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Use of plant protection in winter cereals and growth regulators

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Agronomy plan cereals

This paper is written by Ton Boers as a graduate paper. This paper contains a description for the growing conditions and practices for producing winter cereal seeds on sandy soils in the Netherlands

Summary

Growing conditions

The growing conditions depend on several factors such as soil, sowing and the growing season. These factors must be used as optimally as possible.

Soil

The soil consists of physical, chemical and biological properties. With sandy soils, this means that there is a coarse grain that allows water and nutrients to pass through easily, allowing it to wash out. The sandy soils are typically low in pH.

Drilling

Before sowing, plowing, cultivation and spraying are necessary to prevent weeds and volunteers. A compact layer must be present under the cultivated layer to bring moisture up through capillary function. Sowing takes place 10-14 days earlier than in conventional cultivation to come up with a well-developed plant for the winter.

Growing stages

The growth stages of grains are divided into a scale of 100 stages, this scale is named after the compiler namely Zadok. An overview of these growth stages can be seen in appendix 1. Many plant protection products contain advice at which stage the best can be applied. That is why it is important to know what stage the plant has reached.

Harvest

To harvest, the circumstances must be correct. The soil must have sufficient capacity, the moisture content of the plants must be around 14% and there must be enough room to be able to turn with the combine.

Problems and recommendations

In seed production it is important that the crop remains vital. It is therefore necessary to have a good understanding of which diseases, pests and weeds can occur, like lack of nutrients or fungi's. It is also important to know what can be done if problems arise.

Growth

To stimulate or regulate growth, use can be made of growth regulators. To regulate growth, use can be made of growth regulators, these means are used to keep the plants short to prevent lodging. It is also used to keep the first shoot short so that the secondary shoots develop further and several large culms are created for higher seed yield. This report works out which products can be used on what time to achieve optimum results within the law, like CCC UPL-750 or Medax.

Weeds

Many weeds are found on Dutch sandy soils. It is important to have as few weeds as possible in the crop because they compete and nutrients are taken from the crop. It is important to start with a clean field, therefore a non-selective herbicide is used for the first soil preparation. This is repeated a few weeks after plowing so that the field is as weed-free as possible before sowing. Various herbicides can be used during cultivation. An overview of this is included in the report based on the Dutch authorizations for plant protection products.

Diseases / fungi

There are many diseases and fungi that can occur in winter grains. The most common are listed in an appendix. The plant protection products that are permitted against diseases and fungi have been investigated and worked out in this report.

Pests

There are not many pests in winter grains. The only one covered in this report is the aphid. Other pests such as snails and ride needles do not occur on sandy soils. Aphid is a problem in cereals because it transmits the barley yellowing virus.

Samenvatting

Groeiomstandigheden

De groeiomstandigheden zijn afhankelijk van meerdere factoren zoals bodem, zaaien en het groeiseizoen. Deze factoren moeten zo optimaal mogelijk benut worden.

Bodem

De bodem bestaat uit fysieke, chemische en biologische eigenschappen. Bij zandgronden betekent dit dat er een grove korrel is die water en nutriënten makkelijk doorlaat, waardoor deze uitspoelen. De zandgronden zijn vaak ook laag van pH.

Zaaien

Voor het zaaien moet er geploegd, gecultiveerd en gespoten worden om onkruiden en opslag te voorkomen. Onder de gecultiveerde laag moet een compacte laag aanwezig zijn om door capulaire werking vocht naar boven te brengen. Het zaaien gebeurt 10-14 dagen eerder dan in conventionele teelt om voor een goed ontwikkelde plant te komen voor de winter.

Groeistadia

De groeistadia van granen zijn verdeeld in een schaal van 100 stadia, deze schaal is genoemd naar de samensteller, namelijk Zadok. Een overzicht van deze groeistadia is te zien in bjilage 1. Veel gewasbeschermingsmiddelen bevatten een advies in welk stadium ze het beste toegepast kunnen worden. Daarom is het belangrijk te weten welk stadium de plant bereikt heeft.

Oogst

Om te oogsten moeten de omstandigheden juist zijn. De bodem moet draagkracht genoeg hebben, de vochtgehalte van de planten moet ongeveer 14% zijn en er moet genoeg ruimte zijn om met de combine te kunnen draaien.

Problemen en aanbevelingen

In de zaadproductie is het belangrijk dat het gewas vitaal blijft. Het is daarom noodzakelijk om goed inzicht te hebben wat er aan ziekten, plagen en onkruiden voor kunnen komen. Het is ook belangrijk om te weten wat er gedaan kan worden als er zich problemen voordoen.

Groei

Om de groei te stimuleren of te reguleren kan er gebruik gemaakt worden van groeiregulatoren. Om de groei te reguleren kan er gebruik worden gemaakt van groeiregulatoren. Deze middelen worden gebruikt om de planten kort te houden, om legering te voorkomen. Het wordt ook gebruikt om de eerste scheut kort te houden zodat de secundaire scheuten verder ontwikkelen en er meerdere grote halmen ontstaan voor hogere zaadopbrengst. In dit rapport wordt uitgewerkt welke middelen er op welk moment moeten worden toegediend om binnen de lijnen van de wet een optimaal resultaat te behalen.

Onkruiden

Op Nederlandse zandgronden komen veel onkruiden voor. Het is belangrijk zo weinig mogelijk onkruid in het gewas te hebben, omdat deze concurreren en voedingstoffen afnemen van het gewas. Het is belangrijk om met een schoon perceel te beginnen. Daarom wordt er voor de eerste grondbewerking een niet-selectieve-herbicide gebruikt. Een aantal weken na de grondbewerking wordt dit herhaald, zodat het perceel zo onkruidvrij mogelijk is voodat er gezaaid wordt. Tijdens de teelt kunnen er verschillende herbiciden ingezet worden. Hiervan is een overzicht opgenomen in het rapport gebaseerd op de Nederlandse toelatingen van gewasbeschermingsmiddelen.

Ziekten/schimmels

Er zijn veel ziekten en schimmels die kunnen voorkomen in wintergranen. De meest voorkomende zijn opgenomen in een bijlage. De gewasbeschermingsmiddelen die toegelaten zijn tegen ziekten en schimmels zijn onderzocht en uitgewerkt in dit rapport.

Plagen

Er zijn in wintergranen niet veel plagen. De enige die in dit rapport wordt behandeld is de bladluis. Andere plagen zoals slakken en ritnaalden komen niet op zandgronden voor. Bladluis is een probleem in granen omdat de bladluis het gerstvergelingsvirus overbrengt.

Contents

1. Preface

Syngenta is one of the world's leading agriculture companies. The ambition is to help safely feed the world while taking care of the planet. Syngenta want's to improve sustainability, quality and safety of agriculture with science and innovative crop solutions. The technologies enable farmers to make better use of limited agricultural resources. With 28.000 people in more than 90 countries and working together through partnerships and collaboration the company is committed to improve farm productivity and care for the planet.

In Zeewolde, The Netherlands, is a station for cereals seeds production. This is a team with 6 people producing hybrid winter barley and winter wheat seeds. This team exist in 3 parts, the first part is for Parental Line Purification (PLP). The next part is Parental Line Maintainance (PLM) and the third part is the (Pre-) Basic Seeds Production ((P)BS).

Seed production starts after a new potential variety has been found during breeding. Only a small number of plants are present in breeding. In the first phase (PLP), small plots are sown that are checked for genetic purity by laboratory research as well as by phenotyping characteristics. This step is followed by a scaling-up to sow larger plots (PLM), and the next step is bulk propagation by sowing and harvesting large fields ((P)BS). This process continues until there is enough seed to sell to customers.

Because the plants must be genetically pure, it is important that the right actions are done during growing. A correct agronomic plan is necessary for good growth and development. The challenge here is to handle according to the Dutch law.

In the first place it is important that the plants are (/become) genetically pure. This is done through laboratory tests, which are not further discussed in this report. In addition, this is done by looking at the plants one by one in the field for specific characteristics. It is important to prevent the plants from being pollinated by other cereal varieties, this influences the genetic purity for the next generation. Therefore it is important that the fields are drilled at a correct distance from other fields, this is called the isolation distance.

In the Netherlands there are fertile (clay) soils and less fertile (sandy) soils. The most arable activities are done on the fertile clay soils. Because of the isolation distances, mentioned before, must be taken into account, the multiplication of cereal seeds in the Netherlands mainly takes place on the poorer sandy soils. Because these soils are not the most optimal for arable crops, it is a challenge to take the right actions to promote growth and development.

This report is made to create an overview on what activities have to be done for producing quality seeds on sandy soils by taking the right decisions and using the right products.

Firstly, this report describes the conditions required for cereal cultivation on sandy soils. After that, activities are described that must be carried out to keep the crop in optimum condition for a healthy plant, good development and the highest possible yield. Secondly, the minimum isolation distances are described and the further conditions that are needed for cereal seed production.

2. Growing conditions and producing hybrid seeds

This chapter contains the summary of the knowledge about growing cereals and about growing crops on sandy/poor soils. It also gives the requirements of producing hybrid cereal seeds. It further contains what has to be investigated to develop the growth of the plants.

