Controlling skin diseases in seed potato production in Norway

Mart Kamping
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A literature study on controlling skin diseases in seed potatoes in Norway.

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Preface

This report is the preliminary research of my graduation project of the education Horticulture and Arable Farming. As a fourth-year student at Aeres University, this project marks the finalization of my academic journey. For this thesis I was inspired by my experiences during my internship at Bjertnæs & Hoel AS, a prominent food producer in Norway where I serve as the manager of potato production, I chose a subject closely aligned with my daily responsibilities.

The research question for this thesis naturally emerged from the challenges encountered in my role at Bjertnæs & Hoel AS, and the insights gained from my professional network within the company significantly contributed to the depth of this study. The overarching goal of this thesis is to provide valuable insights that can benefit not only Bjertnæs & Hoel AS, but also other companies involved in the procurement of seed potatoes in Norway.

I extend my sincere gratitude to my teachers, Mohamad Al Hassan and Kees Westerdijk, for their valuable feedback and guidance throughout writing this thesis. Special thanks are due to Mohamad Al Hassan, whose constructive feedback played a prominent role in shaping this report. Additionally, I would like to express my appreciation to my employer at Bjertnæs & Hoel AS for generously dedicating time and providing essential information for the advancement of my graduation project.

Mart Kamping, December 2023

Abstract

Potato is an important crop in Norway. In the whole country potatoes are grown, even in the most northern county. It is not allowed to import seed potatoes into Norway. A non-Norwegian potato variety has to be imported as meristem plantlets. The seed potato multiplication in Norway is controlled by the Norwegian Food Safety Authority. In their seed growing protocol they describe the allowed maximum thresholds for diseases found in certified seed potatoes. Despite the strict protocol of the Norwegian Food Safety Authority, the seed buying companies still find quite a big number of skin diseases in their bought seed batches. The most common skin diseases that are present in seed batches are: black dot, silver scurf, black scurf, powdery scab, and skin spot. This is a big problem because skin diseases result in a lower marketability of the produced potatoes and damage thereby the economical yield. That is why the main question of this literature study is: How can skin diseases be controlled in seed potatoes in Norway?

The research focused on conducting a literature study on the five most common skin diseases that are found in seed batches. Each skin disease took up a sub-question. The research existed of a literature study that mainly focused on finding relevant information in online databases. By collecting all this information, it was possible to answer each sub-question on controlling each skin disease.

The findings underscore the multifaceted nature of controlling these diseases, with considerations for soil influences, cultivation practices, chemical interventions, and storage methods.

For black dot, addressing soil influences, careful fungicide use, and proper storage practices, including quick drying and cooling, are crucial. Silver scurf control revolves around managing seed tubers, cultivation practices, and effective chemical interventions such as Emesto Silver. Controlling black scurf requires attention to soil and cultivation factors, including crop selection and chemical interventions like Amistar. Powdery scab control focuses on soil and cultivation aspects, with specific attention to crop rotation, soil pH management, and chemical interventions like zinc application. Controlling skin spot necessitates measures such as seed quality, soil influences, chemical interventions like Fungazil 100 SL, and proper storage practices.

In conclusion, the study supports a tailored approach for each fungal skin disease, highlighting the importance of understanding the unique characteristics of each disease for effective control. The outlined strategies encompass a combination of cultivation methods, chemical interventions, and storage practices, providing a comprehensive guide for managing fungal skin diseases in seed potatoes in Norway.

Samenvatting

Aardappel is een belangrijk gewas in Noorwegen. In het hele land worden aardappelen verbouwd, zelfs in de meest noordelijke provincie. Het is niet toegestaan om pootgoed naar Noorwegen te importeren. Een niet-Noorse aardappelras moet als meristeemplantjes worden geïmporteerd. De vermeerdering van pootgoed in Noorwegen wordt gecontroleerd door de Noorse Voedselveiligheidsautoriteit. In hun protocol voor pootgoed vermeerdering beschrijven ze de toegestane maximale percentages voor ziekten die worden aangetroffen in gecertificeerd pootgoed. Ondanks het strenge protocol van de Noorse Voedselveiligheidsautoriteit vinden de pootgoed aanschaffende bedrijven nog steeds een behoorlijk aantal schilziekten in hun gekochte pootgoed partijen. De meest voorkomende schilziekten die aanwezig zijn in partijen pootgoed zijn: zwarte spikkel, zilverschurft, lakschurft, poederschurft en pukkelschurft. Dit is een groot probleem omdat schilziekten leiden tot een lagere verhandelbaarheid van de geproduceerde aardappelen en daarmee schade toebrengen aan het economisch rendement. Daarom is de hoofdvraag van deze literatuurstudie: Hoe kunnen schilziekten worden gecontroleerd in pootaardappelen in Noorwegen?

Het onderzoek richtte zich op het uitvoeren van een literatuurstudie naar de vijf meest voorkomende schilziekten die worden aangetroffen in partijen pootgoed. Elke schilziekte nam een deelvraag in beslag. Het onderzoek bestond uit een literatuurstudie die zich voornamelijk richtte op het vinden van relevante informatie in online databases. Door al deze informatie te verzamelen, was het mogelijk om elke deelvraag over het beheersen van elke schilziekte te beantwoorden.

De bevindingen benadrukken de veelzijdige aard van het beheersen van deze ziekten, met overwegingen voor bodeminvloeden, teeltmethoden, chemische interventies en bewaring.

Voor zwarte spikkel is het rekening houden met bodeminvloeden, voorzichtig gebruik van fungiciden en juiste bewaarmethode, waaronder snel drogen en koelen, cruciaal. Beheersing van zilverschurft draait om de kwaliteit van het pootgoed, teeltmethoden en effectieve chemische interventies zoals Emesto Silver. Het beheersen van lakschurft vereist aandacht voor bodem- en teeltfactoren, waaronder ras selectie en chemische interventies zoals Amistar. Het beheersen van poederschurft richt zich op bodem- en teeltaspecten, met speciale aandacht voor gewasrotatie, bodem-pH-beheer en chemische interventies zoals zinktoepassing. Het beheersen van pukkelschurft vereist maatregelen zoals pootgoed kwaliteit, bodeminvloeden, chemische interventies zoals Fungazil 100 SL en juiste bewaar methoden.

Tot slot ondersteunt de studie een op maat gemaakte aanpak voor elke schimmel schilziekte, waarbij het belang wordt benadrukt van het begrijpen van de unieke kenmerken van elke ziekte voor een effectieve controle. De geschetste strategieën omvatten een combinatie van teeltmethoden, chemische interventies en bewaar methoden en bieden een uitgebreide gids voor het beheer van schimmel schilziekten in pootgoed in Noorwegen.

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1. Introduction

1.1 Seed potatoes in Norway

Potato is an important crop in Norway. In the whole country potatoes are grown. Even in the northernmost county Finnmark, with a latitude of 70°N, is potato production. In 2010 there were 13.212 hectares of potato production with a total approximately yield of 321.000 tons (Hermansen et al., 2012). Only 3% of the land is used for growing food. From that, 30% is used for growing grains, and only 1.4% is used for potato production (Forbes et al., 2023). In average there is a yearly production of 300.000 tons of potatoes. This 300.000 ton is divided in three categories: fresh consumption, frozen products, and crisps, which are each around 100.000 tons. Norway is not self-sufficient with its potato production, a rough estimation is that circa 60.000-tons potatoes is imported according to Henrik Hoel, Sales manager of Bjertnæs & Hoel AS.

It is not allowed to import seed potatoes into Norway. This regulation is to protect Norwegian potato production from quarantine diseases which are present in neighbouring countries and Europe. A non-Norwegian potato variety has to be imported as meristem plantlets. Thereafter, controlled by an authorised laboratory on quarantine and bacterial diseases, whereafter minitubers can be produced to start multiplication and variety introduction. Graminor AS is the only company that introduces varieties for the whole Norwegian potato market. Beside Graminor AS there are some private companies that imports, introduces, and use potato varieties that are bred in other countries for the Norwegian potato market (Landbruks- og matdepartementet, 1996).

According to A. Bjørnstadt, production manager seed potatoes from Norgro AS, there was certified seed potato production of 11.162 ton in 2021. Estimated is that those certified seed potatoes cover around 30% of potato production in Norway. It is common for Norwegian potato farmers to multiply their own seeds. Mattilsynet is the Norwegian Food Safety Authority and the responsible organisation of certification of seed potatoes.

1.1.1 Regulation by Mattilsynet

The Norwegian Food Safety Authority is the controlling organisation of seed quality. In their seed growing protocol they describe the allowed maximum thresholds for diseases found in certified seed potatoes (Landbruks- og matdepartementet, 1996). In table 1 is shown the Norwegian regulations of seed potatoes.

Table 1 Allowance of skin diseases in Norwegian seed potatoes (Lovdata, 1996)

Designation of illness or injury	***Max weight %***	***Assessment basis***
A. Wet rot	1	Clearly attack by wet rot
B. Dry rot		Clearly attack by Phytophtora, Phoma, Fusarium and other rots
c. Mechanical Damage	3	Wounds, open cracks, internal crushing which are deeper than 10% of the tuber length. Open wounds covering more than 10% of the tuber survace.
d. Misshapen tubers		Tubers that deviate significantly from the typical shape of the variety. Growing cracks more than 5 mm deep.
e. Scurf (without Silver Scurf)	5	Attack of Common Scab what covers more than 20 % of the tuber surface. Attack of Powdery Scab, Skinspot or Black Skurf what cover more than 10% of the tuber surface.
f. Silver Scurf	15	Attack of Silver Scurf what cover more than 30% of the tuber surface.
g. Internal Defects	2	Internal necrosis caused by Tabaco Mosaic Virus or potato MopTop Virus

1.2 Skin diseases

Bjertnæs & Hoel AS is potato producer located in Vestfold, South-East of Norway. Yearly the company produces baby potatoes with seeds bought from Norgro AS and Strand AS. Norgro AS and Strand AS are the only two seed potato selling companies in Norway. Skin quality is one of the most important factors in this type of potato production. Skin blemishes resulting in lower marketability of produced potatoes and damaging the economical yield. Good seed quality is a very important factor for a successful production of baby potatoes.

