Rhizoctonia solani in potatoes and its control

Specific recommendations for seed potato production in Punjab (India)

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Praktijkonderzoek Plant & Omgeving, part of Wageningen UR
Business Unit AGV
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Applied Plant Research (Praktijkonderzoek Plant & Omgeving), part of Wageningen UR
Business Unit for Arable farming, Field production of vegetables and Multifunctional agriculture (PPO-agv)

Address	:	P.O. Box 430, 8200 AK Lelystad, The Netherlands
	:	Edelhertweg 1, 8219 PH Lelystad
Tel.	:	+31 320 291111
Fax	:	+31 320 230479
E-mail	:	infoagv.ppo@wur.nl
Internet	:	www.ppo.wur.nl

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1 Preface

During visits of Wageningen UR researchers to potato production fields in Punjab (India) in 2013 and 2014, it appeared that many plants had severe incidences of *Rhizoctonia solani*. *Rhizoctonia* has become a serious problem in the Punjabi seed potato production system. This report summarizes information on *Rhizoctonia* and its control.

2 Description of the disease

Rhizoctonia solani (Thanatephorus cucumeris) is a fungus which is causing damage to many crops. The fungus is divided into subgroups called anastomosis groups (AGs), in which isolates are categorized according to the ability of their hyphae to anastomose (fuse) with one another. The most well-known anastomose groups are AG-2, AG-3 and AG-4. AG-3 is relatively specific to potato, and sclerotia on tubers belong almost exclusively to AG-3. Other AGs may be pathogenic to potato at some temperatures, but they generally cause little damage.

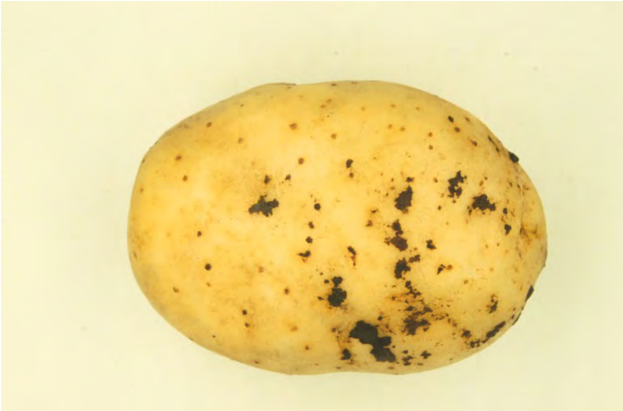
Rhizoctonia diseases are initiated by seed-borne or soil-borne inoculums. The fungus survives in the form of sclerotia and mycelium on infected tubers, in plant residue or in infested soils. Both mycelium and sclerotia may become destroyed by soil inhabiting micro-organisms, insects (springtails) and nematode species. In absence of a host plant, the density of the pathogen decreases significantly. Because of its capacity of rapid growth, however, the population can quickly recover if a suitable host is available. Most damage is caused at temperatures below 10 °C and above 24 °C. Under these temperature conditions it takes the sprouts longer to emerge, and consequently the fungus has the opportunity to infect the underground shoots. Susceptibility of the plant tissue decreases quickly when shoots emerge and chlorophyll is formed. Cool temperatures, high soil moisture, fertility and a neutral to acid soil (pH 7 or less) are thought to favor development of *Rhizoctonia* diseases of potato.
When infected seed tubers are planted, the fungus grows from the seed surface to the developing sprout, and infection of root primordial, stolon primordia and leaf primordia can occur. Infection is also possible from soil-borne inoculum. Roots and stolons may be attacked anytime during the growing season. However, most infections probably occur in the early part of the plant growth cycle. The plant's resistance to stolon infection increases after emergence, eventually limiting expansion of lesions. At the end of the growing season, especially after vine death, sclerotia are formed on the daughter tubers. The mechanisms that trigger sclerotial formation are not well understood, but they may involve products related to plant senescence. However, daughter tubers produced from infected mother plants do not always become infested with sclerotia. Sclerotial formation can continue during storage, especially if too much soil is present.
Rhizoctonia can cause considerable damage to the crop. After emergence infected sprouts may die and as a consequence crop stand will be poor. Infection of young stolons may cause their tips to die and as a consequence the numbers of tubers may decrease. Multiple branching of stolons may occur, which lead to tuber formation near the stem, resulting in nests of small, deformed tubers at or just above soil surface. These tubers cannot be sold. Also tubers in the soil can show a lot of deformations and cracks. Presence of sclerotia on the tubers is downgrading tuber quality, especially in seed potato production. *Rhizoctonia* potato disease can cause marketable yield losses up to 30% (Tsror, 2010).