2.1. Soil

There are a lot of things important for the soil. This can be brought back to three main points, the physical, chemical and biological characteristics of the soil. The physical characteristics tells something about the structure of the soil, the water and oxygen content and the permeability. The chemical characteristics tells something about the pH of the soil, the nutrients that are present and the EC (electric conductivity/saltiness). The last main characteristics are the biological characteristics, this means the soil life and the processes behind it. (N-XT soil services, sd)

2.1.1. Physical characteristics

2.1.1.1. Sand grains

The optimum soil contains 6-10% sand, 80-90% clay, 6-12% silt (Eurofins-agro, 2014) and organic matter but also water and air. These percentages are the best according to nutrient release and water management. Sandy soils contains less or no clay. The grain size of a sand grain is 0,5-2,0 mm. Because of the relative big size of sand grains there is relative a lot of air (O_2) between the grains. Sand grains/soils do not contain much nutrients and drains water easily. This means that nutrients are easily rinsed out, which can be developed by adding as much as possible organic matter to the soil because this will adsorb the water and prevent it from drain the nutrients. In this way organic matter can build up over the years and the available nutrients will be more and more. (N-XT soil services, sd)

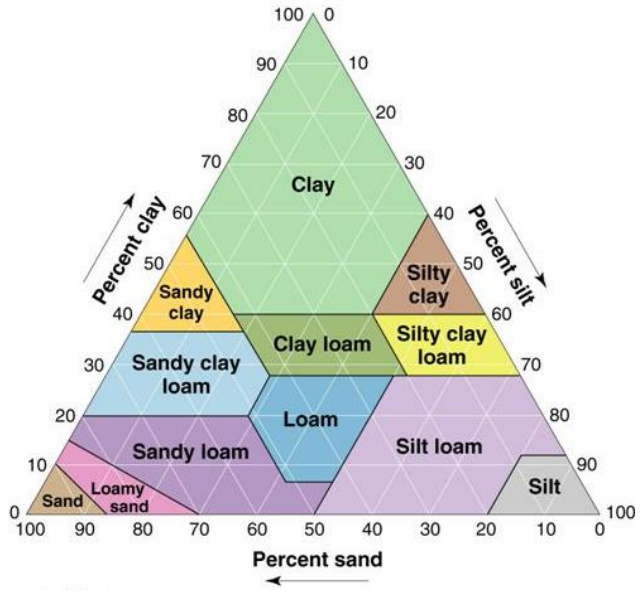

Figure 1 The soil texture triangle (Maxwell, 2016)

Sandy soils contains less than 20% clay and less than 40% silt. It is all in the left bottom in the soil texture triangle in Figure 1.

2.1.1.2. Pores

The pores between the sand grains are imported the take up O_2 and release CO_2, also to drain the water. Soil with much air and less water will warm up easier in spring. Most plant roots needs pores form 0,3-0,5 mm width. Roots can grow in smaller pores and expand these. The penetrate resistance may be maximal 1,5 MPa (Mega Pascal) and can be measured with a penetrologger. A higher penetrate resistance can be avoided by good soil preparations, adding organic matter/manure/Ca, Mg, K, Na, this also will prevent compacted soils. (Alexander & Miller, 1991), (N-XT soil services, sd)

2.1.1.3. Water

Water is an important element for growing plants. Sandy soils drains water easily if there are no hardened layers in the soil. This is an advantage because the chance on anaerobic circumstances are low. The disadvantage is that the soil will dry out easily, this is not a common problem in cereals in the Netherlands, but this depends on the local circumstances.

2.1.2. Chemical characteristics

2.1.2.1. Acidity (pH)

If the pH is to low or too high the plants take up the nutrients more difficult (van de Vegte, 2017). For cereals the desired pH is between 5 and 6. This needs to be checked strictly on sandy soils because sandy soils mostly have a low pH. To higher the pH on a sandy soil it is possible to add calcium as fertilizer. It is not possible to bring the pH on sandy soils on a stabile desired level in one year because most of the fertilizers will rinse away. It is necessary to add each year the right amount of fertilizer to bring the pH to the right level and to maintain this level.

2.1.2.2. Nutrients

Nutrients can be divided in three groups (ICL Specialty Fertilizers, sd):

- Macro-elements: Nitrogen (N), Phosphorus (P), Potassium (K)
- Meso-elements: Calcium (Ca), Sulphur (S), Magnesium (Mg) (Sodium (Na), Silicon (Si))
- Micro- or trace-elements: Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu), Boron (Br), Molybdenum (Mo), Chlorine (Cl) (Cobalt (Co), Nickel (Ni))

In Figure 2 are all the elements shown that the plant needs for growth, they are all divided in different section. Some elements are not always as essential as others.

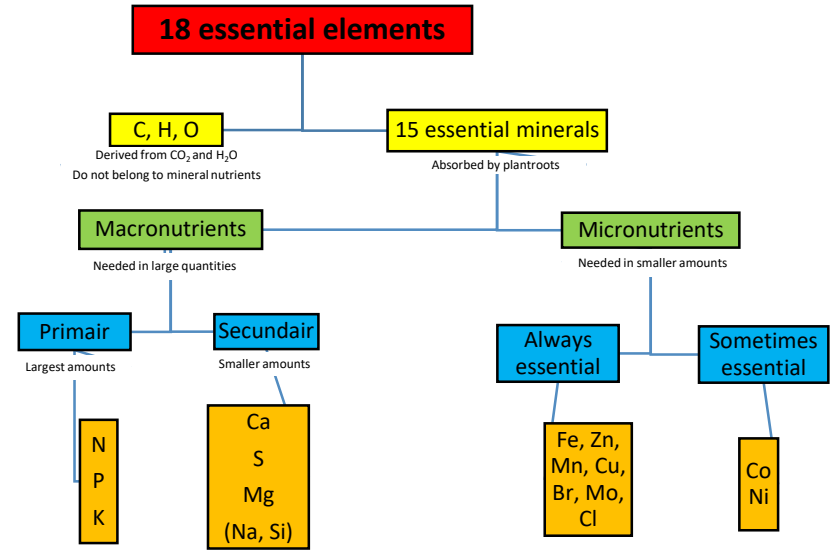

Figure 2 Classification of elements

The differences between these groups is the ratio of presence. All the nutrients are needed for a good growth. It is not good to have a lack of nutrients, besides that too much nutrients can cause plant-poisoning. Also the balance is important on the availability on all elements for the plant.

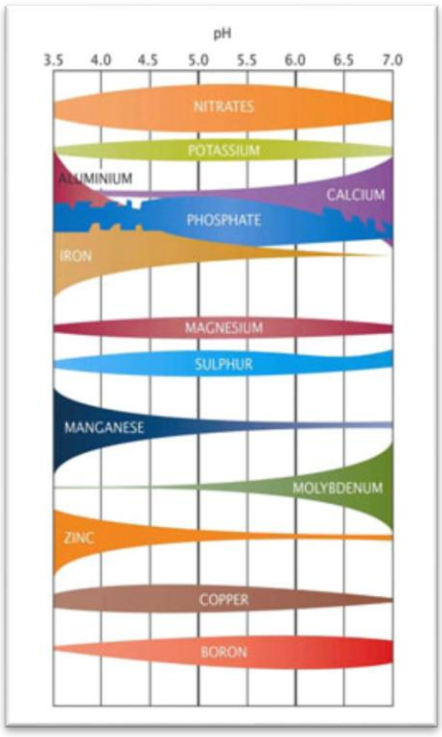

Figure 3 Effect of pH on availability of plant elements (Hollier & Reed, 2005)

The table (Figure 3) makes clear that the pH is important to make the elements suitable for the plant.

2.1.2.3. Salt (EC)

Salt can be toxic in the soil. It can be that there is an overdose of fertilizer that makes the soil salt or that the area has a higher salt-concentration. Salt can cause a lack of nutrients in the plant because

the osmotic balance between the roots and the soil is not good. The plants can also dry out because the salt extracts the moisture out of the roots due to the osmotic principal.

The salt-concentration can be measured with an EC-meter, EC stands for Electrical Conductivity. The meter uses the conductivity of salt-ions to measure the salt-concentration. The maximal EC for growing plants is 0,25. (Canna, sd)

2.1.3. Biological characteristics

All the living organisms in the soil are part of the biological soil characteristics. These organisms loosen the soil (physical advantage) and make nutrients available for the plants by ferment organic matter into smaller, plant available nutrients (chemical advantage). (N-XT soil services, sd)

2.2. Drilling

After ploughing or deep cultivation the soil is too loose for machinery to ride over and for the seeds to absorb water. Therefor the soil needs to be flatten out with a harrow. In figure 4 it is visible why there is a second preparation needed. On the left-side is drawn a good seedbed, here the soil above the seed is loose so there can come air to the seeds, under the seeds is a pressed layer where due to capillary function water rises to the seeds. On the right-side is drawn a seedbed that is too deep, this causes drought around the seed that hinders the germination. (Stichting IRS, 2015)

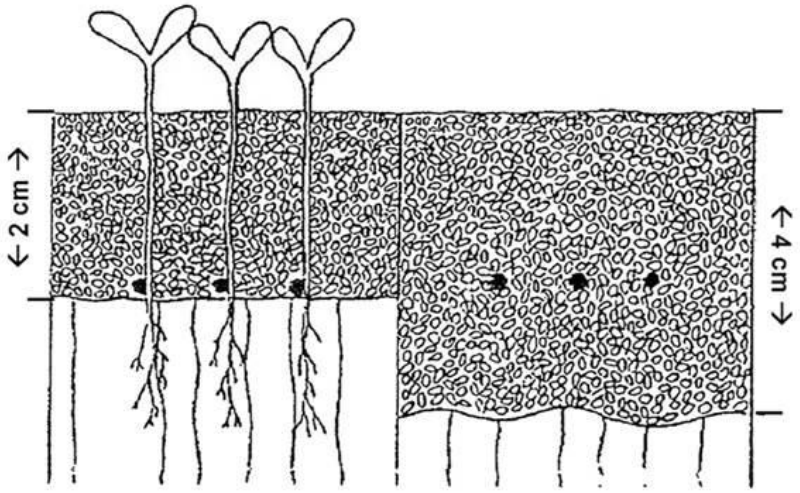

Figure 4 At the left a good seedbed for a good moisture for the best germination. On the right a seedbed that is too deep. (Stichting IRS, 2015)

Drilling needs to be done according to the planting plan that is made by the field technician. The field technician is responsible for the planting plan so if any issues occur the field technician has to be informed.