Seed potatoes arriving at Bjertnæs & Hoel AS do get inspected by an agronomists of the company. It is important to control the seeds to get overview if and how much diseases are present in the seed batches. This information is used to give an overview of the seed quality for growing season 2023. In table 2 is shown an overview of all the seed potato batches that Bjertnæs & Hoel AS received in 2023 and how many skin diseases where found in these batches. This table shows that there are five skin diseases most present. These diseases are black dot, skin spot, black scurf, silver scurf, and powdery scab.

Table 2 Skin diseases in seed potatoes delivered to Bjertnæs & Hoel in 2023 (Bjertnæs& Hoel, 2023)

Skin diseases in Norwegian seed potatoes							
			% of tubers with visual symptoms of tuber blemsish disease				
Variety	Batchnumber		Black dot	Skin spot	Black scurf	Silver scurf	Powdery scab
Folva	2410601-01			13%	1%	4%	
Folva	2410601-02				1%	1%	29%
Folva	2630601		13%		7%		
Folva	2022-10061			6%		3%	
Folva	2022-10061			9%		5%	
Anouk	2615101-01		12%		7%	15%	
Anouk	2615101-02		7%		4%	2%	
Anouk	2615101-03		4%		5%	12%	
Anouk	2022-10077		1%	12%			
Anouk	2022-10077			34%		10%	
Anouk	2022-10077		2%	22%		5%	
Anouk	2022-10078		10%	12%		3%	
Colomba	2085201-01			2%	2%	2%	
Colomba	2085201-02			2%		3%	
Colomba	2022-10091						3%
Colomba	2022-10091						4%
Colomba	2022-10145			2%		2%	
Colomba	2022-10151				1%	1%	
Hassel	2614701-02					56%	
Cerisa	2614001-01		8%			34%	
Cerisa	2614001-02		31%			15%	
Cerisa	2022-10162			1%	1%	13%	
Cerisa	2022-10162			2%	4%	24%	
Cerisa	2022-9999			6%	5%	34%	
Mandel 6	2080901-01						
Mandel 6	2080901-02				1%		
Mandel 1	10258-02				4%	1%	
Total	**27**		**9**	**11**	**13**	**19**	**3**
			33%	**41%**	**48%**	**70%**	**11%**

1.2.1 Black dot

Black dot is a potato skin disease caused by *Colletotrichum coccodes.* The disease causes important losses in potato production. Black dot occurs worldwide but especially in Europe (Massana-Codina et al., 2021). Yield per hectare is rarely affected, but the potatoes destined for table markets and seed potato sales could be affected due to quality restrictions and seed potato tolerances (Wale et al., 2008). Infected tubers can lose more water than normal, due to this there is more loss of weight than normal in storage (Schnee et al., 2020).

Figure 1 Microsclerotia on potato stem (BASF, 2019)

Symptoms of black dot can be found in all parts of the potato plant. Infected plant tissue is characterized by the presence of small black microsclerotia (Schnee et al., 2020). In Figure 1 is shown microsclerotia of black dot on a potato stem. Skin blemish caused by black dot on the tubers can be confused with silver scurf, but black dot lesions are more irregular with undefined margins. Black dot will have microsclerotia that are visible with a magnifying glass. When the infection of black dot is extensive there could be an increase of respiration of the tubers that can cause shrivelling and shrinkage of the tubers (Wale et al., 2008).

In 2008 and 2009 on visual inspections of Norwegian ware potatoes was found that 59% of the batches showed presence of black dot. An incubation test at Bioforsk resulted in 85% to 90% of batches were infected with black dot (Nærstad et al., 2012).

1.2.2 Silver scurf

Figure 2: Silver Scurf (AHDB Potatoes, 2018)

Silver scurf is a tuber blemish disease that is recognisable due to grey to silver-coloured blemishes on the tuber surface, shown in figure 2. The fungus *Helminthosporium solani* is causing silver scurf on potato and potato is the only host of *Helminthosporium solani.* Silver scurf's blemishes is impairing the appearance of washed potatoes and is an important factor of affecting marketability of infected potatoes (Sedláková et al., 2013). Especially on red skin varieties of potato silver scurf is reducing marketability due to the contrast of light grey spots on red skin (Wale et al., 2008).

Figure 3: Conidia of Helminthosporium solani (Hamm, 2012)

The greyish spots of silver scurf can be confused with the darker spots of black dot, but silver scurf tends to have metallic grey look with a darker bronze tone outer line and when viewed with a microscope, silver scurf will show conidia shaped like a pine tree (Wale et al., 2008). Figure 3 shows conidia of silver scurf. There are no symptoms of silver scurf on leaves or roots of the potato plant. Symptoms are only known to be found on the

tubers. When infection is severe tubers can get shrivelled. This can lead to excessive weight loss in storage (Turkensteen & Meijers, 2008).

Silver scurf is a common potato disease in Norwegian potato production. Like in all countries where potatoes are an important crop, silver scurf became an important disease through the reduction of cosmetic quality. Estimated is that in 2008 13.3% of the tuber surface in Norway was covered with silver scurf and 11.1% in 2009. With visual inspections 93.1% of the samples taken that year where infected by silver scurf. Therefore, silvers scurf is the most appearing tuber blemish disease in Norway in 2008 and 2009 (Nærstad et al, 2012). 70% of the batches of seeds bought by Bjertneas & Hoel in 2023 was infected with silver scurf. With one extraodenary batch where 56% of the tubers was infected by silver scurf. This is shown in Table 2.

1.2.3 Black scurf

Black scurf is easy to recognise. Soil-free tubers will have black to dark brown structures attached on the tuber surface. These structures are sclerotia of *Rhizoctonia Solani. Rhizoctonia Solani* is commonly present on most areas where potatoes are grown. The fungus disease has several strains that normally exist in soils, but the AG-3 strain is generally associated with black scurf on potatoes (Wale et al., 2008). The loss of up to 30% marketable yield caused by black scurf makes the fungus diseas one of the most economically important disease in potato production (Li et al., 2023).

Figure 4 Three tuber symptoms Black Scurf (Bjertnæs & Hoel, 2022)

Beside the sclerotia structures attached to the tuber surface does *Rhizoctonia Solani* have more symptoms affecting the tuber. Tubers can have netted scab like lesions that is caused by the fungus threads. This fungus threads also can cause small round lesions with a hole in the middle what is known as dry core (Turkensteen, 2008). In Figure 4 are the 3 tuber symptoms shown. The black scurf clear visable as the cluster of black paint like spots. In the right top of the tuber is the typical netted scab symptom shown. In the middle of the tuber in Figure 4 shows the dry core symptom.

Tuber symptoms are lowering the marketable yield, but haulm symptoms is lowering the harvestable yield of potato crops. Losses of stems, uneven emergence to no emergence, air tubers, damaged roots and damaged stolones are all symptoms that have negative effect to the end harvest of potatoes (Jaradat et al., 2022).

Rhizoctonia Solani is widely spread in Norway. In a visual inspection survey of potato samples that do represent the regional production and varieties in 2008 and 2009 shows that 53.4% of the batches black scurf was present (Nærstad et al., 2012). In Table 2 is visuable that from the seed potato batches arriving at Bjertneas & Hoel AS in growing season 2023 was on 48% of the batches presence of black scurf.

1.2.4 Powdery scab

Spongospora subterranea a zoophoric fungus is causing one of the main diseases in potato production worldwide. This disease is better known as powdery scab of potato. The disease was long underestimated what has led to lack of appropriate control strategies (Merz, 2008). Powdery scab cause usually only cosmetic damage to tubers what have effect on the marketability of potatoes. On heavy affected batches the losses can be up to 50%. Besides cosmetic damage powdery scab is a vector of Potato Mop-Top Virus (PMTV). This virus can lead to poorer growth and internal defects in potatoes (Harrison et al., 2003).

Figure 5 Lesions of Powdery Scab (AHDB Potatoes, 2018)

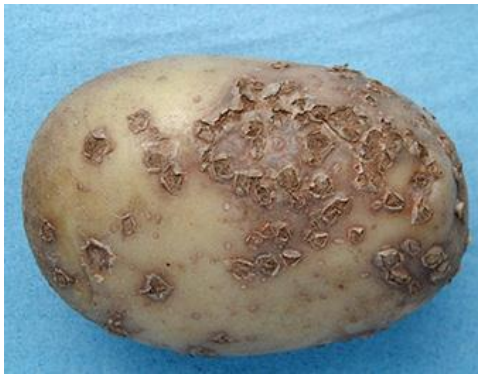

Figure 6 Root galls of Powdery Scab (Miller Research, 2023)

Powdery scab is characterized by unsightly pustules shattered on the tuber surface. When matured the pustules could break open and the spore balls containing large numbers of rest spores are spread. Leaving crater like scab lesions on the tuber surface (Brierley et al., 2012). Those crater like scab lesions are shown in figure 5. In a growing crop, powdery scab can be seen when crop is infected by galls on the roots. These galls are wart like thickening of the roots (Brierley et al., 2012). In Figure 6 these root galls are visualized.

In 2008 was in a survey of Norwegian potatoes 65.8% of the batches visual affected by powdery scab. In 2009 was this 82.2% of the batches (Nærstad et al., 2012). Table 2 shows that of the seed batches bought by Bjertnæs & Hoel AS 11% was visually affected by powdery scab.

1.2.5 Skin spot

Skin spot, a potato skin disease caused by *Polyscytalum pustulans,* is commonly found on stored potatoes. The disease lowers the value of batches of potatoes that are produced for pre-packing. Also, the value of potatoes produced for industrial purposes is lower because of the increased peeling that is needed to remove the pustules (Wastie et al., 1997). Skin spot is most common in regions with a cooler climate, particular in northern Europe (Wale et al., 2008).

Figure 5 Skin spot on ware potato (Bjertnæs & Hoel, 2023)

Tubers infected with skin spot have black to dark purple spots of about 1-3 mm diameter in size. The spots sometimes are slightly raised of the surface of the tuber. Spots can appear singly or in small clusters. In figure 7 are the lesions of skin spot visible. Beside symptoms on the tuber there can be presence of symptoms on the plant parts. Symptoms on the haulm, stem bases, roots and of stolon's are recognisable by small light brown spots which could form together to larger areas. These larger lesions are often superficial and can have cracks in the length of the plant part (Wale, et al., 2008).

