is a need to search for an environmentally safe and economically viable strategy for the control of diseases and to reduce the dependence on the synthetic agrochemicals. Therefore present time focus is shifting towards the biological control of plant diseases and biological control programs (Myers and Bazely, 2003, Seastedt, 2015). The natural plant products are sources of new agrochemicals which are useful for control of plant diseases (Kagale *et al.,* 2004, Maya and Thippanna, 2013). Plant based agrochemical could be an alternative, environmentally safe and economically viable strategy for the control of disease. Plant based products do not leave any toxic residues in soil, hence led to an increased use in agriculture that can effectively replace synthetic fungicides. For control of plant disease various traditional agriculture practices are used that require approval, such as use of organic materials (cow dung, oil cakes, etc.).

3. Biological control

Antagonists

Suppression of *R. solani* has been achieved with various fungi and bacteria like Actinomycetes, *Bacillus*, fluorescent *Pseudomonas* as well as nematodes (Escande and Echandi, 1991; Tuitert *et al*., 1998). In-furrow treatment of *T. harzianum* was more efficient than broad application. The effect of antagonistic *T. harzianum* on the dynamics of soil borne *R. solani* on individual potato plants has been recently reported (Wilson *et al*., 2008). *T. harzianum* reduced the severity of stem lesion symptoms during the first 7 days post inoculation, but later, the antagonistic effect was overcome. Also the severity of black scurf on progeny tubers was reduced, and there were fewer malformed and green-coloured tubers in pots treated with *T. harzianum* than in the controls. *Verticillium biguttatum* Gams, a specific antagonist of *R. solani* (Boogert *et al*., 1989) has the potential to control *Rhizoctonia* diseases in potato (Jager *et al*., 1991) as it suppresses the production of sclerotia. As a biotrophic mycoparasite, *V. biguttatum* penetrates the hyphae of *R. solani* and forms haustorium-like branches without killing the host cells the haustoria support the mycoparasite’s external mycelial network. Later when the mycoparasite sporulates the infected host cells die (Van den Boogert and Deacon ,1994). There was a close relationship between the population dynamics of the mycoparasite and its host fungus. An increase in *R. solani* was followed by an increase in *V. biguttatum* depending on the initial soil population densities, temperature and soil type. A positive correlation was observed between the host fungus population density and the parasitized fraction, suggesting that *V. biguttatum* causes population-density-dependent mortality.

In the absence of the host plant mycoparasitism plays only a minor role in regulating *R. solani* as contact between the host and the mycoparasite cannot be established (Van den Boogert and Velvis, 1992). Micropropagated plants inoculated with *Glomus etunicatum* exhibited a significant reduction in *Rhizoctonia* ranging between 60.2 and 71.2%, on both shoots and crowns, as well as a significant increase in shoot fresh weight, root dry weight and number of tubers produced per plant in greenhouse experiments. *Glomus intraradices* only significantly increased the number of tubers (Yao *et al*., 2002).

4. Antifungal activity against *Rhizoctonia Solani*

Somani *et al.,* 2009 was reported that Antifungal effect of *Chlorella vulgaris* extract against *Rhizoctonia solani* was evaluated *in vitro*. Azhar *et al.,* 2014 was reported the antifungal efficacy of six botanical extracts like Cannabis *sativa, Peganum harmala, Datura starmonium, Artemisia brevifolium, Capparis spinosa, Mentha royleana* and two bioagents *viz., Trichoderma harizanum and Trichoderma viride* were evaluated *in vitro* against *Rhizoctonia solani* causing black scurf of potato through food poison and dual culture technique. According to Othman, 2012 antifungal activities of five plant species (*Thymus vulgaris, Lavandula vera, Menta viridis, Rosmarinus officinalis* and *Cassia italic*) extracts were tested against *Rhizoctonia solani* using three different solvents (methanol, acetone and chloroform). Atiq *et al.,* 2014 evaluated that plant extracts *Azadirachta indica, Alliums ativum, Eucalyptus camaldulensis, Allium cepa* and *Peganum harmala* showed antifungal effect on the black scurf disease of potato. Harnessing a cost-effective management of this pathogenic fungus three botanical species *Acalypha wilkesiana, Moringa oleifera* and *Carica papaya* leaves were evaluated *in vitro*. The plant leaf extracts were prepared using methanol and were evaluated for their toxicity using agar well diffusion method evaluated by Adebola *et al.,* 2020. Kordy *et al*.,2021 was conducted to study the effect of clove extract for controlling *R. solani*. Six isolates were obtained from infected potato plants from different potato growing areas.