2.3. Fertilizers

Fertilizers be applied on soil test basis. While the crop is growing fertilizer can be applied at leaf test basis or just by monitoring the plants and use leaf fertilizer on experience. It is important to take in account that the trace elements have antagonism and synergism function in the soil (Figure 5). That means that it looks like there is a deficiency of an element but that it is caused when the content of another element was too high. When fertilizing is done by looking at the plant for deficiency it is possible that a wrong conclusion is taken and the fertilizing is not done properly, or even harm the crop.

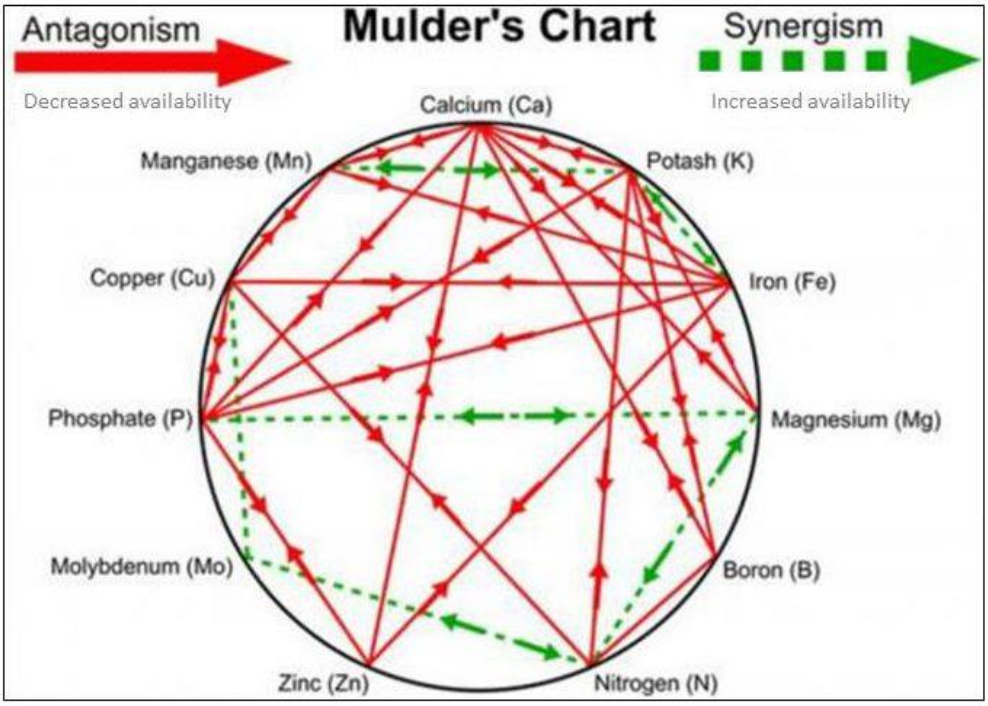

Figure 5 Mulder's chart shows positive and negative interactions between plant nutrients. (Carlow, 2016)

Fertilizers can be selected (Figure 2) on main fertilizers (N, P, K) or trace elements (Mg, S, Zn, etc.) according on the needs of the crop. In appendix 5 is an overview of symptoms when the plant has got a deficiency.

2.4. Growing stages

The growing stages of cereals are divided in the Zadok system. In figure 6Figure 6 it is made visible on a scale and in

Appendix 1 it is worked out in a table.

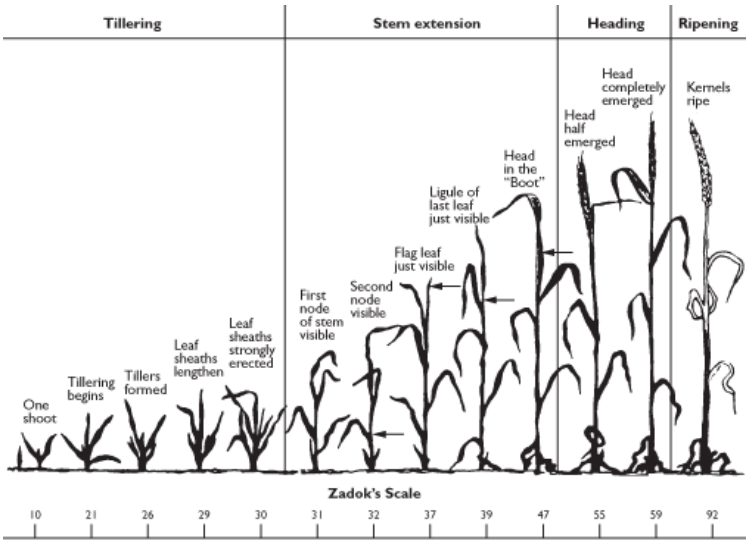

Figure 6 Zadok scale of growing stages in cereals (Cowbrough, 2016)

It is important to check the growing stages because the most crop protection products will give an advice for a certain growing stage according to the Zadok scale. The whole scale is explained in the first appendix (

Appendix 1) attached to this paper.

2.5. Harvest

For harvesting the crop the conditions have to be right (Syngenta; Reliance, 2017):

- No other crops in surrounding of 6 meters because the harvester need space to turn on each side of the field.
- No lodging plants that should not been harvested with the crop
- The soil have to meet the right conditions to drive over it with the combine
- The ideal target is 14% moisture content, 18-20% could be acceptable if the conditions would not become better according to the forecast and when drying facilities are available.

(And the crop should have ripened enough for a good cleaning.)

If all the requirements, mentioned in paragraph 1.4, are reached there can be harvested. First check if the harvester is clean. The combine must be cleaned between every line that needs to be harvested. All the settings for best harvest can be found on the machine label, during harvesting it is necessary to check if the settings are according to the conditions.

When harvesting the grains are collected in bags. 1-4 plots in 1 bag with the right label attached to it and a same label in it. The bag needs to be closed securely and lay in good sight for collecting.

The A and B lines have to be collected and stored separately. The bags have to be stacked evenly with minimal gaps for an evenly and efficient drying. The box with the collected bags must be transported to the station every evening and not stay a night over at the field.

2.6. Drying seeds

All the plots are packed separately because first there needs to be done some tests before mixing the different plots to a bulk. A sample is taken and checked on moisture content. The target is 12%-14,5%. The maximal drying temperature is 40 degrees Celsius to ensure smooth drying without harming the germination. (Syngenta; Reliance, 2017)

Another sample is taken for laboratory tests. These tests determine which bags can be mixed and which bags are contaminated and not used in further stages.

The drying equipment comes with its own manual that can be explained by the dealer if it is unclear. The goal is to reach a moisture content of 12%-14,5% without damaging, harming the seeds and germination. The equipment settings for temperature needs to be less than 40 degrees Celsius. The air flow is determined while loading the shed because the bags are light and with a high airflow they will fly out of the boxes.

2.7. Producing hybrid seeds

When and how to do things and what is needed to do this. This following paragraphs are mostly based on experiences from Syngenta employees (Syngenta; Reliance, 2017) unless something else is mentioned. These are the instructions based on the previous information from this chapter.

2.7.1. Growing area and field selection

For the fields of cereal seed production there are some isolation distances to fulfill:

- Area without any cereals (winter or spring) with the following criteria:
    - 3 km from other fields with the same cereal crop
    - 2 km from pre-basic and basic seed production or any other A-line production
    - 1 km from other Parental Line Maintenance (PLM) and Parental Line Purification (PLP) fields.

These distances are important to prevent cross pollination between different lines or between conventional fields.

Other criteria are:

- Windy, open field to support wind-pollination.
- No frost risk.
- No flooding risk.
- Reasonable soil quality
    - Analyse sample
    - Moisture circumstances
- Weed and volunteer free field
    - Pre-crop has to be a leaf-crop, no cereals (no barley before barley and no wheat before wheat etc.)
    - 5 years no cereal cultivation (no barley before barley and no wheat before wheat etc.) (this is a quite long isolation-time)
- Pre-crop has to be harvested 6 weeks (maximum 3 weeks) before in advance for soil preparation.

2.7.2. Soil preparation

2.7.2.1. Timing of activity

Crop management activities start with soil preparation and end with harvest. Soil preparation must be done before 30th September for the climatic area of the Netherlands. For other regions the timing has to be adapted according to the circumstances.

2.7.2.2. Equipment/PPE (Personal Protective Equipment)

All required equipment (tractors, sprayers, fertilizers, trailers, etc.) has to be checked for suitability. Is this equipment does not fit with the requirement it either has to be changed or the field design has to be modified slightly to fit with the equipment. This adjustment has to be finalized before planting.

2.7.2.3. Field preparation

- Field preparation has to be done accurately by the grower so that high crop emergence rate will be guaranteed.
    - Ploughing or deep cultivation (15-25 cm).
    - Seed bed preparation with discs or rotor harrow.
    - Even if soil preparation is difficult, planting can only happen if seed bed is appropriate.