When infected seed potatoes are planted, the infection could harm the underground stems and roots of the potato plant. This could result in uneven emergence, loss of stems and in a worst case of blanking of the seed potato (Wastie et al., 1997).

With visual inspection of potato batches in Norway in 2008 and 2009 was found in 59.9% of the batch's lesions of skin spot. An incubation test showed that in 2008 86% and in 2009 90% of the batches where infected with skin spot. This investigation also shows that potato batches from the northern areas of Norway had more infection than other regions of the country (Nærstad et al., 2012). In Table 2 is shown that on seed potatoes arriving at Bjertnæs & Hoel AS 41% of the batches was infected with skin spot.

1.3 Knowledge gap

As mentioned previously the Norwegian Food Safety Authority controls diseases in seed potatoes according to a strict set of regulation. However, as shown in table 2, there is still a high percentage of skin diseases found in seed potato batches. The bad quality of seed potatoes has a direct influence on the quality that will be harvested for the commercial market. The current seed potato quality in Norway is not living up to the requirements of the Norwegian Food Safety Authority. Therefor this research is focused on a way to control skin diseases in seed potato production in Norway. The results of this research can be helpful for the seed selling companies to control skin diseases in their seed batches.

The main question of this research will therefore be: How can skin diseases be controlled in seed potato production in Norway? To find the answer to this main question, sub-questions are formulated. The sub-questions for this research are:

- How can black dot be controlled in seed potatoes in Norway?
- How can silver scurf be controlled in seed potatoes in Norway?
- How can black scurf be controlled in seed potatoes in Norway?
- How can powdery scab be controlled in seed potatoes in Norway?
- How can skin spot be controlled in seed potatoes in Norway?

2. Method

2.1 Literature study

To be able to answer the main- and sub-questions of this research a literature study was conducted. To be able to collect as much relevant literature as possible, multiple databanks were used. Examples of suitable databanks are, Green-I, Springer, Science Direct, Google Scholar and Wageningen University. The references that were selected had to be reliable and relevant for this research. To guarantee this was the case, criteria were made up to guarantee the quality of the references used in this research. Table 3 will show these criteria and explain each criterion.

Table 3 Criteria of relevant references

	Criteria
Year	The literature used for this research may not be older than ten years. Exemptions are made when some topics are only found in older research. References older than twenty years might be outdated and not reliable anymore.
Language	The language of the references may only be English, Dutch, or Norwegian.
Kind of source	For this research scientific references are used. At least 10 references must be peer reviewed. Trade journals and websites of reliable companies are approved as reliable references. Also, scientific books with good references are considered as reliable source.
Source reference	All references are collected in a literature logbook. In 2.2 will be more information about this logbook. References will be referred to according to the APA-method.
Quality	References will be judged by the CRAAP-method to decide if a source is good enough to be included in this research. 2.2 will give an explanation on the CRAAP-method.
Quantity	For each sub-question at least 5 suitable references will be collected. There is a maximum of 15 suitable references for each sub-question. In total that means that at least 25 references and maximum of 75 references are collected for this research.

For all the sub-questions the aim was to find solutions on controlling that specific skin disease in potato production in Norway. Therefor the focus of the literature study was on scientific references and research in controlling these specific diseases in potatoes. For each of the diseases the search topic are displayed in a table. The expectation was that these search topics will result in suitable and usable literature to answer the sub question. The search topics are displayed in the English language but were also translated into Dutch and Norwegian during the research to have a broader search.

2.1.1 Sub-question 1

"How can black dot be controlled in seed potatoes in Norway?"

Table 4 shows the search topics and search topic combinations for answering the first sub-question.

Table 4 Search topics and combinations for Black Dot

Search topic	Combinations
Black dot	Black dot (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Colletotrichum coccodes	Colletotrichum coccodes (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
C. Atramentarium	C. Atramentarium (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Skin disease	Skin disease (AND) Black dot (AND) Colletotrichum coccodes (AND) C. Atramentarium (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment
Controlling	Controlling (AND) Black dot (AND) Colletotrichum coccodes (AND) C. Atramentarium (AND) Skin disease (AND) Growing method (AND) Storing method (AND) Treatment
Growing method	Growing method (AND) Black dot (AND) Colletotrichum coccodes (AND) C. Atramentarium (AND) Controlling (AND) Skin disease (AND) Storing method (AND) Treatment
Storing method	Storing method (AND) Black dot (AND) Colletotrichum coccodes (AND) C. Atramentarium (AND) Controlling (AND) Growing method (AND) Skin disease (AND) Treatment
Treatment	Treatment (AND) Black dot (AND) Colletotrichum coccodes (AND) C. Atramentarium (AND) Controlling (AND) Growing method (AND) Storing method (AND) Skin disease

2.1.2 Sub-question 2

"How can silver scurf be controlled in seed potatoes in Norway?"

Table 5 shows the search topics and search topic combinations for answering the second sub-question.

Table 5 Search topics and combinations for Silver Scurf

Search topic	Combinations
Silver scurf	Silver scurf (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Helminthosporium solani	Helminthosporium solani (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease

Skin disease	Skin disease (AND) Silver scurf (AND) Helminthosporium solani (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment
Controlling	Controlling (AND) Silver scurf (AND) Helminthosporium solani (AND) Skin disease (AND) Growing method (AND) Storing method (AND) Treatment
Growing method	Growing method (AND) Silver scurf (AND) Helminthosporium solani (AND) Controlling (AND) Skin disease (AND) Storing method (AND) Treatment
Storing method	Storing method (AND) Silver scurf (AND) Helminthosporium solani (AND) Controlling (AND) Growing method (AND) Skin disease (AND) Treatment
Treatment	Treatment (AND) Silver scurf (AND) Helminthosporium solani (AND) Controlling (AND) Growing method (AND) Storing method (AND) Skin disease

2.1.3 Sub-question 3

"How can black scurf be controlled in seed potatoes in Norway?"

Table 6 shows the search topics and search topic combinations for answering the third sub-question.

Table 6 Search topics and combinations for Black Scurf

Search topic	Combinations
Black scurf	Black scurf (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Rhizoctonia solani	Rhizoctonia solani (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Skin disease	Skin disease (AND) Black scurf (AND) Rhizoctonia solani (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment
Controlling	Controlling (AND) Black scurf (AND) Rhizoctonia solani (AND) Skin disease (AND) Growing method (AND) Storing method (AND) Treatment
Growing method	Growing method (AND) Black scurf (AND) Rhizoctonia solani (AND) Controlling (AND) Skin disease (AND) Storing method (AND) Treatment
Storing method	Storing method (AND) Black scurf (AND) Rhizoctonia solani (AND) Controlling (AND) Growing method (AND) Skin disease (AND) Treatment
Treatment	Treatment (AND) Black scurf (AND) Rhizoctonia solani (AND) Controlling (AND) Growing method (AND) Storing method (AND) Skin disease

2.1.4 Sub-question 4

"How can powdery scab be controlled in seed potatoes in Norway?"

Table 7 shows the search topics and search topic combinations for answering the fourth sub-question.

Table 7 Search topics and combinations for Powdery Scab

Search topic	Combinations
Powdery scab	Powdery scab (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Spongospora subterranea	Spongospora subterranea (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Skin disease	Skin disease (AND) Powdery scab (AND) Spongospora subterranea (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment
Controlling	Controlling (AND) Powdery scab (AND) Spongospora subterranea (AND) Skin disease (AND) Growing method (AND) Storing method (AND) Treatment
Growing method	Growing method (AND) Powdery scab (AND) Spongospora subterranea (AND) Controlling (AND) Skin disease (AND) Storing method (AND) Treatment
Storing method	Storing method (AND) Powdery scab (AND) Spongospora subterranea (AND) Controlling (AND) Growing method (AND) Skin disease (AND) Treatment
Treatment	Treatment (AND) Powdery scab (AND) Spongospora subterranea (AND) Controlling (AND) Growing method (AND) Storing method (AND) Skin disease

2.1.5 Sub-question 5

"How can skin spot be controlled in seed potatoes in Norway?"

Table 8 shows the search topics and search topic combinations for answering the fifth sub-question.

Table 8 Search topics and combinations for Skin Spot

Search topic	Combinations
Skin spot	Skin spot (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Polyscytalum pustulans	Polyscytalum pustulans (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment (AND) Skin disease
Skin disease	Skin disease (AND) Skin spot (AND) Polyscytalum pustulans (AND) Controlling (AND) Growing method (AND) Storing method (AND) Treatment

Controlling	Controlling (AND) Skin spot (AND) Polyscytalum pustulans (AND) Skin disease (AND) Growing method (AND) Storing method (AND) Treatment
Growing method	Growing method (AND) Skin spot (AND) Polyscytalum pustulans (AND) Controlling (AND) Skin disease (AND) Storing method (AND) Treatment
Storing method	Storing method (AND) Skin spot (AND) Polyscytalum pustulans (AND) Controlling (AND) Growing method (AND) Skin disease (AND) Treatment
Treatment	Treatment (AND) Skin spot (AND) Polyscytalum pustulans (AND) Controlling (AND) Growing method (AND) Storing method (AND) Skin disease

2.2 Processing data

The collected literature according to the previous mentioned criteria and search topics was rated according to the CRAAP-method. The CRAAP-method is a tool that helps to judge a source if it is good enough to be included in this research. The CRAAP-method consists out of five topics, currency, relevance, authority, accuracy, and purpose. For each topic the source can earn 10 points, so if a source scoring perfect on all five topics it was rated with 50 points. In attachment 1 is more information given about the CRAAP-method.

If a source was found good enough it was included in the literature logbook. The logbook was an Excel sheet that collected all the useful references. In this Excel sheet the title of an article, the author, the publication, a summery, the DOI/link, the CRAAP-score, which sub-question and if the source is peer reviewed or not, was collected. Only the literature that was rated good enough for this research was included in this literature logbook. Table 9 shows an example of the format used in this Excel sheet. The product is a convenient document with all the literature that was needed to find the answers to the sub-questions.

Table 9 Example excel sheet CRAAP method.

Title article	Author	Publication	Summery	DOI/Link	CRAAP-score	Sub-question	Peer-reviewd

3. Results

In this chapter the results are expanded for each sub-question. Like mentioned in chapter 2, a literature study was conducted to be able to answer the sub-questions. Out of this literature study 43 references were found. These references are collected in table 9 and can be found in attachment 7.2. In this chapter every sub-question will be answered.