3 Symptoms

Symptoms of *Rhizoctonia solani* are described by Mulder and Turkensteen (2005). Symptom descriptions in this chapter are mainly based on this publication.

3.1 Black scurf on tubers

Black scurf is the best known symptom of *Rhizoctonia* in potatoes. On the skin of the tubers dark, crust-like structures are present. They can be observed easily after washing. Washing should be done carefully, otherwise black scurf is removed. They can be easily removed with the fingernail. The distribution of black scurf on the tuber and the size of the sclerotia may vary. Usually, the individual sclerotia are 1 mm to 5 mm thick and 1 mm to 10 m long, but sometimes an entire tuber or part of it is covered by a black crust. Black scurf is developing on the tubers especially after haulm killing and it can continue during storage. Some varieties show varying degrees of resistance to formation of sclerotia on tubers (Johnson and Leach, 2003).



Pictures 1. Black scurf on harvested tubers in a field in Punjab, 26 January 2014. Picture 2. Black scurf in the Netherlands.

3.2 Damaged young sprouts, poor crop stand

Subterranean penetration of developing sprouts is causing considerable damage to the crop. On the young sprouts reddish-brown to grey, distinctly sunken lesions could be observed. With the aid of a magnifying glass, many dark brown, long hyphae can be seen on the lesions. Lesions can girdle the young sprout completely, causing the part above the lesion to die. Secondary sprouts are often formed below the affected area. If these secondary sprouts also become infected, tertiary sprouts may be formed from non-affected lower buds. This process may be repeated several times. As a consequence, sprouts will fail to emerge or will wilt after emergence. This is causing uneven and irregular emergence and, in severe cases, may lead to a poor crop stand. These symptoms can easily be confused with those of calcium deficiency. However calcium deficiency causes lesions directly below the top, which are not sunken. Poor stands may also be mistaken for seed tuber decay caused by *Fusarium* or soft rot bacteria unless plants are dug up and examined. *Rhizoctonia* does not cause seed decay, damaging only sprouts and stolons. Poor stands and stunted plants can also be caused by blackleg, a bacterial disease that originates from seed tubers and progresses up stems, causing a wet, sometimes slimy rot. In contrast, *Rhizoctonia* lesions are always dry and usually sunken.

Picture 3. Damaged young sprouts in a field in Punjab (India; November 2013). Picture 4. Damaged young sprouts in the Netherlands.

3.3 White fungus sheets and lesions on stems and stolons

At the base of the stems and on the stolons reddish-brown to brown lesions could be seen. As these lesions mature, they become cankers that are rough and brown and can have craters, cracks or both. At the base of the stem and on the parts of the plant that are in contact with soil a white fungus sheet can be formed. These sheets consist of greyish-white, felt-like mycelium. The sheet symptom of *Rhizoctonia* may be confused with an attack by *Rosellinia necatrix*. The *Rhizoctonia* sheets, however, are mostly on and just above soil surface, while those of *Rosellinia* are found just below soil surface.

Picture 5. Rhizoctonia lesion on an underground stem part; Punjab (India), November 2013. Picture 6. Rhizoctonia lesions on sprouts in the Netherlands.


Picture 7. White sheet on a stem; Punjab (India), November 2013. Picture 8. White sheets on stems in the Netherlands.

3.4 Tuber formation near the stem and nests of small, deformed tubers

Infection of young stolons causes their tips to die. One of the consequences of this may be a drop in the number of tubers. Another possible consequence is multiple branching of the stolons, which may lead to tuber formation near the stem, resulting in nests of small, deformed tubers at or just above soil surface. These symptoms are often confused with those caused by pink rot and phytoplasmas. In case of *Rhizoctonia*, however, these symptoms are accompanied by underground stem infection.