    - The field must be available at least three weeks before the intended sowing date to allow suitable cultivation.
- In case the pre-crop was grassland:
    - It has to be cut 6 weeks before desired planting date and grass has to be removed.
    - Re-growing grass has to be treated with a full doses of Glyphosate.
    - Ploughing not earlier than 2 weeks after spraying.
- Field technician has to perform checks that soil preparation enables a planting into a clean seed bed of fine soil particles with a planting depth of 2-4 cm.
- Planting date should ensure at minimum temperature summary is 500 degrees Celsius between crop emergence and winter (average temperature ≤5 degrees Celsius).

2.7.3. Drilling

In barley drilling needs to be done 10-14 days before conventional cultivation because the goal is to reach fully developed all tillers (4-5 primary and 4-5 secondary tillers) in autumn. Other tillers that developed later will be retired by the plant in spring, this leads to uneven pollination and a lot of un-pollinated flowers with a low yield as result.

2.7.4. Monitoring and rouging off-types

Starts after crop emergence and is a regular process during the season until harvest. For rouging off-types it is necessary to look for:

- Height
- Color
- Shape
- Fertile off-types in a sterile line

During flowering period field personnel has to wear an overall specific to each line to avoid cross-pollination between lines. Overalls have to be left in a storage box before leaving the field. Hands have to be disinfected with alcohol to avoid transfer of viable pollen to another field. If gloves are used they have to be disposed.

It is essential to remove off-type cereal plants. A cereal plant is considered an off-type if its phenotype differs from the line in question. Character differences can be subtle and care must be taken when looking at plants within the plots. Removed plants must be collected in plastic bags and removed from the field and not left on the ground near the plots. If pulled plants are not removed from the area they may re-grow. Record in the field book:

- When and where off-type plants were found and removed (which plant plot)
- The number of plants removed
- Description of off-types removed (which characteristics were identified as wrong?)
- Who found the off-types

Special instructions for rouging cereals at flowering season

The objective is not to shed anymore pollen in the rest of the field. At the arrival in the field, wear a field-specific overall coat + new gloves or disinfect your hands with hydro-alcoholic solution. Check the whole field for the off-types. If you find off-types:

- Carefully remove the flag and place it in a paper envelop.
- Label it according to the plot plant and family plant.
- Cover all flowering ears of the off-type with a suitable sized bag before pulling the plant out.
- Put this bagged plant into a bigger plastic bag for final removal from the field.

2.8. Research questions

From Syngenta Seeds it is known that hybrid seed propagation is a complex process. Mainly for crops grown in the open field, because isolation distances have to be taken into account. These isolation distances are important to take into account in connection with possible cross-pollination of nearby crops. As a result, the seed propagation of cereals in the Netherlands and France is increasingly on poorer soils. Syngenta is currently growing a large proportion of the barley in the Veluwe. This problem is also increasing in France.

For this, the client would like to have a literature study carried out into the best growing conditions for growing cereals on sandy soil. This also includes the work that must be carried out to make the crop successful and to achieve a good yield. This is accompanied by a piece of evaluation of current work with a piece of advice.

The important thing in this whole is that it is desirable to achieve a high yield from the crop, but also that the seeds are of high quality for bulk propagation, this has an effect on the advice of the use of resources in relation to a crop where it is grown for a high thousand-grain weight. In addition, it is difficult that a line, which is ultimately part of a hybrid, sometimes has characteristics that would not be desirable in a variety, but which are cancelled again due to crossing with another line. It is important here that the genetic purity of the crop must be taken into account at every stage and every action.

The main question is:

How can hybrid winter cereals be produced in the most optimal way on sandy soil when it comes to crop care?

- How can the use of growth regulators be improved when growing hybrid cereals?
- How can crop protection be improved when growing hybrid cereals?

Ultimately, the conclusion and recommendations provide an overview of which actions must take place and at what point in the process. The discussion will work out which optimization this brings to the current working method. The report is ultimately focused on sustainability because the conclusion is on reducing crop protection products and increasing food production.

3. Investigation of resources

This chapter gives an overview how this research is carried out and which methods are used. Because this paper is a desk research there will be fundamental sources be added.

- How can the use of growth regulators be improved when growing hybrid cereals?

In this sub-question there will be an investigation of the purpose of growth regulation during the seed production of cereals. For this purpose a decision tree is drawn up in order to be able to make the right choice in various situations in order to achieve the optimum goal. This will be done by searching the literature for the effect of growth regulators such as (Nederhoff, 2011) and (Nickell, 1983). In addition, an interview is being held with a German cereals seed cultivation expert, Bernd Mischer, on the application of growth regulators, and with Sandrine Collalto will be a discussion about the goals of growth regulation.

3.1.1. Resources

- (Alexander & Miller, 1991) *Peer reviewed*
  - Found via Google Scholar, keywords: root response soil structure.
    In this search, you forgot to select by date, so this is a relatively older source compared to the other sources. Selected because there is a lot of information about the root formation in different soil types and circumstances. Not a specific study on cereals, but the information is relevant because it can be transferred to cereals.
- (Canna, sd)
  - Found via Google, keywords: EC meten grond. This source is useful because explanations are given about the ions and their action in the soil and how this can be measured. This is not a reliable source, but it provides information that can be confirmed by other sources or own science.
- (Hollier & Reed, 2005)
  - Found via Google, keywords: acid soils. Selected because it contains broad information about pH and micronutrients. New topics can be addressed from this source, but there is also a lot of relevant information in it. The source is quite reliable because it is a site of the Australian government and written by scientists who have written peer-reviewed reports and studies.
- (ICL Specialty Fertilizers, sd)
  - Found via advertisement. Geselecteerd omdat het een relevant overzicht geeft over micro, meso en macro elementen. Betrouwbaar omdat het van een specialistisch bedrijf komt.
- (N-XT soil services, sd)
  - Found via Google, keywords: bodemeigenschappen. A site that fully, briefly and fairly detailed discusses the properties of the soil. Many new searches have emerged from this site, such as searching for (Alexander & Miller, 1991).
- (van de Vegte, 2017)
  - Found via Wageningen Universiteit, keywords: pH bodem. Overview of the pH in different soils and how it can be made suitable. Reliable source, written by a specialist from a university institution who has written peer reviewed reports and research.

- (Stichting IRS, 2015)
    - Found via Google, keywords: zaaibedbereiding. Selected because this site gives a good description of seedbed preparation and has also visualized this in a figure. The source is reliable because it comes from a knowledge and research institution that is renowned in the Netherlands.
- (Syngenta; Reliance, 2017)
    - This is the Syngenta intranet system where all information from the field is processed. From this the current method can be described or the ideal method can be formulated. This source is reliable because it only mentions facts as they occur in practice and these files are authorized by 2 and sometimes 3 people before they are placed. This source is also used when it comes to employee experience.

- How can crop protection be improved when growing hybrid cereals?

This sub-question investigates how the usability of plant protection products, in particular fungicides, can be increased. It is important to know when a substance is used. This depends on various factors, whether it is permitted in accordance with the applicable laws and regulations, whether the plant has reached the correct growth stage and whether the agent is sufficiently effective against the diseases or pests to be controlled or prevented. The first to be investigated is which means are permitted (College voor de toelating van gewasbeschermingsmiddelen en biociden , 2019) and in which period, this will be made clear to get a good picture of which means are available. In addition, it will be investigated which resources are best to use at the stage of growth, this will be discussed with Bernd Mischer.

When answering these questions, the most important thing is to consider that it is about seed production. This cultivation often has other objectives in mind than arable farming, also because it concerns parent lines for a hybrid variety.

3.2.1. Resources

- (Gardena, sd)
    - Found via Google, keywords: sneeuwschimmel. Used because snow fungus was unknown, first gained basal knowledge to search deeper in the sources. This source is reliable but is not supported by scientific sources and such. The information that emerges from this source will therefore have to be checked on the basis of other sources or knowledge of people.
- (Prescott, et al., 1986) *Peer reviewed*
    - Found via Google Scholar: Wheat diseases pests guide. Useful for (almost) all common pests and diseases that occur in grains. This source is peer reviewed and also substantiates the information from (Groenkennisnet, sd). For this search, you forgot to select by date, this is no problem for this source because the information is still up-to-date and can be compared with other sources such as (Groenkennisnet, sd). As search criteria, a maximum age of 10 years was used to expect relevant sources.
- (Kundu, 2009) *Peer reviewed*
    - Found via APS net, keywords: BYDV (barley yellow dwarf virus). A peer reviewed report on the damage and control of barley yellow dwarf virus.
- (Canolawatch, 2016)
    - Found via Google, keywords: potassium deficiency. Search term used to get a quick broad look about the symptoms of calibrum. This site quickly gave a

nice overview of that. It is not a very reliable source but it is verifiable information. It is also a source of a body that works from the Canadian government, a certain reliability can be considered.