3.1 Controlling black dot

The first sub-question: *How can black dot be controlled in seed potatoes in Norway?* Is focussing on the fungal skin disease black dot. During the literature study 13 references were found. Out of these 8 references with the highest CRAAP-score were used to answer this sub-question. This paragraph aims to summarise the information out of these papers.

3.1.1 Cultivation method

Soil influence

Black dot caused by the fungi *Colletotrichum coccodes,* is able to infect tubers in two manners. The first way tubers get effected is by infected seed tubers. The second way of infecting the tubers is from microsclerotia in the soil. Out of research it became clear that microsclerotia in the soil have the biggest impact on infecting tubers with black dot (Peters et al., 2016). Microsclerotia of black dot are mostly found in sandy soils with a bad draining capacity (Syngenta, 2023). Research shows that there are limited options in the way of controlling Black Dot by crop rotation. The soilborne inoculum will stay present in the soil for many years, even up to 13 years in some cases. The microsclerotia can also survive on, and colonize on, a lot of weed species (Peters et al., 2016). As mentioned, crop rotation is a limited option for controlling black dot, but research also shows that a 1 to 3 rotation increases the infection of tubers with black dot severely. After 6 years without potato cultivation the level of microsclerotia in the soil was lower (Johnson & Cummings, 2015). There are potato varieties that are less susceptible to black dot. By selecting these varieties in a crop rotation, the pressure of soilborne inoculum can be controlled (Schnee et al., 2021). Besides creating a big rotation, it helps to have a good understanding on the level of infection of the soil. Advised is to use PCR to determine the black dot inoculum levels in the soil. This information is crucial in creating long term field strategies (Harper & Peters, 2009).

Cultivation influence

Research shows that black dot can be caused and promoted by abiotic stress of the plants. This abiotic stress can be caused by for example drought and of nutrient deficiency. Black dot is not able to colonize on dead plant material, but the symptoms of black dot occur mostly when the crop starts to ripen right before harvesting (Johnson & Cummings, 2015). Unbalanced fertilization can be a trigger for the development of black dot on tubers. Soil sampling is advised to get a clear understanding on the condition of the soil before making a fertilization strategy (Syngenta, 2023). Black dot symptoms are more observed at higher temperatures with wet conditions, for example in irrigated fields during high temperatures. Irrigation of fields must be well managed to prevent the creation of too wet conditions (Schnee et al., 2021). After a wet growing season, the level of black dot is much higher than in dry growing seasons (Tönjes, 2019). The severity of black dot disease correlates with a long cultivation period. This indicates that early lifting can be an efficient strategy on managing black dot (Schnee et al., 2021).

3.1.2 Chemical interventions

The intensive use of fungicides can have as a side effect that the plants get more sensitive for black dot. Intensive use of fungicides makes an unbalanced soil what can result in a disbalance in the presence of antagonist. These antagonist can reduce the *C. coccodes* in the soils (Tönjes, 2019). A research that took place in Great Britain in 2007 proved that treating the soil with Amistar while planting could limit the damage of black dot (Bus & Wustman, 2007). The spread of black dot during seed multiplication can also be reduced by treating the seed tubers before planting. A suitable chemical to use as seed treatment is Maxim 100FS. The Chemical protects the tuber from getting effected by infection of black dot out of the soil. Besides the protection of the tuber the chemical also stops the spread of black dot to the soil from already infected seed tubers (Syngenta, 2023).

3.1.3 Storage

To avoid the development of black dot on tubers in storage it is important to quickly dry the potatoes after harvest, especially if there are wet conditions during harvesting. There should not be any condensation in storage (Tönjes, 2019). Besides drying the harvested potatoes as quick as possible, it is important to cool down the potatoes immediately after storing them. The potatoes must be stored cold to prevent the development from black dot in storage (Bus & Wustman, 2007). Advise on preparing seeds after harvesting for storage is to first let the harvested tubers dry at 10-15 °C for at least two weeks. After two weeks the storage should be further cooled down to 5 °C. These steps decrease the severity of Black Dot in storage (Wale et al., 2008). There should be as little soil in the boxes as possible. Research shows that black dot severity in storage increases when there is a lot of soil in the boxes that contains black dot inoculum (Harper & Peters, 2009).

3.2 Controlling silver scurf

The second sub-question: *How can silver scurf be controlled in seed potatoes in Norway?* Is focussing on the fungal skin disease silver scurf. During the literature study 10 references were found. Out of these references the 7 references with the highest CRAAP-score were used to answer this sub-question. This paragraph will summarise the information out of these references.

3.2.1 Cultivation method

Seed tuber influence

Silver scurf on seed potatoes is the primary infection source. When these infected seeds are grown for multiplication, the seed potato can contaminate the daughter potatoes (Bayer Agro Nederland, 2020). The fungi *Helminthosporium solani* that causes silver scurf is present in most potato-growing areas in the world. Therefore, seeds are easily infected with silver scurf during the multiplication process (Martinez et al., 2004). Infected seed potatoes can infect the soil, but spores cannot survive for a long period of time in the soil. Research shows that the fungi is not present in infected soil after nine months. Crop rotation has therefore no effect on the spread of silver scurf. Out of an infected mother seed tuber the daughter tubers are contaminated by passive transport of spores. The daughter tubers that are closest to the mother tuber are the first tubers that get contaminated (Veerman, 2001).

Cultivation influence

Research shows that irrigation has a positive effect on the prevention of silver scurf because it is believed that the water flushes down the spores of silver scurf before it can contaminate the daughter tubers. The size of the seed tuber also has effect on the size of the contamination of daughter potatoes. The bigger the seed tuber, the bigger the spots of silver scurf can be, the bigger the contamination of daughter potatoes can be (Veerman, 2001). Planting distance might also affect the level of infection of daughter potatoes. With a higher plant density, the infection can be higher. When the plants are close to each other it is easier for the spores to contaminated tubers close by (Veerman, 2001). A long cultivation period higher the risk of tubers getting infected with silver scurf out of the soil. Therefor early harvesting of the crop is recommended (Errampalli, 2008). Harvesting seed tubers in two phases might help to lower the infection with silver scurf. This means that in the first phase the tubers are lifted and left on the field for a few hours to dry off and in the second phase the tubers are picked up with a harvester (Turkensteen & Meijers, 2008).

3.2.2 Chemical interventions

Treatment of seed potatoes can prevent the spread of silver scurf from seed potato to daughter potatoes. A suitable chemical for seed treatment is Emesto Silver. Table 10 shows the results of a test field of Wageningen University research station Lelystad. Half of the field was planted with seeds that were treated with Emesto Silver and the other half was not treated with Emesto Silver. The untreated part of the test field was for 15,9% infected with silver scurf where the treated part was only for 3,9% infected (Bayer Agro Nederland, 2020).

Table 10, Results test Emesto Silver (Bayer Agro Nederland, 2020)

		30-Januar-20
Product	Dose	% contamination Silver Scurf
Untreated		15,9
Emesto Silver	0,2 l/ton	3,9

Other seed tuber treatments that have proven to be successful are benomyl, imazalil, thiophanate-methyl, captan, thiabendazole, and thiophanate-methyl. However, these effects are restricted to the growth period and not during postharvest (Errampalli, 2008).
It is possible to use a fungicide to treat silver scurf. The use of benzimidazoles have proven to be most effective. However, silver scurf can easily get resistant for that kind of fungicides. To prevent the development of resistance it is advised to use products that contain imazalil. Also, the chemical Mancozeb is proven to be a very effective disinfectant for seed potatoes (Veerman, 2001).

3.2.3 Storage

Silver scurf is a diseases that mostly develops and spreads in storage, as such, storing seed potatoes in a suitable way is crucial. The storage must be clean and have enough capacity to store and dry the seed potatoes. Because silver scurf can spread with dust, the storage must be completely dust free. Batches with a higher infection of silver scurf must be stored separately from batches with less infection to prevent contamination. The temperature in storage must be stable. Changes in temperature might cause condensation and silver scurf can spread with condensation. The ideal temperature to store the seed potatoes to prevent silver scurf is between 3-5 °C (Bus & Balen, 2022).

3.3 Controlling black scurf

The third sub-question: *How can black scurf be controlled in seed potatoes in Norway?* Is focussing on the fungal skin disease black scurf. During the literature study 18 references were found. Out of these references the 8 references with the highest CRAAP-score were used to answer this sub-question. This paragraph will summarise the information out of these references.

3.3.1 Cultivation method

Soil influence

The field selection for multiplying seed potatoes can have an influence on the contamination level of black scurf. The fungi *Rhizoctonia solani* that causes black scurf, is mostly found on light sandy soils, and is found less on heavier clay soils. Black scurf gives less problems on soils with a high organic matter. Research shows that growing cover crops can stimulate soil life and can reduce the presence of *R. solani* in the soil (Wageningen University, 2005). Also, the previous crop on a field might have a negative influence on the infection of black scurf. Especially grasses are known to have a negative effect on the presence of *R. solani* in the soil (BO akkerbouw, 2022).

Cultivation influence

The seed tubers should be green-sprouted and be planted in warm, well-drained soils. The ridges must not be too deep to stimulate a rapid emergence of healthy plants. This will help to strength the plants before the fungi can attack (Wale et al., 2008). Planting on a later moment when the temperatures are a bit higher can also have a positive effect. With a soil temperature of 12 °C the antagonists that are present in the soil are able to attack the spores of *R. solani.* This makes it more difficult for *R. solani* to infect the young plants (BO akkerbouw, 2022). A field gets easily infected by *R. solani* by infected seed potatoes. By sorting out infected tubers before planting, the infection of the field can be prevented (Lamers, 2022). Besides infected seeds can volunteer potato plants can increase the level of *R. solani* in the soil, Therefor, it is very important to take out volunteer potato plants in the field (BO akkerbouw, 2022).