Picture 9. Nests of small, deformed tubers (the Netherlands).

3.5 Stunting and rosetting of plant tops

Infection of the stem causes stunting and rosetting of plant tops (curled leaves), which sometimes turn red or yellow. Sometimes the affected plants are more erect than the unaffected plants. Curling of the leaves could be confused with symptoms of potato leaf roll virus (PLRV). However, PLRV symptoms appear at the lower plant parts while *Rhizoctonia* caused curling is in the upper plant part.

Picture 10. Stunting and rosetting of plant tops; curled leaves (Punjab, December 2013).

Picture 11. Erect plants and curling of top leaves (Punjab, December 2013).

3.6 Aerial tubers

The interference of carbohydrate movement may also cause the formation of aerial tubers in the leaf axils of stems. These are green to reddish-purple round to bottle-shaped transformations of lateral shoots in the axils, with a few small leaves at the top. Aerial tubers are not only caused by *Rhizoctonia*, but it could be also a result of damage to the stem caused by pests, machinery, wind, late blight, pink rot and phytoplasmas.

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Picture 12. Aerial tubers (the Netherlands).

3.7 Scab-like lesion on tubers, deformed and eyeless tubers, dry core symptom

On tubers large, scab-like lesions may develop. The fungus growing on the tuber surface retards the growth of the underlying tissues, which may result in deformed tubers. The typical scab-like structures on mature tubers are caused by the structure of the rectangular mycelium of Rhizoctonia solani (picture 13). Also growth cracks could be developed.

Picture 13. Typical rectangular mycelium growth of Rhizoctonia solani.

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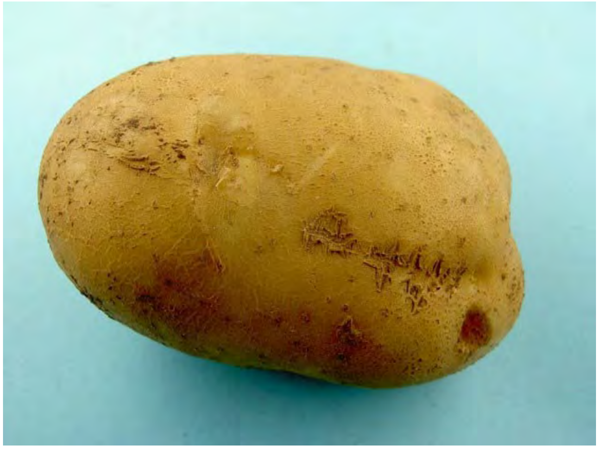
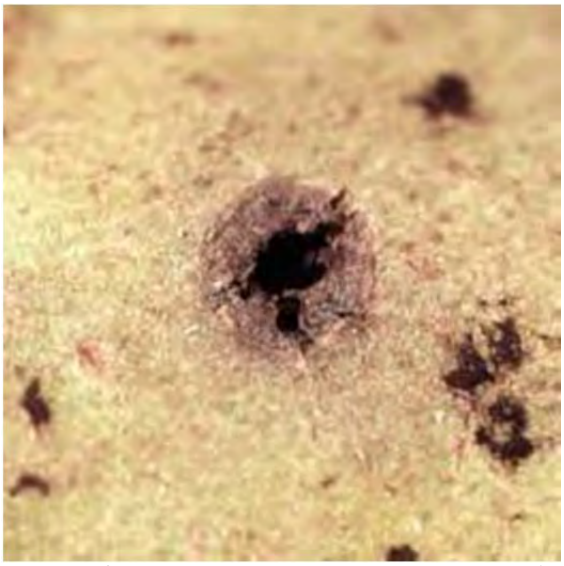
 

Picture 14. Scab-like symptoms, growth cracks and deformed tubers; (Punjab, February 1014). Picture 15. Slight symptom of Rhizoctonia solani (the Netherlands).