- (College voor de toelating van gewasbeschermingsmiddelen en biociden , 2019)
  - This site was already known to the author. This is a very reliable source that is also kept up-to-date. All agents that are allowed are listed in here. The recommendations for the use of plant protection products will largely be based on this source.
- (Deutsche Saatveredelung, sd)
  - Found via Google, keywords: Pseudocercosporella herpotrichoides. Extra information about eye spot disease because complete information cannot be found from other sources. Reliable because it is a reputable German consulting firm.
- (Groeipartners, sd)
  - Found via Google, keywords: chemische bestrijding graanluizen. Bruikbaar als algemeen Nederlands bestrijdingsadvies op basis van een kennisinstelling.
- (Groenkennisnet, sd)
  - Website was already known to the author as a complete and informative website. This website is based on a knowledge institution that is reliable. This source is used as information for diseases and pests and to support other sources like (Prescott, et al., 1986).
- (Groenkennisnet, sd)
  - Website was already known to the author as a complete and informative website. This website is based on a knowledge institution that is reliable. This source is used as information about grain lice and to support (Groeipartners, sd).
- (Nederhoff, 2011)
  - Found via Google, keywords: groeiregulatoren toepassen. Brief overview of commonly used growth regulators in grains. Starting from Wageningen University, a certain degree of reliability can be expected.
- (Scanlan, Critical tissue nitrogen concentrations for diagnosis of nitrogen deficiency in wheat, 2017) *Peer reviewed*
  - Found via Google Scholar, keywords: Nitrogen deficiency wheat. Useful for supplying information about nitrogen because this is an important component of why sandy soils are difficult to grow grain. As search criteria, a maximum age of 10 years was used to expect relevant sources.
- (Scanlan, Diagnosing iron deficiency in cereals, 2015) *Peer reviewed*
  - Found via Google Scholar, keywords: iron deficiency cereals. Useful for working out various defects such as sulfur. Reliable peer reviewed source. As search criteria, a maximum age of 10 years was used to expect relevant sources.
- (Scanlan & Brennan, Diagnosing manganese deficiency wheat, 2017) *Peer reviewed*
  - Found via Google Scholar, keywords: manganese deficiency cereals. Useful for working out manganese deficiency. Reliable peer reviewed source. As search criteria, a maximum age of 10 years was used to expect relevant sources.
- (Wilhelm, 2016) *Peer reviewed*

        - Found via Google Scholar, keywords: trace-elements deficiency. Useful for working out micro-element defects. Reliable peer reviewed source. As search criteria, a maximum age of 10 years was used to expect relevant sources.
    - (kali-gmbh, 2017)
        - Found via Google, keywords: Phosphorus deficiency. Extra information for (Prescott, et al., 1986) about phosphorus deficiency. Reliable because it is a reputable German consulting firm.
    - (Canna, sd)
        - Found via Google, keywords: EC meten grond. This source is useful because explanations are given about the ions and their action in the soil and how this can be measured. This is not a reliable source, but it provides information that can be confirmed by other sources or own science.
    - (Hollier & Reed, 2005)
        - Found via Google, keywords: acid soils. Selected because it contains broad information about pH and micronutrients. New topics can be addressed from this source, but there is also a lot of relevant information in it. The source is quite reliable because it is a site of the Australian government and written by scientists who have written peer-reviewed reports and studies.
    - (ICL Specialty Fertilizers, sd)
        - Found via advertisment. Selected because it provides a relevant overview of micro, meso and macro elements. Reliable because it comes from a specialist company.
    - (N-XT soil services, sd)
        - Found via Google, keywords: bodemeigenschappen. A site that fully, briefly and fairly detailed discusses the properties of the soil. Many new searches have emerged from this site, such as searching for (Alexander & Miller, 1991).
    - (van de Vegte, 2017)
        - Found via Wageningen Universiteit, keywords: pH bodem. Overview of the pH in different soils and how it can be made suitable. Reliable source, written by a specialist from a university institution who has written peer reviewed reports and research.
    - (Milosavljević, Esser, & Crowder, 2016) *Peer reviewed*
        - Found via Google Scholar, keywords: soil dwelling pests. Search was used to find out which soil-related pests occur in sand and clay soils because there could be a difference here.
    - (Cowbrough, 2016)
        - Found via Google Afbeeldingen, keywords: Zadoks Growth Scale. Clear overview of the stages of growth in the Zadok scale. Fully controllable and correct.
    - (Zadoks Growth Scale, 2018)
        - Found via Google, keywords: Zadoks Growth Scale. Full growth stages worked out per stage. Recorded to create an overview of the growth stages. Reliable because it is published by the Australian government.
    - (College voor de toelating van gewasbeschermingsmiddelen en biociden, 2019)
        - This site was already known to the author. This is a very reliable source that is also kept up-to-date. All agents that are allowed are listed in here. The

recommendations for the use of plant protection products will largely be based on this source.

- (Rueda-Ayala, Rasmussen, & Gerhards, 2010) *Peer reviewed*
  - Found via Google Scholar, keywords: weed control. Published 10 years ago. Can be used to provide additional advice on current weed control activities.

4. Discussion

Review on research methods

To review this report this chapter is added to discuss if the methods are valid.

4.1. Searching sources

It was quite difficult to find good resources about cereal cultivation on sandy soils. It is not very common to grow cereals in these areas, and it is completely different compared to clay soil. This is the same issue with searching for information about hybrid cereals, there is a lot in literature about the breeding but not as much about producing hybrid seeds. After all, the information that was found is applied to hybrid seed production on poor, sandy soils to come to a good overview.

4.2. Information from authorizations

All the information about the allowance of chemicals came from only one website. For a research it is normal to use several sources to make a stronger report. For the use of chemicals is only the website of the Ctgb in The Netherlands, this is one of the most used sources.

5. Function of crop protection and growth regulators

This chapter gives an overview about growth regulators. Why to use them, how they work and when to apply.

5.1. Plant growth regulators

In cereals the height of a plant is important. A plant that is too long can be weak and fall over, this is what is called lodging. Most of the times fast growing cereals are caused by an overdose nitrogen (N). This in combination with a heavy, long and closely seeded crop. When the crop lodges the grains become wet and will shoot while in the ear. The grains will also stay smaller. A wet ear is more difficult to harvest which costs time, labor and quality.

Plant Growth Regulators (PGR) reduce the plant hormone gibberellin. When gibberellin is less active in the plant auxin will become active in the roots, so the roots will elongate. Less gibberellin causes stem shortening and will stimulate the production of ethylene. Ethylene overcomes the apical dominance, which means that the energy of the plant will not go directly to the mean tiller but it will spread to all tillers. (Rajala, Peltonen-Sainio, Onnela, & Jackson, 2002) (Burg, 1973)

Plant Growth Regulators (PGR) shortens the plant and thickens the stem. This gives the stem more strength to hold the ear right up (Nederhoff, 2011). PGR's are also used to shorten the head tiller to give the other tillers more space so the plant can develop more big tillers instead of one big tiller and a several small ones (Nickell, 1983). It is important that the roots are good as well. This will prevent the plant from falling over at the roots instead of snap at the stem.

To improve the use of growth regulators there is made an overview in table 1 and 2. The active ingredients are also added and the dates for application are based on the Ctgb (College voor de toelating van gewasbeschermingsmiddelen en biociden , 2019).

Table 2 Plant growth regulators applicable in winter wheat and winter barley

	UPL CCC-750*	Moddus 250ec	Medax Top	Prodax	Yatze
Jan					
Feb					
Mar					
Apr					
May					*
Jun					
Jul					
Aug					
Sep					
Okt					
Nov					
Dec					
Growing stage Zadok					
0-20					
21-25					
26-30					
31-35					
35-40					
40-45					*
45-50					
50-99					
* Only allowed in wheat					

Table 1 Extra information about the plant growth regulators

	Active ingredient(s)	Expiration date
UPL CCC-750*	Chloromequat chloride	1-6-2025
Moddus 250ec	Trinexapac-ethyl	1-6-2020
Medax Top	Prohexadion-calcium/mepiquat chloride	1-2-2027
Prodax	Prohexadion-calcium/trinexapac-ethyl	30-4-2021
Yatze	Ethephon	31-7-2020

Information from the Ctgb about growth regulators is placed in an overview in tables 1 and 2. The different products have differences in function, this is worked out in chapter 5 in the decision tree. The doses to apply depends per product and is on the etiquette.

5.2. Weed control

Sandy soils in The Netherlands are known as containing a lot of weeds. This can be sprayed with the following products (Syngenta; Reliance, 2017) in all the growing stages, be careful with permission of application time:

- Dicotyls → Flufenacet, Pendimethalin, Fluroxypyr-meptyl, Methyl-ChlorophenoxyAcetic, Florasulam, Diflufenican
- Monocots → Flufenacet, Pendimethalin, Pinoxaden, Diflufenican

In table 3 there is an overview which herbicides can be used in cereals according to the Dutch law (Ctgb) February 2019. Also the working ingredients and for which weeds it is useful.