A research of the University of Maine shows that there are a few crops that can be used as green manure before and/or after seed potato multiplication that will reduce the presence of *R. solani* in the soil. rapeseed, canola, and yellow mustard reduced black scurf by 70-80% (Larkin & Griffin, 2007). When a green manure is used before the cultivation of seed potatoes it is important that the growth of the green manure is stopped early enough so it can degrade well enough before the cultivation of seed potatoes (BO akkerbouw, 2022). Besides growing green manures an extensive crop rotation has a positive effect on reducing the fungi population in the soil. However, an extensive crop rotation should not consist of crops that multiply *R. solani* even more. A crop rotation should not exist of corn, sugar beet, or grasses (Venneman, 2014). The University of Salamanca researched the use of compost teas (mixture of mature compost with tap water) to suppress *R. solani*. The research shows that potato plants that are treated with compost teas have a higher resistance to *R. solani.* This might be the result of the plants getting stronger and healthier when they are treated with compost teas (Plaza et al., 2022).

Chemical killing of the foliage increases the chance of infection with black scurf. Therefor it is advised to use a stem puller or harvest the seed potatoes when the crop is still green (Turkensteen, 2008). Prior to harvesting it is important to separate roots, stolons, and haulm from the tubers. Early harvesting might reduce the damage by black scurf, especially if the skin is completely set. No soil in the harvested seed potatoes also prevents the spread of black scurf (Wale et al., 2008).

3.3.2 Chemical intervention

To prevent daughter tubers from getting contaminated with black scurf it is important to prepare the soil well before the seeds are planted. An advised chemical for soil preparation is Amistar. In a research in a test field with strip cultivation revealed what dose of Amistar was the most effective. Research shows that the most effective dose is 3,0 liter per hectare (Syngenta, 2022). After harvesting the tubers can be immediately treated with a tuber treatment to limit the damage of black scurf. It is advised to use a product that contains thiabendazole. This treatment compared with no adhering soil will limit the damage in storage (Wale et al., 2008).

3.3.3 Storage

If the conditions are wet during the harvesting of the seed potatoes and there is a lot of soil still attached to the tubers, the black scurf can develop further in storage. This makes it important to dry the seed potatoes fast after harvesting. If the attached soil dries it can fall of easily and the risk of infecting tubers with black scurf becomes less (BO akkerbouw, 2022). If the seed potatoes are not stored in boxes but are in one big pile in storage it is important to prevent cone shaped hills. The pile must be as even as possible (Turkensteen, 2008).

3.4 Controlling powdery scab

The fourth sub-question: *How can powdery scab be controlled in seed potatoes in Norway?* Is focussing on the fungal skin disease powdery scab. During the literature study 10 references were found. Out of these references the 6 references with the highest CRAAP-score were used to answer this sub-question. This paragraph will summarise the information out of these references.

3.4.1 Cultivation method

Soil influence

Spores of *Spongospora subterranea* the fungi that causes powdery scab can stay present in the soil for many year. Crop rotation has therefore no effect. However, it is wise to take in account what the previous crop was because some crops are known to severely increase the levels of *S. subterranea* in the soil. Ploughed-up grassland is known to give a higher infection of powdery scab in a potato crop. Active control on volunteer potatoes and black nightshade in the field might help to control Powdery Scab (Baarlen & Turkensteen, 2008). Before field selection it is advised to take soil samples to get a clear view on the infection levels in the soil. PCR can confidently predict the contamination of the field. The knowledge on contamination levels can be valuable in making field strategies and the choice of variety (Brierley et al., 2008).

There is evidence that soil pH can influence the levels of powdery scab in the soil. Increasing the pH by using nitrochalk or lime gives a higher risk on the increase of powdery scab. A

lower pH in combination with additional sulphur can reduce powdery scab levels in the soil (Brierley et al., 2008).

Cultivation influence
The previous crop can have effect on the severity of powder scab like mentioned, but there are also crops that might result in reducing the infection of powdery scab on the crop. Research shows that especially Indian mustard has a positive effect on reducing powdery scab pressure in the soil. Using Indian mustard as green manures before growing seed potatoes on a field might help to reduce the pressure in the soil (Larkin & Griffin, 2007).

Tuber set is a crucial phase in preventing infection of powdery scab because this is the phase when the plant is most susceptible (Wale et al., 2008). The susceptible phase starts about one week before tuber set and is lasting until 3-4 weeks after tuber set starts. Beneficial factors for the development of powdery scab, like temperatures between 16-20 °C and moist conditions, have great impact in this phase of the growing season (Bus, 2003).
The soil temperature and moisture are crucial factors for infection of powdery scab. In warmer climates with higher temperatures during the growing season there is less pressure of powdery scab infection. Too extensive use of irrigation can cause problems with infection of powdery scab because it might cool down the soil and create a high soil water content (Wale et al., 2008). Advised is to irrigate high risk fields with a maximum of 75% of the water capacity of the soi to prevent the soil from getting too wet (Baarlen & Turkensteen, 2008). Besides controlling irrigation, it is also advised to avoid compaction of the soil. This can cause standing water on the field and might increase the susceptibility to an infection with powdery scab (Brierley et al., 2008).

Using clean seeds has also no effect if the soil is already contaminated. The solution is to select fields that have no history of with powdery scab contamination and plant there clean seeds. For the contaminated fields the only solution is to grow resistant varieties (Wale et al., 2008). A field can very easily be infected with powdery scab by infected seeds but also by the choice of fertilization. The use of animal manure can increase the risk of infection when the animals where fed with infected potatoes (Baarlen & Turkensteen, 2008).

3.4.2 Chemical intervention
Research shows that soils with a higher level of zinc have a lower risk on powdery scab. This is the case for soils with a zinc level greater than 6 mg/kg. When soil samples show that the zinc levels are lower it is advised to apply zinc to the field. It is advised that the maximum application is 15 kg of zinc per hectare (Brierley et al., 2008).For the prevention or control of powdery scab not many fungicides have proven to be successful. For a soil treatment, fluazinam and flusulphamide have shown some promising results, but the effects are variable (Wale et al., 2008).

Research of the British Potato Council shows that Fluazinam and Mancozeb are the most effective fungicides in the treatment of powdery scab. The research compared many fungicides as a soil treatment around tuber initiation. Fluazinam and Mancozeb where the only to fungicides that where effective against root galls and Powder Scab both caused by *S. subterranea* (Wale et al., 2005).

3.4.3 Storage

Research shows that air-drying before storing the seed potatoes does not kill the spores of powdery scab. The harvested potatoes must be free of soil before they are put into storage. When the conditions are moist and there is still a lot of soil in the boxes that contains spores of Powdery Scab it is possible that tubers get infected with Powdery Scab in storage (Brierley et al., 2008).

3.5 Controlling Skin Spot

The fifth sub-question: *How can skin spot be controlled in seed potatoes in Norway?* Is focussing on the fungal skin disease skin spot. During the literature study 7 references were found. Out of these references all 7 references were used to answer this sub-question. This paragraph will summarise the information out of these references.

3.5.1 Cultivation method

Seed influence

The most important control measure is using clean seeds because skin spot can multiply significantly during seed multiplication. Tubers with physical symptoms of skin spot must be rogued out of the seeds before planting. To keep the disease pressure low in seed multiplication it is important to use long crop rotations, material out of clean stock material, and use as less possible multiplications as possible. (Wale et al., 2008). There are differences in sensibility of varieties for skin spot. Usually, varieties with a thicker skin are less sensitive to skin spot than varieties with a thin skin (Turkensteen, 2008).

Soil influence

Sclerotia of skin spot can remain up to 7 years in the soil. Therefore, it is important to control volunteer potatoes in other crops because these can increase the level of infection in the soil (Lees et al., 2009). Skin spot tends to have a bigger impact in heavier soils with bad drainage. Well drained light soils are preferred in strategies to reduce skin spot in seed multiplications (Sutton et al., 2004).

Cultivation influence

Research shows that varieties with short stolons have a higher risk on Skin Spot infection than varieties that form daughter tubers on a further distance. It is advised to multiply varieties with short stolons less than varieties with long stolons (Sutton et al., 2004). Research from the British Potato Council shows that irrigation might increase the infection of skin spot. The fungi *Polyscytalum pustulans* that causes skin spot can transfer easier from seed tuber to daughter tuber in moist soils. Irrigating the field too much is there for increasing the infection of skin spot (Sutton et al., 2004). The ideal circumstances for harvesting the seed potatoes are warm and dry conditions. Early harvesting can help to minimize the development of skin spot (Agriculture and Horticulture Development Board, 2023).

3.5.2 Chemical intervention

Before 2007 skin spot could easily be prevented with the application of 2-aminobutane. This fungicide was very effective but since this fungicide is no longer allowed the prevention is more challenging. A research out of 2010 from the Potato Council of the Agriculture and Horticulture Development Board researched other fungicide application methods. The

research tested the application of Fungazil 100 SL, Xedazil hot fogging treatment, and drying untreated tubers. The research showed that both Fungazil 100 SL and Xedazil hot fogging treatment are effective in reducing skin spot infection. An important factor for this research is that the tubers are completely covered with the use fungicide for a good result (Wale & Harper, 2010).

The timing of tuber treatment is preferred to be shortly after harvesting. This is because the symptoms of skin spot start to show after two months of storage. By treating the tubers before the symptoms start to show the development can be better repressed (Sutton et al., 2004).

3.5.3 Storage

It is ideal to know if seed potatoes are infected with skin spot before they are put into storage. However, this is difficult to know because symptoms of infection start to show after about two months in storage. Research shows that PCR testing a harvested crop can contribute into making a better strategy plan for storing seed potatoes. Taking samples of the tuber peel can give a good view on the severity of the infection with skin spot before the symptoms start to show after a long time of storage (Peters et al., 2010).

Dry curing immediately after harvesting is an effective way to control skin spot in storage. The temperature in storage has an influence on the development of skin spot in storage. Storing the tubers in the cold gives a higher risk of the development skin spot. Research shows that storage below 4°C gave a higher development than storage at 5-8 °C (Sutton et al., 2004).

Hygiene is an important measure to prevent the spread of skin spot to healthy stock material. This measure is especially important for storage between seasons. Condensation must be prevented in storage and during sprouting (Wale et al., 2008). Storages that had problems with infection with skin spot must be cleaned and disinfected thoroughly before new seeds will be stored in the same storage (Agriculture and Horticulture Development Board, 2023).

4. Discussion

In this chapter, the discussion is presented, addressing the five research sub-questions. The research approach, findings, and the course of the study are critically examined, incorporating areas for improvement. A comprehensive analysis of the results is conducted and considering specific circumstances influencing the research findings. The discussion is further elaborated, with each sub-question discussed in its respective sub-section.