Rhizoctonia is sometimes causing small lesions with a relatively deep, dry core on the tubers. The lesion is characterised by the presence of a hole in the centre of the affected skin. The latter symptom may be confused with a wire worm infection. Infection of the initiating sprouts on the young tuber will result in eyeless or blind tubers, which do not sprout.

Picture 16. Dry core symptoms observed on the surface of the tuber. Picture 17. Dry core symptom observed after cutting the tuber (pictures from the Netherlands).


Picture 18. Eyeless or blind tuber (the Netherlands).

4 Host plants and crop rotation effects

Rhizoctonia is surviving in the soil in the form of sclerotia and mycelium. Mycelium is able to survive in dead plant cells. Planting potatoes too frequently in a crop rotation increases the risk of infection. In literature it is stated that three-year rotations or longer are often required to reduce damage caused by *Rhizoctonia*. The frequency of potato in a crop rotation has a larger effect on *Rhizoctonia* than crop rotation (Tsror, 2010).

In literature it is shown that AG-3 strains are specialized to potato, whereas strains of other less-specialized AGs of *Rhizoctonia solani* infect potato as an alternative host. AG-3 has been isolated from different other crops: barley, flax, sugar beet (Tsror, 2010). In pathogenicity trials, many other crops were susceptible to AG-3 isolates: buckwheat, carrot, cauliflower, alfalfa, oats, reddish, clover, tobacco, tomato, wheat, bean, lettuce, maize, onion, sweet clover and sunflower. In general, *Solanum* species are belonging to the host range for AG-3.

AG-3 has been isolated from various weeds: *Chenopodium album, Diplotaxis eurocoides, Solanum nigrum* and *Sorghum halepense*; and also from various wild plants: *Capsella bursa-pastoris, Cirisum arvense*, *Elytrichia repens, Fumaria officinalis and Matricaria recutita*. In Canada 56 weed species were found to harbour *Rhizoctonia* (Sturz et al., 1995).

In several parts of Punjab potato is planted after rice. Thind and Aggarwal (2008) found that isolates from potato and rice in Punjab were belonging to different anastomose groups: Potato isolates were belonging to AG-3 and AG-5 and rice isolates were belonging to AG-1 1A. Isolates from rice showed a varied degree of virulence on potato with some isolates unable to cause disease while others produced black scurf symptoms of different severity. However, the sclerotia formed by rice isolates on potato tubers were observed to be less firm and could be removed easily when washed in water indicating their weak pathogenic nature on potato. Sclerotia formed on tubers by potato isolates were more firm and were not removed easily while washing in water (cv. Kufri Jyoti).
From research in the Netherlands it is known that next to AG-3 also AG-5 and AG-2-2 are occurring in potato. Both, AG-5 and AG-2-2, are giving less sclerotia on the tubers than AG-3. Maize is a host for AG-2-2.

There is no specific information available about the effect of inundation, which is occurring during paddy, on *Rhizoctonia*. In literature, it is stated that *Rhizoctonia solani* is sensitive to CO_2 accumulation in soil, which occurs during periods of water retention (Wale, 2004). For obtaining a significant effect of inundation on *Rhizoctonia solani* at least a three weeks inundation period is needed (personal communication Lamers.) It is known that AG-3 is suppressed more by inundation than AG-2-2.

In 3-year cropping systems in Canada it appeared that canola, barley or sweet corn grown prior to potato led to lower levels of *Rhizoctonia* in potato than soybean, green bean and clover. *Rhizoctonia* disease was aggravated by rotation with certain legumes, sugar beet and broccoli (Baker and Martinson, 1970). In 2 – year cropping systems in Canada it appeared that potatoes grown after red clover were showing less black scurf than potatoes grown after barley or Italian ryegrass. Bains et al. (2002) found that sugar beet, *Brassica campestris*, barley, peas, wheat and maize could not be infected by potato isolates of *Rhizoctonia solani*, suggesting that these crops are acceptable choices as rotation crops.

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5 Control strategy in seed potato production

Currently, it is hardly possible to control *Rhizoctonia* completely. In the control strategy cultural measures and crop protection strategies should be combined: an integrated control is to be used. Monitoring of the disease level of seed potatoes and in the soil are important elements of the control strategy.