Table 3Harbicides applicable in winter wheat and winter barley

	Malibu	Starane Top	U46 MCPA	Primstar	Primus	Herold	Axial 50	Atlantis Star ***	Stomp SC
Jan									
Feb									
Mar									
Apr									
May									
Jun									
Jul									
Aug						*			
Sep						*			
Okt						*			
Nov						*			
Dec						*			
Growing stage Zadok									
< 0						*			
0-5									
6-10,									
11-15,						*			
16-20									
21-25									
26-30									
31-35									
36-40									
41-45									
46-99									

* Allowed in winterwheat before emergence
** Only allowed in winterwheat
* Allowed in winterwheat and winterbarley
** Pre-emergent herbicide

Table 4 Extra information about the herbicides

		Weeds		
	Active ingredient(s)	Monocots	Dicots	Expiration date
Malibu**	Flufenacet/Pendimethalin	+++	+++	1-9-2019
Starane Top	Fluroxypyr-meptyl	-	++	31-12-2022
U46 MCPA	2-Methyl-4- Chloro Phenoxy Acetic	-	++	1-6-2025
Primstar	Fluroxypyr-meptyl/Florasulam	-	+++	1-4-2020
Primus	Florasulam	-	+++	1-1-2020
Herold	Diflufenican/Flufenacet	+++	+++	1-2-2022
Axial 50	Pinoxaden	+++	-	1-3-2020
Atlantis Star**	Iodosulfuron-methyl-natrium/Mesosulfuron-methyl/Thiencarbazon-methyl	+++	+++	1-4-2020
Stomp SC	Pendimethalin	++	++	1-1-2021

+++ most weeds are viable
++ a lot of weeds are viable
+ some weeds are viable
- weeds are not viable

5.3. Fungi/diseases

Disease problems in nearly all stages (Zadok scale 26-70) can be treated with the following chemicals (Syngenta; Reliance, 2017):

- Mildew (*Erysiphe* spec.) → Fenpropimorph, Metrafenone
- Brown rust (*Puccinia triticina*) → Fenpropimorph, Tebuconazole, Prothioconazole, Epoxiconazole
- Yellow rust (*Puccinia striiformis*) → Fenpropimorph, Epoxiconazole, Tebuconazole, Prothioconazole
- Snow mold (*Microdochium nivale*) → Prochloraz, Prothioconazole
- Fusarium head blight (*Fusarium graminearum*) → Prothioconazole, Tebuconazole
- Eyespot (*Rhizoctonia cerealis and Pseudocercoporella herpotrichoides*) → Bixafen, Prochloraz, Prothioconazole

In chapter 0 is an overview of the most common diseases. In **Fout! Verwijzingsbron niet gevonden.** 7 and table 10 there is an overview of fungicides that can be used in cereals.

Table 7 Fungicides applicable in winter barley

	Propi 25 ec	Ampera	Opus Team	Flexity	Aviator	Bravo Premium
Jan						**
Feb						**
Mar						**
Apr						**
May						**
Jun						**
Jul						**
Aug						**
Sep						**
Okt						**
Nov						**
Dec						**
Growing stage Zadok						
0-25						
26-30						
31-35				*		
36-40						
41-45						
46-50						
51-55						
56-60						
61-65						
66-70						
71-99						

* No application time known for Flexity at the CTGB. Advice on the label is growing stage 30-32.

** There is no application time known for Bravo Premium.

Table 6 Useful against these diseases

	Propi 25 ec	Ampera	Opus Team	Flexity	Aviator	Bravo Premium
Net blotch						
Yellow Blotch						
Dwarf rust						
Yellow rust						
Brown rust						
Mildew						

Table 5 Extra information about fungicides in winter barley

	Active ingredient(s)	Expiration date
Propi 25 ec	Propiconazole	31-1-2020
Ampera	Tebuconazole/Prochloraz	31-12-2022
Opus Team	Epoxiconazole/Fenpropimorph	1-7-2024
Flexity	Metrafenone	1-7-2019
Aviator	Prothioconazole/Bixafen	1-10-2024
Bravo	Propiconazole/Chlorothalonil	31-10-2020

Table 10 Fungicides applicable for winter wheat

	Propi 25 ec	Ampera	Opus Team	Prosaro	Flexity	Aviator	Bravo Premium
Jan							**
Feb							**
Mar							**
Apr							**
May							**
Jun							**
Jul							**
Aug							**
Sep							**
Okt							**
Nov							**
Dec							**
Growing stage Zadok							
0-25							
26-30							
31-35					*		
36-40							
41-45							
46-50							
51-55							
56-60							
61-65							
66-70							
71-99							

* No application time known for Flexity at the CTGB. Advice on the label is growing stage 30-32.

** There is no application time known for Bravo Premium.

Table 9 Useful against these diseases

	Propi 25 ec	Ampera	Opus Team	Prosaro	Flexity	Aviator	Bravo Premium
(Yellow) blotch							
Net blotch							
SNB							
Eyespot							
Brown rust							
Yellow rust							
Fusarium							
Mildew							

Table 8 Extra information about the fungicides in winter wheat

	Active ingredient(s)	Expiration date
Propi 25 ec	Propiconazole	31-1-2020
Ampera	Tebuconazole/Prochloraz	31-12-2022
Opus Team	Epoxiconazole/Fenpropimorph	1-7-2024
Prosaro	Prothioconazole/Tebuconazole	31-7-2019
Flexity	Metrafenone	1-7-2019
Aviator	Prothioconazole/Bixafen	1-10-2024
Bravo Premium	Propiconazole/Chlorothalonil	31-10-2020

5.4. Pests

In winter cereals are not a lot of pests. The most common pest is aphids (*Metopolophium dirhodum, Rhopalosiphum padi, Sitobion avenae)*. These insects cause suction damage at the plants that are penetrable for viruses like Barley Yellow Dwarf Virus (BYDV). (Groenkennisnet, sd)

Beside aphids there are pests like slugs and wireworms/larvae of click beetle (*Elateridae*). Wireworms appear more in warmer soils and are significant less present in sandy soils (Milosavljević, Esser, & Crowder, 2016).

It is preference to use a selective pesticide against the aphids because they have natural enemies which are good and you don't want to kill. (Groenkennisnet, sd)

- Aphids → Flonicamid, Lamba-cyhalothrin, Deltamethrin

In appendix 3 the pests are and in appendix 4 the viruses worked out in detail. In table 12 is an overview of which products can be used against pests.

Table 12 Insecticides applicable in winter wheat and winter barley

	Karate Zeon	Decis	Teppeki*
Jan			
Feb			
Mar			
Apr			
May			
Jun			
Jul			
Aug			
Sep			
Okt			
Nov			
Dec			
Growing stage Zadok			
0-20			
21-30			
31-40			
41-50			
51-60			
61-70			
71-80			
81-90			
91-99			

* Only allowed in wheat

Table 11 Extra information about the insecticides

	Active ingredient(s)	Expiration date
Karate Zeon	Lambda-cyhalothrin	1-10-2019
Decis	Deltamethrin	1-1-2023
Teppeki*	Flonicamid	1-5-2024

6. Best use of crop protection and growth regulators

6.1. Decision tree

PGR-use based on plant status (massive/ lots of tillers). Based on tillering (supporting or reducing tillers). Circumstances to achieve (Nitrogen + micronutrients are needed for optimal use). Growing plants for uptake of PGR (5 cm new roots after winter). Early stage and later stage if the PGR is not functional in specific stages.

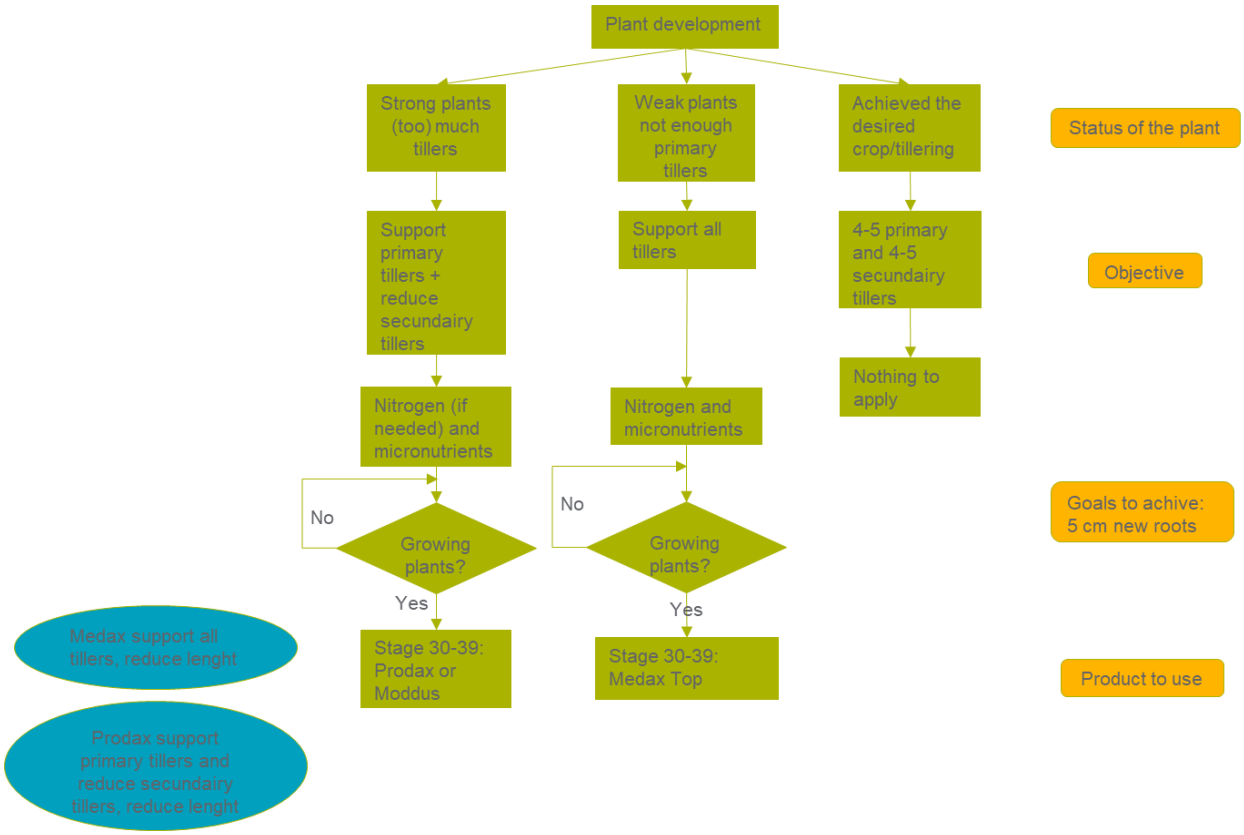

Figure 7 Decision tree for the use of Plant Growth Regulators in Winter Barley (Boers, 2019)