4.1 Sub-question 1: How can black dot be controlled in seed potatoes in Norway?

During the literature review, it became evident that a considerable number of recent references were available on the topic of the black dot. As anticipated, all pertinent sources utilized in this research were located in online databases. The search topics employed in the methodology of this study proved to be comprehensive enough to address the specified sub-question. The abundance of valuable information, both in Dutch and English, greatly contributed to the effectiveness of this research.

The literature study on controlling black dot in seed potatoes in Norway resulted valuable insights. It shows the important role of microsclerotia in soil as the major source of infection. However, the difficulty lies in the presence in the soil of microsclerotia for up to 13 years, posing difficulties in effective crop rotation (Peters et al., 2016). The study pointed out the limited success of crop rotation and suggested alternative strategies such as selecting black dot-resistant potato varieties (Schnee et al., 2021) and utilizing PCR to assess soil infection levels for long-term field planning (Harper & Peters, 2009).

Chemical interventions were investigated, revealing a potential negative effect of the intensive use of fungicides (Bus & Wustman, 2007). While fungicides like Amistar and Maxim 100FS showed promise, it was noted that excessive use might cause plants more susceptible to black dot (Bus & Wustman, 2007). Careful consideration of dosage and alternative methods like seed treatment were suggested to strike a balance between disease control and maintaining soil health (Tönjes, 2019).

Efficient post-harvest practices were found to reduce black dot in storage. Quick drying and cooling of potatoes (Bus & Wustman, 2007), along with soil reduction in storage boxes, were proposed to minimize the infection of black dot. Additionally, the use of PCR to assess black dot levels before storage was recommended for informed decision-making in implementing long-term storage strategies (Harper & Peters, 2009).

4.2 Sub-question 2: How can silver scurf be controlled in seed potatoes in Norway?

The literature review on silver scurf closely mirrored the approach taken for black dot. Digital databases provided a substantial number of relevant references on silver scurf. The available information on silver scurf appeared to be less current compared to, for instance, black dot. However, despite this, there were still sufficient recent and relevant references to gain valuable insights. The introduction already confirmed that silver scurf is present in most countries where potatoes hold significant agricultural importance, potentially explaining the high number of accessible information in online databases.

The research on managing silver scurf underscored the important role played by infected seed tubers in the transmission of the disease. While crop rotation had minimal impact, irrigation and planting density were identified as influential factors (Veerman, 2001).

Chemical interventions played a crucial role in managing silver scurf. Seed treatments, including Emesto Silver, demonstrated effect in controlling infection during seed multiplication (Bayer Agro Nederland, 2020). Moreover, the study showed the importance of choosing fungicides wisely, considering their impact on both pre -and post-harvest periods (Veerman, 2001).

Preventing the development of silver scurf in storage involved good post-harvest practices. Rapid drying, cooling, and minimizing soil content in storage boxes emerged as key measures. The significance of separating batches based on infection levels to prevent cross-contamination in storage was underlined. The most important measurement in controlling silver scurf in storage is avoiding dust in storage (Bus & Balen, 2022).

4.3 Sub-question 3: How can black scurf be controlled in seed potatoes in Norway?

The literature review on black scurf followed a pattern similar to that of the first two sub-questions. The factsheet on the integrated approach to rhizoctonia in potatoes, published by BO akkerbouw in 2022, offered valuable and up-to-date insights. In addition to this factsheet, online databases proved to be rich sources of information on black scurf. Both Dutch and English references were abundant. As expected, the majority of information was sourced from online databases. The search topics outlined in the methodology were extended enough to answer the third sub-question.

The study on black scurf control results in the importance of soil and cultivation measurements. Field selection, cover crops, and the influence of previous crops were identified as crucial factors (Wageningen University, 2005; BO akkerbouw, 2022). Additionally, green-sprouting seed tubers and careful timing of planting were suggested to strengthen plants against *R. solani* (Wale et al, 2008).

Chemical interventions, particularly soil treatment with Amistar, showed good results in black scurf control. However, it was crucial to determine the optimal dosage for effectiveness. 3L Amistar per hectare is the most optimal dosage (Syngenta, 2022). Additionally, tuber treatments with thiabendazole were recommended for limiting damage and spreading in storage (Wale et al, 2008).

Effective control of black scurf in storage involved strategies such as rapid drying, avoiding cone-shaped hills (Turkensteen, 2008), and ensuring an even pile of seed potatoes. These measurements aimed to minimize moisture and soil content in the box as crucial factors in preventing black scurf development during storage (BO akkerbouw, 2022).

4.4 Sub-question 4: How can powdery scab be controlled in seed potatoes in Norway?

The literature study for the fourth sub-question presented a somewhat greater challenge compared to the first three sub-questions. The majority of valuable references on powdery scab dated back to before 2010, raising concerns about the current relevance of the

information. Although the online databases utilized in this study did not yield sufficient results, two key resources, namely "Aardappelziektenboek" by A. Mulder and L. J. Turkensteen and "Diseases, Pests, and Disorders of Potatoes" by S. Wale, H. W. B. Platt, and N. Cattlin, proved to be highly beneficial. The integration of information from these two books, along with the online databases, made it possible to answer the fourth sub-question.

The study on powdery scab control shows the importance of presence of *S. subterranea*spores in the soil on the risk of infection. Crop rotation, soil pH management (Brierley et al., 2008), and the influence of the previous crop grown as important factors (Baarlen & Turkensteen, 2008). Additionally, cover crops, particularly Indian mustard (Larkin & Griffin, 2007), and close attention to tuber set timing were found as effective measures (Wale et al., 2008).

The role of zinc levels in soil (Brierley et al., 2008) and the limited success of fungicides like fluazinam and flusulphamide were found in the context of powdery scab control. It was noted that soil treatment around tuber initiation with specific fungicides, including Fluazinam and Mancozeb, showed efficacy against root galls and powdery scab (Wale et al., 2008).

Preventing powdery scab in storage required attention to factors such as air-drying, soil cleanliness, and maintaining stable temperatures. Research emphasized the importance of preventing dust, segregating batches based on infection levels, and following specific temperature ranges (Brierley et al., 2008).

4.5 Sub-question 5: How can skin spot be controlled in seed potatoes in Norway?

The final sub-question of this literature study proved to be the most challenging. As outlined in the introduction, skin spot is predominantly problematic in colder regions of Europe, with limited impact in larger parts of the world. This regional specificity likely contributed to the scarcity of available references in online databases. While the expectation was to uncover the majority of information online, it became evident that the most valuable resource for this sub-question was "Diseases, Pests, and Disorders of Potatoes" by S. Wale, H. W. B. Platt, and N. Cattlin. Given that skin spot is a significant issue in Scotland, the majority of relevant references originated from Scottish sources. Despite the challenge in locating relevant information for this sub-question, the ultimate outcome was satisfactory.

Effective control of skin spot started with seed selection, focusing the importance of clean seeds. Crop rotations, good soil drainage (Wale et al., 2008), and varieties with thicker skin were recommended practices (Turkensteen, 2008). Additionally, the study underscored the need for controlling volunteer potatoes and the preference for well-drained light soils (Lees et al., 2009).

The study acknowledged the challenge caused by the discontinuation of the fungicide 2-aminobutane for skin spot prevention. However, alternative fungicides such as Fungazil 100 SL and Xedazil hot fogging treatment showed promise (Wale & Harper, 2010). The timing of tuber treatment, shortly after harvesting, was crucial for optimal results (Sutton et al., 2004).

Preventing skin spot in storage involved practices such as PCR testing (Peters et al., 2010), immediate drying after harvesting (Sutton et al., 2004), and maintaining hygiene (Wale et al., 2008). The study shows the role of temperature in storage, advising against extremely cold conditions (Sutton et al., 2004). Additionally, thorough cleaning and disinfection of storages and boxes with a history of skin spot infection were deemed necessary (Agriculture & Horticulture development board, 2023).

5. Conclusion

The main question of this research was "*How can skin diseases be controlled in seed potato production in Norway?*" To answer this main question, five sub-question were answered by conducting a literature study. The next paragraphs will explain the proposed answers and conclusion deduced from this work for each sub-question:

Controlling black dot:
For black dot, it is essential to address soil influences, considering factors such as crop rotation, soilborne inoculum levels, and selecting less susceptible potato varieties. Chemical interventions involve cautious fungicide use, considering the potential side effects, and seed treatment. Proper storage practices, including quick drying, cooling, and soil management, are crucial in minimizing black dot development.

Controlling silver scurf:
The control of silver scurf revolves around managing seed tubers, cultivation practices, and chemical interventions. Attention to seed tuber quality, planting distance, and irrigation practices plays a key role. Chemical treatments such as Emesto Silver and other fungicides are effective, particularly in seed treatment. Storage practices emphasize cleanliness, separation based on infection levels, and maintaining stable temperatures.

Controlling black scurf:
Effective control of black scurf involves addressing soil and cultivation influences. Crop selection, green manure crops, and comprehensive crop rotation are essential. Chemical interventions such as Amistar for soil preparation and thiabendazole for tuber treatment are recommended. Storage practices emphasize fast drying, separating roots, and avoiding soil in storage boxes.

Controlling powdery scab:
Powdery scab control focuses on soil and cultivation factors. Crop rotation, soil pH management, and selecting resistant varieties are crucial. Chemical interventions, such as zinc application and specific fungicides, have been identified. Proper irrigation management and avoiding soil compaction are highlighted, along with clean seed selection. Storage practices stress air-drying before storage and avoiding moist conditions.

Controlling skin spot:
Controlling skin spot requires attention to seed quality, soil influences, and cultivation practices. Clean seeds, long crop rotations, and avoiding excessive irrigation are important. Chemical interventions, including fungicide applications such as Fungazil 100 SL, are effective. Storage practices involve early treatment, dry curing, and maintaining proper hygiene to prevent the spread.

In conclusion, the strategies for controlling various fungal skin diseases in seed potatoes in Norway involve a combination of cultivation methods, chemical interventions, and storage practices. Each fungal disease requires a tailored approach based on its unique characteristics. This makes it important to know which fungal skin disease is causes the biggest problem to decide what controlling measures are needed.