According to Kordy *et al.,* 2021 an experiment was conducted to study the effect of clove extract for controlling *R. solani*. Six isolates were obtained from infected potato plants from different potato growing areas. Askar *et al*., 2010 was reported that antifungal activity of ethanol-water extracts of four medicinal plants, cinnamon (*Cinnamomum verum* Presl.), anise (*Pimpinella anisum* L.), black seed (*Nigella sativa* L.) and clove (*Syzygium aromatic* L. Merr. & Perry.) against root-rot disease on pea caused by *Rhizoctonia solani.* The antifungal effect of forty-four plant extracts and eight plant oils against the pathogen *Rhizoctonia solani* was evaluated by disc diffusion method. Out of forty-four plants tested thirty six plant extracts showed varied degree of antimicrobial effect at different concentrations against the pathogen where eight plant extracts, viz. *Abrus precatorious, Acacia auriculiformis, Bougainvillea glabra, Convolvulus arvensis, Hibiscus rosa-sinensis, Morus alba, Thevatia peruviana, and Withania somnifera*.

Table no. 2 Antifungal activity of various plant extract against *Rhizoctonia solani*

S.No.	**Fungus Name**	**Host**	**Plant Extract of Different Plants**	**References**
1.	*Rhizoctonia Solani*	Potato	*Carthamus oxycantha*	Rafiq *et al.,* 2021
2.	*Rhizoctonia Solani*	Potato	Clove	Kordy *et al.*, 2021
3.	*Rhizoctonia Solani*	Potato	*Acalypha wilkesiana*, M*oringa oleifera* and C*arica papaya* leaves	Adebola *et al.*, 2020
4.	*Rhizoctonia Solani*	Potato	*Azadirachta indica*, A*llium sativum*, E*ucalyptus camaldulensis*, A*llium cepa* and P*eganum harmala*	Atiq *et al.*, 2014
5.	*Rhizoctonia Solani*	Potato	*Tthymus vulgaris, Lavandula vera, Menta viridis, Rosmarinus officinalis* and *Cassia italic*	Othman, 2012
6.	*Rhizoctonia Solani*	Potato	Cannabis *sativa, Peganum harmala, Datura starmonium, Artemisia brevifolium, Capparis spinosa, Mentha royleana* and two bioagents *viz., Trichoderma harizanum and Trichoderma viride*	Azhar *et al.,*2014
7.	*Rhizoctonia Solani*	Potato	*Chlorella vulgaris*	Somani *et al.*, 2009

Hada and Sharma (2017) prepared bioformulation by combining *Cassia fistula* fruit pulp extract with the neem oil cake and cow dung to which found to be effective for control of early blight of potato caused by *Alternaria solani*. Review of literature suggests that several reports are available on the antifungal activity of plant extracts, various elicitor (ground nut oil cake, mustard oil cake, cotton oil cake, clove bud oil cake, coconut oil cake, neem oil cake and seasame oil cake) and binders (guar gum, gum acacia and cow dung) separately or individually (Ye and Ng 2001; Davin and Lewis, 2003; Harish *et al.,* 2008; Benko and Crovella, 2010; Hassan *et al.,* 2010 *;* Mandal 2011; Swati *et al.,* 2015; Rajeswari *et al.,* 2016; Modi *et al.,* 2017; Meena *et al.,* 2020).

CONCLUSION

Potato is the fourth most important vegetable crop in terms of quantities produced and consumed worldwide. However its production is currently threatened by a number of biotic and abiotic constraints. Potato black scruf disease caused by *Rhizoctonia solani* is the major bottleneck in potato production in the world as well as in Ethiopia. The disease can damage both stem and tubers. The disease can causes yield losses of 25-50%. Black scruf is a poly cyclic disease that can cause more than one disease epidemics within a single cropping season. It is difficult to control because of its capacity to produce huge amounts of secondary inoculum. Since the disease is very important in causing economic losses of yields on potato crop developing and using effective and appropriate management options is unquestionable. Using good cultural practices and applying chemical fungicides are important in reducing as well as managing of black scurf disease of potato. Different methods for diminishing and controlling the infection rate by phytopathogenic fungi penetrating through the root system including both the traditional use of biocontrol agents such as antifungal compounds as well as some new strategies that could be used because of their effective application. Even though there is no well-developed plant-based products are used for control of black Scurf it is very important to develop such management strategies. A strategy search for the control of diseases which are environmentally safe and economically viable has led to an increased use of plant-based products in agriculture. Any toxic residues do not leave by plant product and bio–agents hence can effectively replace synthetic fungicides. Because bioformulation measures are specific, efficient and environmentally safe.

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