5.1 Strategy

Top quality seed potatoes must be disease free including free from *Rhizoctonia solani*. Basic seed is the core of each seed potato production system implying the seed grower must keep best seed and sell of poorest seed or sell of poorest seed as ware (fresh) potato. Additional seed disinfection and the selection of *Rhizoctonia* free production fields are elements of the same strategy. In the following paragraphs different measures are described for controlling *Rhizoctonia solani*.

5.1.1 Planting sclerotia free seed potatoes

One of the keys to minimize *Rhizoctonia* is to plant seed potatoes free from sclerotia (or most as free as possible). Tuber inoculum is more important than soil inoculum as the primary cause of *Rhizoctonia* damage. Monitoring black scurf incidence on seed tubers can be the first stage in preventing the disease. Based on knowledge of black scurf incidence of the seed lots it must be decided which seed lot should be planted or which seed lot should be sold as ware potatoes.
There are differences in viability of black scurf sclerotia. There are techniques available for testing the viability of black scurf.

5.1.2 *Rhizoctonia* free fields, crop rotation

Each potato field has a disease history, the farmer should be aware of such a history and use such knowledge strategically.
Fields free from *Rhizoctonia* inoculum are preferred. Advanced molecular techniques for detection of *Rhizoctonia* inoculum in the soil are available. With the aid of these techniques it will be possible to develop a decision support system to assist growers in the selection of fields to be cropped with potato. However, up till now there are no decision support systems which are used in practice (in the Netherlands).

In general, *Rhizoctonia solani* is occurring more on light sandy soils than on clay soils or soils with a high organic matter content. A high frequency of potato in crop rotation will promote *Rhizoctonia solani*. It is not known very well which crops should be preferred to be grown before potatoes. In general, *Solanum* species should be avoided if AG-3 is the most important anastomose group. If AG-2-2 is present, maize should be avoided.
Increasing the rate of crop residue decomposition and the amount of organic matter in the soil decreases the growth rate of *Rhizoctonia*.

5.1.3 Treating seed potatoes with fungicides

In seed potato production, it is almost always needed to treat seed tubers with a fungicide before planting. This is also needed if no sclerotia are visible on the tubers. Tubers with no sclerotia can still be infested with mycelium, which cannot be observed with the naked eye. In potato production for ware, French fries or chips, it depends on the level of infection if treating is needed or not. For each situation, thresholds should be developed. Several fungicides are available for treating seed potatoes against *Rhizoctonia*. The most well-known fungicides are: pencycuron (Monceren), flutolanil, fludioxonil. Table 1 provides an overview of fungicides used in the Netherlands for seed treatment, including the rate of application.

Table 1. Fungicides used in the Netherlands for seed treatment to control *Rhizoctonia solani.*

Fungicide (active ingredient)	**Type of application**	**Rate of application (gram active ingredient/1000 kg seed potatoes)**	**Time of application**
Pencycuron	liquid	250 gram	Before pre-sprouting or just before or during planting
Pencycuron	powder	250 gram	Just before or during planting
Pencycuron/prothioco nazool)	liquid	150 gram pencycuron+ 4,8 gram prothioconazool	Before pre-sprouting
fludioxonil	liquid	25 gram	Before pre-sprouting, before sprout are visible
flutolanil	liquid	92 gram	Before pre-sprouting
Tolclofos-methyl	powder	150 gram	Just before or during planting
flutolanil	powder	90 gram	Just before or during planting

Moncerene (pencycuron) is the most commonly used fungicide. This fungicide can be applied a few weeks before planting or at planting. The product is stable under normal storing conditions. After application extremes of temperature and direct sunlight should be avoided.