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7. Attachments

7.1 CRAAP-Test

Evaluating Information – Applying the CRAAP Test

Meriam Library 🕮 California State University, Chico

When you search for information, you're going to find lots of it . . . but is it good information? You will have to determine that for yourself, and the **CRAAP Test** can help. The **CRAAP Test** is a list of questions to help you evaluate the information you find. Different criteria will be more or less important depending on your situation or need.

Key: ■ indicates criteria is for Web

Evaluation Criteria

Currency: ***The timeliness of the information.***

- When was the information published or posted?
- Has the information been revised or updated?
- Does your topic require current information, or will older sources work as well?
- ■Are the links functional?

Relevance: ***The importance of the information for your needs.***

- Does the information relate to your topic or answer your question?
- Who is the intended audience?
- Is the information at an appropriate level (i.e. not too elementary or advanced for your needs)?
- Have you looked at a variety of sources before determining this is one you will use?
- Would you be comfortable citing this source in your research paper?

Authority: ***The source of the information.***

- Who is the author/publisher/source/sponsor?
- What are the author's credentials or organizational affiliations?
- Is the author qualified to write on the topic?
- Is there contact information, such as a publisher or email address?
- ■Does the URL reveal anything about the author or source?
  examples: **.com .edu .gov .org .net**

Accuracy: ***The reliability, truthfulness and correctness of the content.***

- Where does the information come from?
- Is the information supported by evidence?
- Has the information been reviewed or refereed?
- Can you verify any of the information in another source or from personal knowledge?
- Does the language or tone seem unbiased and free of emotion?
- Are there spelling, grammar or typographical errors?

Purpose: ***The reason the information exists.***

- What is the purpose of the information? Is it to inform, teach, sell, entertain or persuade?
- Do the authors/sponsors make their intentions or purpose clear?
- Is the information fact, opinion or propaganda?
- Does the point of view appear objective and impartial?
- Are there political, ideological, cultural, religious, institutional or personal biases?

9/17/10

7.2 References literature study

Titel artikel	Auteurs	Publicatie	Samenvatting	DOI/Link	Peer-reviewd	Deelvraag	CRAAP-score
A mechanized two-step cleaning and disinfection process strongly minimizes pathogen contamination on wooden potato storage boxes	Hubertus Fehres, Ada Linkies	Crop Protection 103 (2018) 111-114	A research that looked into the best way to disinfect wooden potato boxes to clean them completely of pathogens of deverent diseases. The article talks about a machine that first cleans the box with a disinfectant as a solutiond and second with a disinfectant foam. Black dot pathogens are reduced this way by 96%.	https://doi.org/10.1016/j.cropro.2017.09.016	Yes	1	35
A Quantitative Polymerase Chain Reaction Assay for the Detection of Polyscytalum pustulans, the Cause of Skin Spot Disease of Potato	Allison K Lees, L. Sullivan, Dave Cullen	Journal of Phytopathology 157 (2009)	A research on PCR testing to recognize Skin Spot in the soil. This might help in making good strategies in growing season	DOI:10.1111/j.1439-0434.2008.01459.x	Yes	5	46
Aardappel ziektenboek	A. Mulder & L. J. Turkensteen	PlantijnCasparie (2008)	A book about all diseases that occur in potato production in the Netherlands. The book gives detailed information about all types of diseases and how to prevent them	Physical book	No	1,2,3,4,5	48
Antifungal activity in vitro of *Aloe vera* pulp and liquid fraction against plant pathogenic fungi	D. Jasso de Rodr ́ıguez, D. Hernández-Castillo, R. Rodr ́ıguez-Garc ́ıa, J.L. Angulo-Sánchez	Industrial Crops and Products 21 (2005) 81-87	A research on the use of leaf pulp of Aloe Vera to reduce the colony growth of plant pathogenic fungi. The research shows that The aplication of Aloe Vera has a reducing effect on the colony growth of Black Dot and Black Scurf.	doi:10.1016/j.indcrop.2004.01.002	Yes	1 & 3	32
Beheersing van zilverschurft in biologische aardappelen	Kees Bus & Derk van Balen	Biokennis (2022)	An article on biokennis about the management of silver scurf in organic potato production. The article gives detailed information on the prevention of silver scurf in storage	https://edepot.wur.nl/160149	No	2	42
Characterization of weeds and rotational crops as alternative hosts of Spongospora subterranea, the causal agent of powdery scab in Israel	L. Tsror (Lahkim), R. Shapira, O. Erlich, M. Hazanovsky, S. Lebiush	Plant Pathology 69 (2019) 294-301	A research on hostplants for powdery scab. This research was performed to see the inpact of a previous crop on the development of powdery scab in potaotes.	https://doi-org.aeres.idm.oclc.org/10.1111/ppa.13117	Yes	4	45
Chitinase Production by bacillus Subtilis ATCC 11774 and its Effect on Biocontrol of Rhizoctonia Diseases of Potato	Wesam I. A. Saber, Khalid M. Ghoneem, Abdulaziz A. Al-Askar, Younes M. Rashad, Abeer A. Ali & Ehsan M. Rashad	Acta Biologica Hungarica 66 (2015) 436–448	A research on the use of the enzyme bacillus subtilis ATCC 11774 against rhizoctonia solani.	https://doi.org/10.1556/018.66.2015.4.8	Yes	3	34
Compost tea as a sustainable alternative to promote plant growth and resistance against Rhizoctonia solani in potato plants	Javier Plaza, Ana I.Gonzalez-Hernandez, R. Perez Sanchez, M. Remedios Morales-corts	Scientia Horticulturae 300 (2022) 1090-1100	A research on the use of compost teas as a leaf fertilizer in the prevention of rhizoctonia solani. It is believed that by making the plants stronger that they are more resistant against rhizoctonia solani	https://doi.org/10.1016/j.scienta.2022.111090	Yes	3	47
Control measures for potato skin spot	Stuart Wale, Mark Sutton, Jeff Peters	British Potato Council (2004)	A report on the prevention of skin spot	https://projectbluearchive.blob.core.windows.net/media/Default/Research%20Papers/Potatoes/R251%20Skin%20Spot%20Review_0.pdf	Yes	5	47
Control of soilborne potato diseases using Brassica green manures	Robert P. Larkin, Timothy S. Griffin	Crop Protection 26 (2007) 1067-1077	A research that did a practical research on the use of Brassica crops to prevent soilborne diseases in potato. Multiple Brassica crops were tested on multiple soilborne diseases. Rapeseed and Canola turned out to be most effective on reducing Black Scurf. Indian Mustard turned out to be most effective on reducing Powdery Scab and Common Scab	doi:10.1016/j.cropro.2006.10.004	Yes	3 & 4	45
Crop duration and soil inoculum as predictors of black dot risk after storage	G. Harper & J. Peters	British Potato Council (2009)	A report about the development of black dot during the growing season out of the soil. The research focus on finding black dot and preventing the disease	https://projectbluearchive.blob.core.windows.net/media/Default/Research%20Papers/Potatoes/200913%20R400%20Final%20Report_0.pdf	Yes	1	46
Development of Rhizoctonia solani on Stems, Stolons and Tubers of Potato II. Efficacy of Chemical Applications	Dennis Atkinson, Michael K. Thronton, Jeffery S. Miller	American Journal of Potato Research 88 (2011) 96–103	A research on seed treatment with fungicide to prevent rhizoctonia solani in combination with soil treatment to prevent black scurf.	https://doi.org/10.1007/s12230-010-9172-1	Yes	3	39
Diseases, Pests and Disorders of Potatoes	Stuart Wale, H. W. (Bud) Platt, Nigel Cattlin	CRC Press (2008)	A book on diseases in potatoes. The book gives extended information about all fungal skin diseases in potato and how these can be prevented in the best way possible	Physical book	No	1,2,3,4,5	48
Effect of a combination of chlorine dioxide and thiophanate-methyl pre-planting seed tuber treatment on the control of black scurf of potatoes	Deena Errampalli, Rick D. Peters, Kathy MacIsaac, Danny Darrach, Peter Boswall	Crop Protection 25 (2006) 1231-1237	A research on preventing Black Scurf by using a pre-planting seed super treatment. The seed tuber are treated before planting with a mixture of chlorine dioxide and thiophanate-methyl. The results show that the Black Scurf can not develop on tubers that are treated with the mixture and are therfor protected against Black Scurf.	doi:10.1016/j.cropro.2006.03.002	Yes	3	32