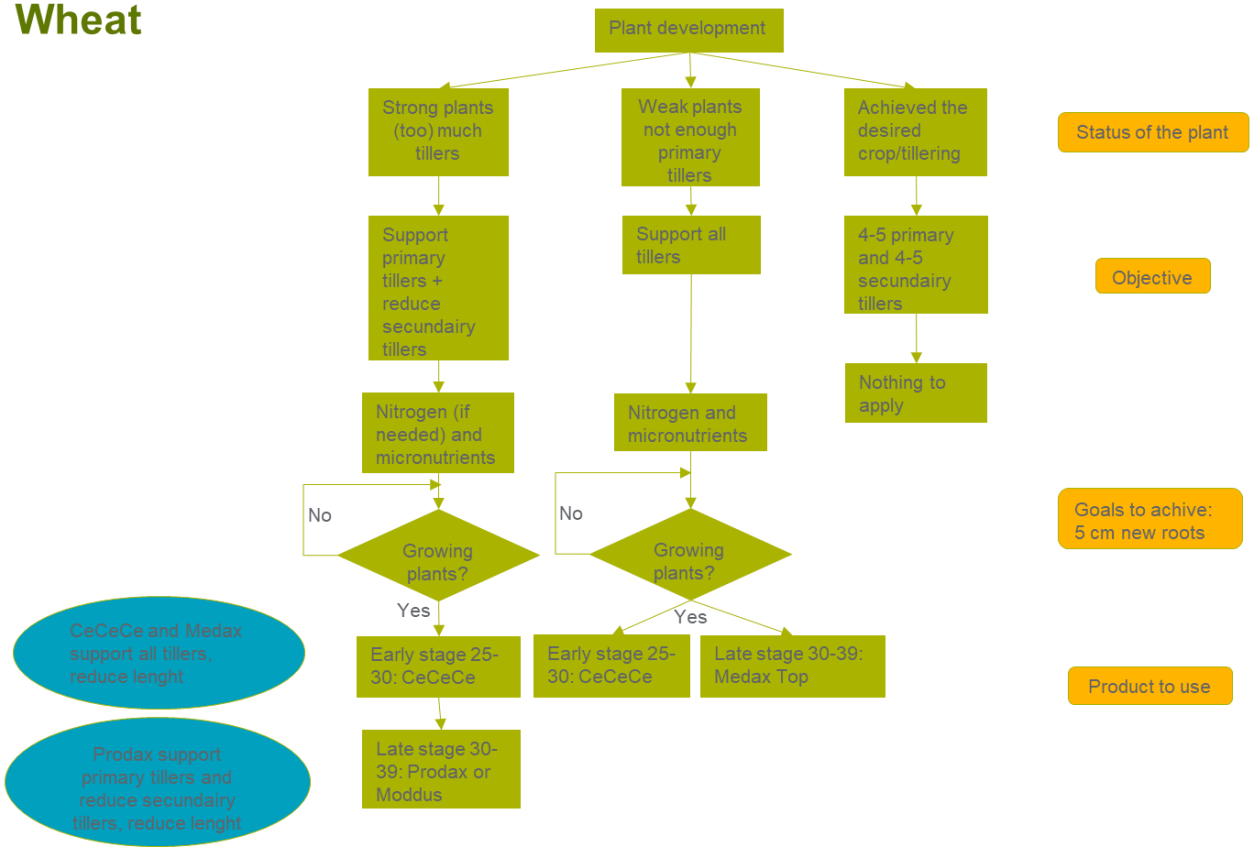

Figure 8 Decision tree for Plant Growth Regulators in Winter Wheat (Boers, 2019)

It is important to keep in mind that most growth regulators thickens the stem. The thickness of the stem is one of the characteristics that institutions define to describe a race/line. When the stem is unnaturally thickened with growth regulators this will give a wrong impression for the characteristic description.

6.2. Conclusion and recommendations

In this paragraph an overview of recommendations is made. All the actions that needs to be done during the year and what to apply during the year. All the crop protection products that are mentioned are allowed in the Netherlands according to the CTGB (Dutch law) (College voor de toelating van gewasbeschermingsmiddelen en biociden , 2019) in February 2019.

Table 13 Actions that are recommend to do during the year

Stage of the month	Month	Wheat/ barley	Action	Season
Begin	August	Both	If pre-crop is grass: *Touchdown Quattro* (glyphosate, herbicide)	Summer
Mid	August	Both	Soil cultivation	Summer
Begin	September	Both	If pre-crop is grass: again *Touchdown Quattro* (glyphosate, herbicide)	Autumn
Mid/end	September	Both	Liquid manure (+ eventually NPK 15+15+15)	Autumn
End	September	Both	Plow and prepare seedbed	Autumn
End	September	Barley	Drilling barley	Autumn
Begin/mid	October	Wheat	Drilling wheat	Autumn
End/begin	Oct/Nov	Both	*Stomp SC* (herbicide)	Autumn
Mid	November	Both	*Karate Zeon* (insecticide)	Autumn
End	November	Both	*Mantrac Pro* + *Lebosol* (fertilizer)	Autumn
End	November	Both	*Decis* (insecticide)	Autumn
End	November	Both	*Propi 25 ec* (fungicide)	Autumn
Begin	December	Both	*Malibu* (herbicide) against all grasses	Winter
	December-February	Both	Only a few herbicides can be used, *Propi 25ec* (fungicide) is also available.	Winter
End	February	Both	*Lebosol Total Care* (fertilizer) When crop start to vegetate apply this NPK fertilizer	Winter
Begin	March	Both	*Medax* (growth regulator)	Spring
Begin	March	Barley	*Ampera* + *Aviator* (fungicide)	Spring
Begin	March	Wheat	*Ampera* + *Prosaro* (fungicide)	Spring
Begin/mid	March	Barley (/both)	*Starane Top* or *MCPA* + *Axial 50* (herbicide)	Spring
Mid	March	Wheat	*Atlantis star* (instead of *Axial 50*) + *Starane Top* or *MCPA* (herbicide)	Spring
Mid	March	Both	*Mantrac Pro* (fertilizer) (+ eventually NPK 15+15+15)	Spring
Mid/end	March	Both	*Teppeki* (insecticide)	Spring
End/begin	March/April	Both	*Moddus 250ec* (growth regulator)	Spring
Mid	April	Both	*Prodax* (growth regulator)	Spring
Mid	April	Both	*Lebosol Total Care* (fertilizer)	Spring
Mid	May	Both	Flowering	Spring
Mid	June	Barley (/wheat)	*Teppeki* (insecticide)	Early summer
Mid	June	Wheat	*Aviator* (fungicide)	Early summer
Mid/end	July	Both	Harvest	Summer

To reach the goal where is aimed for, mentioned in chapter 1, it is important to apply the chemicals similar to the schedule above.

- In the first place it is important to start with a clean soil, therefor a product like *Touchdown Quatro* is used.
- To maintain a weed-free cultivation several herbicides are applied, for instance *Stomp SC.*
- When the crop starts to grow pests and diseases can appear so pesticides and fungicides are applied. This is a critical point because in winter are not much products allowed but the disease-pressure is high. So, apply this fungicide at the right moment and come back directly after winter to capture most of the period.
- Before the crop starts to elongate, in stage 25, growth regulator needs to be applied to prevent a quick elongation and to support as much tillers as possible.
- Use no chemicals during flowering because this can kill the pollen what gives a lower seed yield.

In long term is can be interesting to find out if it is really necessary to use plant growth regulators on poor sandy soils. Sometimes the plants are suffering from deficiencies and regulators can possibly make it worse.

6.3. Protocol overview

To make an overview, a flowchart is made. In these flowcharts it is visible what to do in which circumstances of the crop.