The availability of fungicides differs from country to country. Other potential fungicides are: boric acid, methoxy-ethyl mercuric chloride, captan and iprodione. Experiments in Canada showed that fludioxonil was providing a better protection than captan, iprodione and mancozeb. Experiments in Punjab showed that methoxyethyl mercuric chloride was controlling *Rhizoctonia* better than boric acid and boric acid had a better result if applied before storage than after storage (Somani, 1988). There are very serious disadvantages of mercuric chloride, especially for human beings and the environment. In most countries it is not allowed to apply mercury based product. If mercury is used – where still legal – it should be applied with utmost prudence for humans and environment. Not under any condition and circumstance is skin contact of workers with the liquid allowed. The waste fluid must be disposed of in legal manner and not be flushed to surface nor ground water.
Tsror (2010) stated that *Rhizoctonia* isolates are highly sentitive to flutolanil, iprodione and pencycuron, except AG-5 isolates, which were only moderately sensitive to pencycuron (Campion et al., 2003).

There are different application techniques of liquid fungicides on seed potatoes: spraying with a knapsack, dipping or dusting with a spinning disk atomizer attached on a rolling table. The application with a spinning disk atomizer has the advantages of an even coverage of the tuber and tubers are not becoming wet. Knapsack spraying of the tubers can lead to uneven coverage of the tuber surface. This can be improved by rolling the tubers several times i.e. on a rolling table. Dipping has the disadvantage that the dipping liquid can increase the spread of (dry and wet) rot diseases from tuber to tuber.

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Picture 18. Spinning disk atomizer (Mafex) attached on a rolling table.

5.1.4 In-furrow and whole field treatments with fungicides
Especially on soils infested with *Rhizoctonia*, in-furrow or whole field application of fungicides may improve the control of the disease. Table 2 provides an overview of fungicides used in the Netherlands for in-furrow treatment and for whole field treatment, including the rate of application.

Table 2. Fungicides used in the Netherlands for in-furrow and whole field application to control *Rhizoctonia solani.*

Fungicide	Type of application	Rate of application in the row (gram per ha)	Rate of application whole field (gram per ha)
azoxystrobin	liquid	3 liter amistar	6 liter amistar
Fluoxastrobine/pencycuron	liquid	390 gram fluoxastrobine 1200 gram pencycuron	
pencycuron	liquid	1875 – 3125 gram pencycuron*	3750 – 6250 gram pencycuron*

*Depending on organic matter content of the soil: 1875 gram in the row and 3750 gram whole field if om% < 5%; 2500 gram in the row and 5000 gram whole field if om% between 5 and 10%; 3125 gram in the row and 6250 gram whole field if om%>10%

5.1.5 Optimal emergence and growing conditions
Emergence of potatoes should be as quick as possible. Optimal soil conditions are required for a quick emergence (moisture and temperature). If planting is done in cold, wet soil rate of sprout growth will be low and young sprouts could easily be attacked by *Rhizoctonia*. Shallow planting will promote rapid emergence and less chance for infection of sprouts and stems will occur. A level of resistance to *Rhizoctonia* infection is imparted to an emerging plant with light interception.
Development of black scurf on the tubers is slow during the growing season. Black scurf is increasing under stress conditions, like shortage of water, oxygen around the roots and nutrients and during crop senescence.

5.1.6 Biological control
It is possible to suppress *Rhizoctonia solani* with various fungi, bacteria and nematodes (Tsror, 2010). The most well-known antagonists are *Trichoderma harzianum* and *Verticillium biguttatum*.

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Verticillium biguttatum has the potential to control *Rhizoctonia* diseases in potato, as it suppresses the production of sclerotia. Soil temperature should be 15°C or more. *Rhizoctonia*-specific fungicides (pencycuron, flutalonil) co-applied with *Verticillium biguttatum* showed additive effects on black scurf control, while broad-spectrum fungicides (azoxystrobin, chlorothalonil, thiabendazole) were fungitoxic to *Verticillium biguttatum* (Van den Boogert and Luttikholt, 2004).

Trichoderma harzianum is able to reduce the severity of stem lesion symptoms and black scurf on progeny tubers and it is giving fewer malformed and green-coloured tubers (Tsror, 2010). Based on experiments with the combined use of fungicides and antagonists, Wilson et al. (2008) were suggesting that combining the application of *Trichoderma harzianum* with seed dressing with flutolanil may provide the best protection against damage caused by *Rhizoctonia solani* in potato.