Effect of water activity on the production of volatile organic compounds by Muscodor albus and their effect on three pathogens in stored potato	Ronan CORCUFF, Julien MERCIER, Russell TWEDDELL, Joseph ARUL	Fungal Biology 115 (2011) 220-227	A research on the use of VOC in the control of Silver Scurf. The research has tested multiple VOC's on their effect of the reduce of Silver Scurf in stored potatoes. The results of the research show that VOC m. albus has the best effect on Silver Scurf in storred potatoes.	doi:10.1016/j.funbio.2010.12.005	Yes	2	33
Effects of Different Soil Treatments on the Development of Spongospora subterranea f. sp. subterranea in Potato Roots and Tubers in the Greenhouse	Kenedy Simango & Jacquie E. van der Waals	Potato Research 60 (2017) 47-60	A research on soil treatments in greenhouses to treat the soil on spongospora subterranea that causes powdery scab. The research names usefull chemicals for the treatment of Powdery Scab	https://doi.org/10.1007/s11540-017-9340-5	Yes	4	38
Epidemiology, autecology and control of spongospora subterranea cause of potato powdery scab	Stuart Wale, Pieter van de Graaf, Alison Lees	British Potato Council (2005)	A report on the characteristics of the fungi spongospora subterranea that causes powdery scab. The report gives detailed infomation about the disease and how to prevent it	https://projectbluearchive.blob.core.windows.net/media/Default/Research%20Papers/Potatoes/20054%20Powdery%20scab%20Final%20Report.pdf	Yes	4	46
Factsheet integrale beheersing van rhizoctonia in aardappel	BO Akkerbouw	BO akkerbouw (2022)	A factsheet on the prevention of rhizoctonia solani that causes black scurf. The factsheet gives a lot of detailed information on the prevention of the fungal disease	https://www.bo-akkerbouw.nl/files/Pdfs-Kennis-en-Innovatie/FactsheetRhizoctonia.pdf	No	3	47
Influence of abiotic factors, inoculum source, and cultivar susceptibility on the potato tuber blemish diseases black dot (*Colletotrichum coccodes*) and silver scurf (*Helminthosporium solani*)	Schnee, S., Massana-Codina, J., Lecoultre, N., Droz, E., Dupuis, B., Keiser, A., Werra, de, P., Wolfender, J., Gindo, K., Schürch, S.	Plant Pathology 70 (2021) 885-897	A research on abiotic factors, cultivar and inoculum sources that prevent tuber blemish diseases. The research focusses on black dot and silver scurf.	DOI: 10.1111/ppa.13350	Yes	1 & 2	47
Isolation, identification and biocontrol mechanisms of endophytic bacterium D61-A from Fraxinus hupehensis against Rhizoctonia solani	Tong-wen Zheng, Lu Liu, Qian-wen Nie, Tom Hsiang , Zheng-xiang Sun, Yi Zhou	Biological Control 158 (2021) 104621	A research on finding a bacteria with potential biological control activities against Rhizoctonia Solani. The research shows that endophytic bioctrol bacteria from F. Hupehensis has the best results on reducing Rhizoctonia Solani.	https://doi.org/10.1016/j.biocontrol.2021.104621	Yes	3	30
Karakterisering, pathogeniteit en chemische bestrijding van rhizoctonia spp.	Sofie Venneman	Universiteit Gent (2014)	A detailed report on rhizoctonia solani. The report gives detailed information about the manegement and prevention of black scurf	https://libstore.ugent.be/fulltxt/RUG01/002/166/381/RUG01-002166381_2014_0001_AC.pdf	No	3	42
Literatuuronderzoek zilverschurft	Ir. A. Veerman	Wageningen Universitiy (2001)	A report on silver scurf. The report gives a complete overview on the fungal disease silver scurf. On the	https://kennisakker.nl/storage/1996/RAPPORT_1154388-1_LITERATUURSTUDIE_ZILVERSCHURFT.pdf	Yes	2	43
Managing the elusive potato black dot pathogen, colletotrichum coccodes	Dennis A. Johnson and Thomas F. Cummings	Washington State University (2015)	A report on managing black dot. The report gives a clear and extensive view on the fungi colletotrichum coccodes that causes black dot and how to prevent or treat black dot	https://www.nwpotatoresearch.com/images/documents/Johnson%20and%20Cummings%202015Proceedings.pdf	No	1	45
Onderzoek bestrijding poederschurft bij aardappelen	C. B. Bus	Wageningen University (2003)	A complete report on the prevention of powdery scab in potato production in the Netherlands	https://edepot.wur.nl/233772	No	4	42
Potato Production Worldwide	Mehmet Emin Çalişkan, Allah Bakhsh and Khawar Jabran	Academic Press, ISBN 978-0-12-822925-5 (2022)	A book about all potato production worldwide. The book discusses all topics that are important in potato production. Also a full chapter on all fungal diseases that are causing skin demage on potatoes	https://doi.org/10.1016/C2019-0-04360-9	No	1,2,3,4,5	45
Powdery Scab - Strains and Conducive Conditions	J. Brierley, A. Lees, S. Wale	Agriculture & Horticulture Development Board (2008)	A complete report on powdery scab. The origination of the disease untill the prevention of the disease.	https://projectbluearchive.blob.core.windows.net/media/Default/Research%20Papers/Potatoes/Powdery%20Scab%20Review%20Dec%202008.pdf	Yes	4	43
Quality deficiencies on potato (Solanum tuberosum L.) tubers caused by Rhizoctonia solani, wireworms (Agriotes ssp.) and slugs (Deroceras reticulatum, Arion hortensis) in different farming systems	A. Keiser, M. Häberli, P. Stamp	Field Crops Research 128 (2012) 147-155	A research on different field trials on farming systems focussed on quality deficiencies on potatoes. Rhizoctonia Solani was less in trials were the tubers are treated before planting.	doi:10.1016/j.fcr.2012.01.004	Yes	3	31
Rhizoctonia disease of potatoes (Rhizoctonia solani): Fungicidal efficacy and cultivar susceptibility	P.S. Bains, H. S. Bennypaul, D.R. Lynch, L.M. Kawchuk, C. A. Schaupmeyer	American Journal of Potato Research 79 (2002) 99–106	A research on preventing rhizoctonia solani by seed treatment. The research compars multiple treatments. The most effective one turns out to be Maxim	https://doi.org/10.1007/BF02881518	Yes	3	35
Rhizoctonia solani	Wageningen Universitiy	Wageningen Universitiy (2005)	A small report about rhizoctonia solani. The report gives detailed information about the recognision and prevention of rhizoctonia solani that causes black scurf	https://edepot.wur.nl/30568	No	3	45
Root infection of potato by Spongospora subterranea: knowledge review and evidence for decreased plant productivity	R. E. Falloon, U. Merz, R. C. Butler, D. Curtin, R. A. Lister, S. M. Thomas	Plant Pathology 65 (2015) 422-434	A literature research on the infection of the roots by spongospora subterranea that causes powdery scab. The research helps to understand the fungi better and gives a lot of knowlegde on powdery scab	https://doi-org.aeres.idm.oclc.org/10.1111/ppa.12419	Yes	4	41
Skin Spot	Agriculture & Horticulture Development Board	Agriculture & Horticulture Development Board (2023)	The website of Agriculture & Horticulture Development Board gives clear information about the disease skin spot	https://potatoes.ahdb.org.uk/knowledge-library/skin-spot#:~:text=Skin%20spot%20(Polyscytalum%20pustulans)%20is,show%20spots%20on%20some%20varieties.	No	5	40

Skin Spot management - polyscytalum pustulans qPCR assay	Wale, S. ; Harper, G.	Agriculture & Horticulture Development Board (2010)	A report on the diagnosing skin spot with the help of PCR	https://projectbluearchive.blob.core.windows.net/media/Default/Research%20Papers/Potatoes/201015%20Final%20Report%20Skin%20Spot%20(PCR%20work)%20R413.pdf	Yes	5	41
Strijd tegen zwarte spikkel begint al in teelt	Jorg Tönjes	Nieuwe Oogst (2019)	An article about the development of black dot during the growing season. The article gives advise on how to deal with black dot and prevent it as much as possible	https://www.nieuweoogst.nl/nieuws/2019/11/26/strijd-tegen-zwarte-spikkel-begint-al-in-teelt	No	1	43
Terugdringen zwarte spikkel bij tafelaardappelen in Groot Brittanië	C. B. Bus & R. Wustman	Praktijkonderzoek Plant & Omgeving (2007)	A report on managing black dot in Great Britain. The report gives detailed information on strategies to manage black dot	https://edepot.wur.nl/43443	No	1	46
The effect of post-harvest storage conditions on the development of black dot (Colletotrichum coccodes) on potato in crops grown for different durations	J. C. Peters, G. Harper, J. L. Brierley, A. K. Lees, S. J. Wale, A. J. Hilton, P. Gladders, N. Boonham, A. C. Cunnington	Plant Pathology 65 (2016) 1484-1491	A research on the effect of storage temperature on the severity of black dot. The research compares multiple temperatures and storages with each other to find out what is the optimal way of storing potatoes to prevent black dot in storage	https://doi-org.aeres.idm.oclc.org/10.1111/ppa.12535	Yes	1	45
The Relative Importance of Seed- and Soil-Borne Inoculum of Rhizoctonia solani AG-3 in Causing Black Scurf on Potato	J. L. Brierley, A. J. Hilton, S. J. Wale, J.W. Woodhall, A. K. Lees.	Potato Research 59 (2016) 181–193	A research on the impact of soil borne inoculum of rhizoctonia solani on the development of black scurf.	https://doi.org/10.1007/s11540-016-9320-1	Yes	3	46
The role of storage on Mancozeb fungicide formulations and their antifungal activity against Fusarium oxysporium and Rhizoctonia solani	Azza R. Emara, Hala M. Ibrahim, Sanaa A. Masoud	Arabian Journal of Chemistry 14 (2021) 103322	A research on the effect of the way of storing the fungicide Mancozeb in combination with the anrifungal activity against Rhizoctonia Solani. The research shows that there is a strong corelation with the way of storing and the effectivity of the fungicide against Rihizoctonia Solani.	https://doi.org/10.1016/j.arabjc.2021.103322	Yes	3	38
The use of natural plant volatile compounds for the control of the potato postharvest diseases, black dot, silver scurf and soft rot	Elisabeth M. Wood, Timothy D. Miles, Phillip S. Wharton	Biological Control 64 (2013) 152-159	A research of the use of natural plant volatile compounds (VOC) to prevent the development of Black Dot, Silver Scurf, and Soft Rot in packed potatoes. 2E-hexenal was found to be very effective on stopping the development of these diseases when it is put as a gass into the packaging of packed potatoes for all three diseases.	http://dx.doi.org/10.1016/j.biocontrol.2012.10.014	Yes	1 & 2	35
Tips aanpak rhizoctonia en zwarte spikkel	Syngenta	Akkerwijzer (2022)	A article on the website of akkerwijzer on the management strategy on rhizoctonia solani	https://www.akkerwijzer.nl/artikel/450134-tips-aanpak-rhizoctonia-en-zwarte-spikkel/	No	3	41
Ultrastructure of the infection process of potato tuber by Helminthosporium solani, causal agent of potato silver scurf	Carole Marinez, Danny Rioux, Russell J. Tweddell	Mycol. Res. 108(004) 828-836	A research on the lifecycle of Silver Scurf. The research gives a detailed view on the infection by Helminthosporium Solani which causes Silver Scurf. The article explains how tubers get infected by this pathogen.	DOI: 10.1017/S0953756204000589	Yes	2	45
Zilverschurft op de aardappeloogst van 2020?	Bayer Agro Nederland (2020)	Bayer Agro Nederland (2020)	A article on the website of Bayer Agro Nederland on the status of silver scurf on potatoes in 2020. The article gives information about the development en the prevention of silver scurf	https://agro.bayer.nl/Uit-de-praktijk/Nieuwsoverzicht/Nieuws?item=MTQyYzZhOTgtNjlmNC00MDgzLWI4OGYtOGQ2NzFiYThhYWE1	No	2	45
Zwarte spikkel	Syngenta	Syngenta (2023)	Information on the website of Syngenta about the the conditions that are beneficial for black dot	https://www.syngenta.nl/zwarte-spikkel/zwarte-spikkel	No	1	42