In the Netherlands, it is allowed to apply *Pseumonas* species (Proradix Agro) to control *Rhizoctonia*. It is applied in combination with fungicides.

It is possible to suppress *Rhizoctonia solani* with amendments of compost. However, its efficacy depends on the maturity of the compost. Mature compost is leading to a reduction of the damage caused by *Rhizoctonia*, while immature compost is causing an increase of the disease (Tuiters et al., 1998). Scholte and Lootsma (1998) showed that organic amendments of green manure crops (white mustard, forage rape and oats) and farmyard manure (alone or in combination with white mustard) reduced disease severity.

5.1.7 Methods of haulm destruction

The method of haulm destruction has a major effect on the final incidence of black scurf at harvesting time. Bouman et al. (1983) found that fewer sclerotia on tubers were found after haulm pulling than after chemical haulm destruction. Haulm pulling cuts the stolons from the other plant parts and disturbs the soil. It stops the sap flow from the roots to tubers and reduces exudation of liquids from the tubers. Haulm pulling provides also a better aeration which probably prevents the accumulation of stimulatory volatile exudates at tuber surface (Dijst, 1989). Cutting off the shoots at soil level or 10 cm above soil level is stimulating black scurf formation as much as chemical killing (Dijst, 1989). There are different machines available for haulm pulling. The stems are cut at a length of 15 – 20 cm above ground surface and stems are pulled with belts or rollers. For getting a good result it is required that stems are in centre of the ridges and that the tubers are sufficiently in the soil (more than 4 cm soul cover). The position of the tubers in the ridges is depending on the variety and on the year. Haulm pulling should not be carried out under wet conditions and not every variety is suited for haulm pulling. If haulm pulling has not been carried out successfully, additional chemical killing of the haulm is still needed.

5.1.8 Period between haulm destruction and harvest

Because of the risks of skin losses harvest cannot be carried out directly after haulm killing. For example in many seed potato production systems haulms are killed very early and skins are not set at that moment. For skin setting a 2-3 weeks period between are haulm destruction and harvest is required, while on the other hand black scurf on the tubers will increase when this period is longer. Sometimes it is necessary to find a compromise between a certain level of skin loss and a low level of black scurf.

5.1.9 Green-crop-harvesting

In the Netherlands, the green-crop-harvesting (GCH) method has been developed some twenty years ago. GCH is a combination of mechanical haulm killing and digging. First the haulms are removed by cutting at soil level or by pulling. This is followed immediately by carefully digging with a lifter, while tubers are placed back on the soil and are recovered with soil. Usually tubers of two rows are put together in one row. After skin setting and wound healing during a certain period of time tubers are harvested. GCH can only be successful if skin damage at the first lifting is low. This requirement is met by diggers which are especially designed for the purpose of GCH. Another prerequisite is that no haulm pieces are coming into the new ridge, because these pieces will promote the incidence of black scurf. It is also possible to apply fungicides or antagonists during the first lifting to control the development of black scurf. In the Netherlands in some experiments, GCH combined with the application of *Verticillium biguttatum* resulted in a close to 100% disinfection of *Rhizoctonia solani* on the tuber (Mulder et al., 1992). In the Netherlands, it appeared that GCH could be a useful method on sandy soils and light clay soils. Nowadays however, GCH is not used on a large scale in the Netherlands, because it is too expensive.


Picture 19. Lifter which is lifting two ridges and wich is putting the tubers in one row. Picture 20. Machine which is covering the lifted tubers with soil.

6 Recommendations for controlling *Rhizoctonia solani* in Punjabi seed potato production

In Punjab, *Rhizoctonia solani* has become a serious problem of the seed potato production system. Almost all farmers in Punjab are treating seed potatoes before planting, but nevertheless the incidence of Rhizoctonia seems to increase from year to year. There are also signals that potato growers in other states of India are complaining more and more about the quality of seed potatoes produced in Punjab. It is not clear if these quality problems are only due to *Rhizoctonia solani*. It is also possible that some problems are caused by other diseases, like dry rot and wet rot. Therefore it is needed to find out to which extend *Rhizoctonia* is a problem in seed potatoes sold to the other states.

In Punjab, seed potatoes are treated before planting with one of the following fungicides:

- pencycuron (Moncerene), usually spayed with a knapsack while rolling the tubers, 25 – 80 grams pencycuron per 1000 kg seed potatoes;
- boric acid (Boric Acid powder), applied by dipping in a solution of 2,5 – 3,0%;
- mercury (Emisa-6), applied by dipping in a solution of 0,25%.

Moncerene is the most frequently used fungicide.

The following recommendations could be given for improving the control of *Rhizoctonia solani* in Punjab:

- Planting seed potatoes free from sclerotia (or most as free as possible). Black scurf incidence of the different seed lots should be monitored. Based on knowledge of black scurf incidence of the seed lots it must be decided which seed lot should be planted or which seed lot should be sold as ware potatoes. Planting heavily infected seed lots has the risks that field are becoming more and more infested by *Rhizoctonia* and this should be avoided.
- Selecting *Rhizoctonia* free fields. Farmers have experiences with different fields and very often they know which fields are giving disease problems.
- Optimizing treatments of seed potatoes with fungicides.
    - All seed potatoes should be treated. Even if there is no black scurf visible on the tubers it is possible that mycelium or hidden sclerotia are present on the tubers.
    - It is not advised to use mercury because of its dangerous effects for people and the environment. Skin contact of workers with the liquid is not allowed.
    - The application of Moncerene should be optimized.
        - It should be investigated if the higher dose rate that is common in the Netherlands (250 grams pencycuron per 1000 kg) is giving better results than the dose rates that are common in Punjab (25 – 80 grams pencycuron per 1000 kg). There are no indications that a higher dose rate will be phytotoxic.
        - It is not advised to apply Moncerene by means of a drip treatment. A drip treatment can increase the spread of (dry and wet) rot.
        - The application method should be improved. The risk of applying Moncerene with a knapsack sprayer is that some tubers or parts of tuber will not be covered with fungicide. Making use of a rolling table will be an improvement. The introduction of a spinning disk atomizer attached on a rolling table is the most preferred improvement.
- An investigation on the type of AG (whether AG-3 or AG-5 or AG-2-2) should be carried out at R&D-level (i.e. PAU, Ludhiana). If AG-5 is involved it is possible that pencycuron is not (or less) effective in controlling *Rhizoctonia*. If AG-2-2 is involved, fields on which maize has been grown should be avoided.
- An investigation on different fungicides for controlling *Rhizoctonia* should be carried out at R&D-level (i.e. PAU, Ludhiana). For example it could be investigated if fludioxonil or flutolanil or tolclofos-methyl are giving better results than pencycuron.
- An investigation should be done at R&D-level (i.e. PAU) on the carry-over *of Rhizoctonia* in the most common crop rotation systems in Punjab. For instance studying the effects of maize, paddy,

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sunflower, green manure, cucurbits and legume crops.

- In severely infected fields in-furrow or whole-field fungicide treatments could be tried. Pencycuron, azoxystrobin and fluoxastrobine/pencycuron could be tested.
- An investigation on the possibilities of suppression of *Rhizoctonia* with antagonists should be done at R&D-level (i.e. PAU). The efficacy of the different antagonists under Punjabi conditions should be investigated. Also the possibilities to produce antagonists in a commercial way should be investigated.
- An investigation should be done at R&D-level (i.e. PAU) on possibilities to shorten the period between haulm killing and harvest.
- An investigation should be done at R&D-level (i.e. PAU) on haulm pulling. Haulm pulling is giving a reduction of the incidence of black scurf.
- An investigation should be done at R&D-level (i.e. PAU) on green-crop-harvesting (GCH). With GCH it is possible to reduce the incidence of black scurf, especially if GCH is carried out in combination with the application of antagonists or fungicides.

If mercury is used – where still legal – it should be applied with utmost prudence for humans and environment. Not under any condition and circumstance is skin contact of workers with the liquid allowed. The waste fluid must be disposed of in legal manner and not be flushed to surface nor ground water.

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