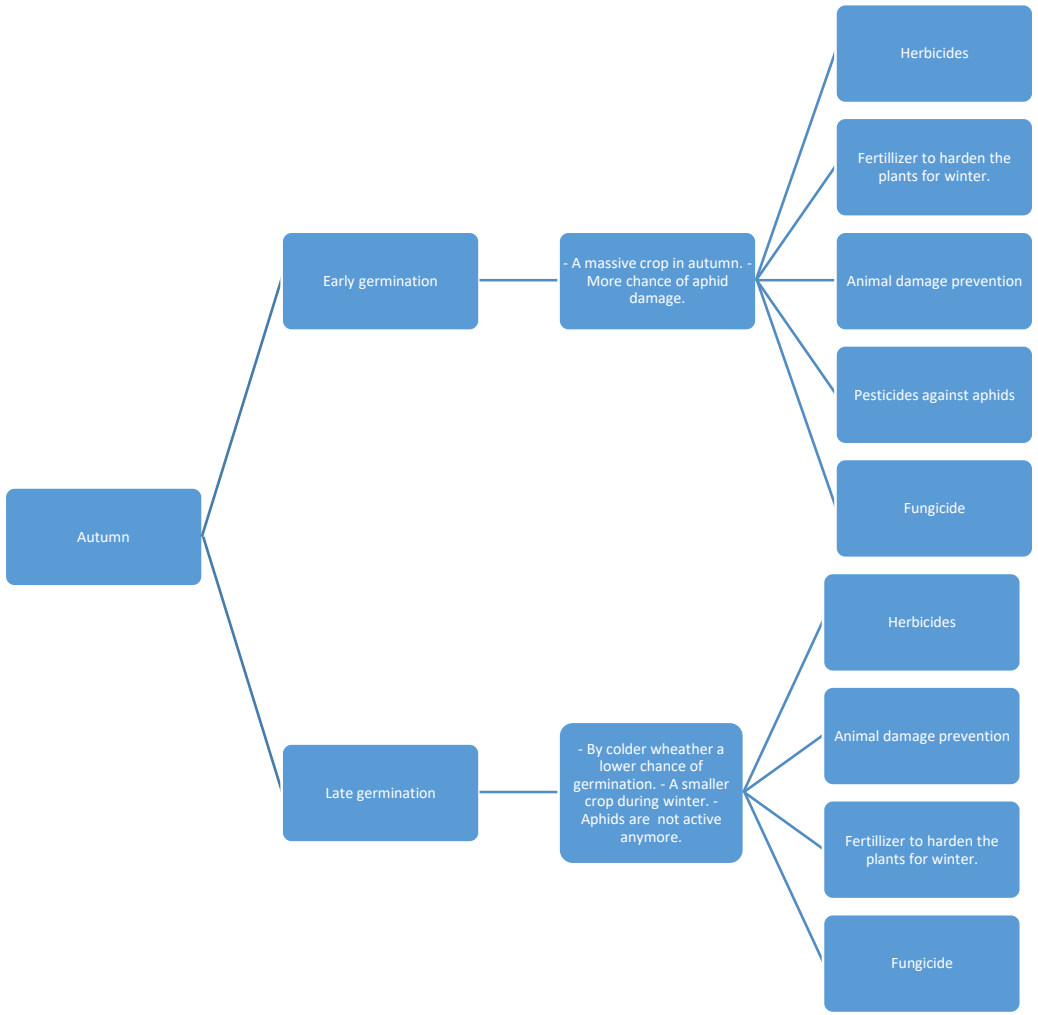

Figure 9 Overview of actions in different scenario's in autumn (Boers, 2019)

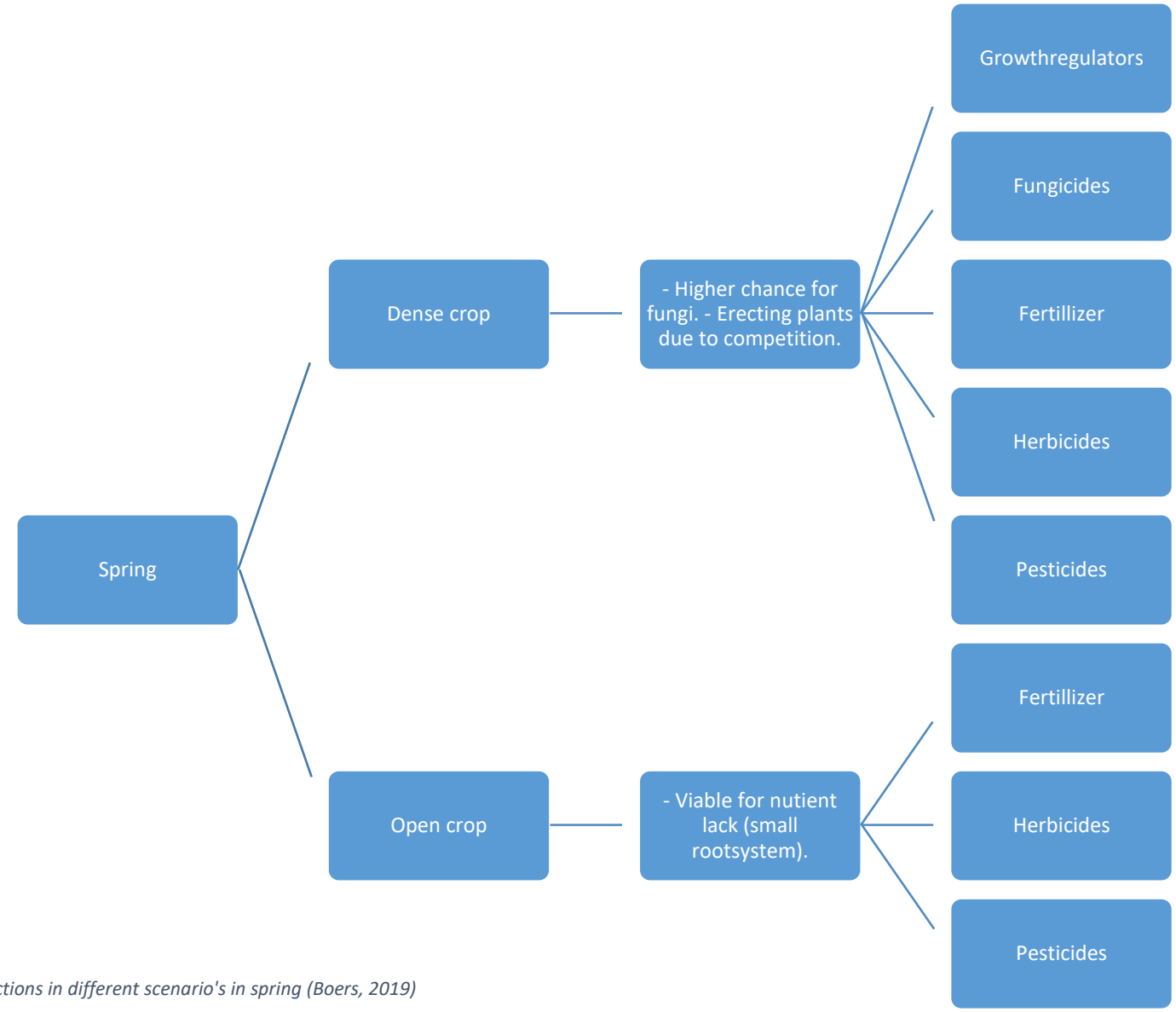

Figure 10 Overview of actions in different scenario's in spring (Boers, 2019)

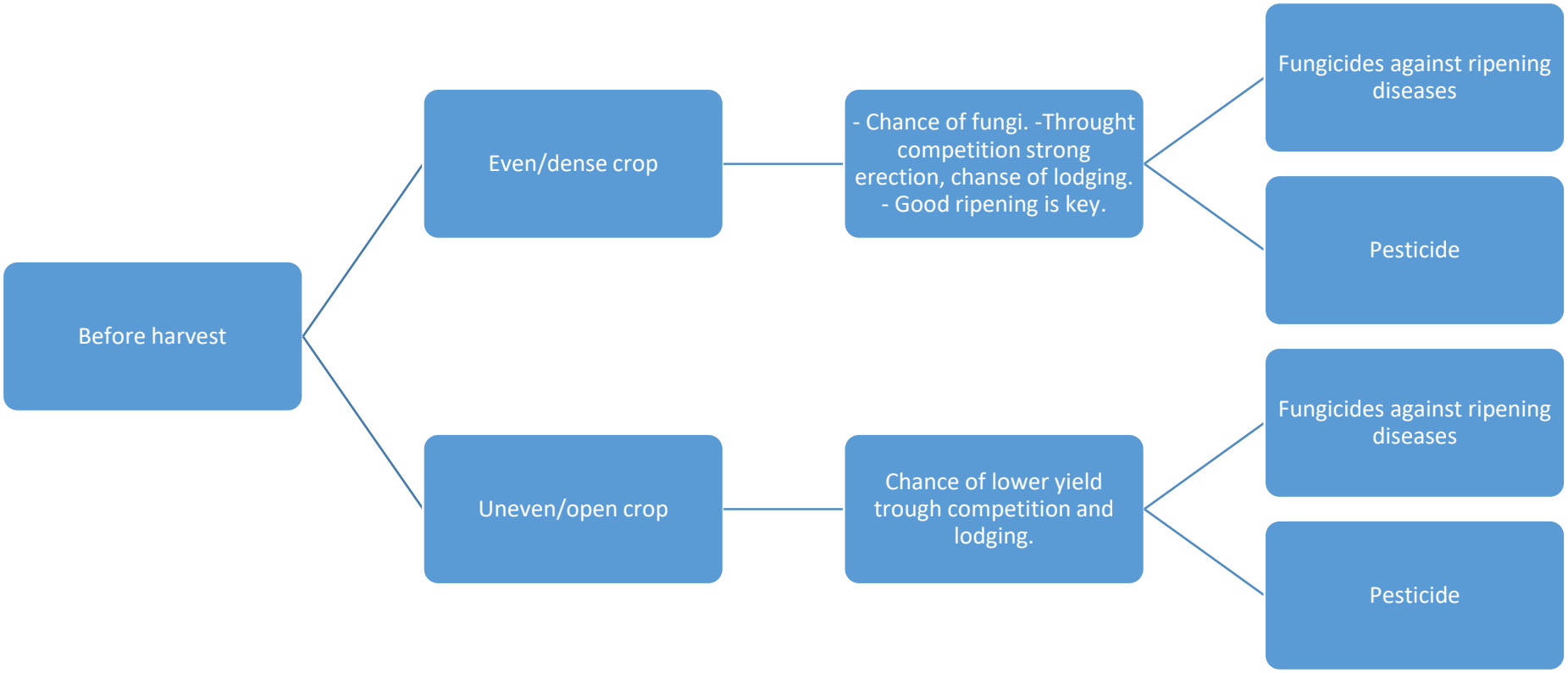

Figure 11 Overview of actions in different scenario's in early summer/ripening stage/before harvesting (Boers, 2019)

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Appendix 1.

Zadok growing stages scale (Zadoks Growth Scale, 2018)

The Zadok's growth scale is based on ten principal cereal growth stages:

- 0 - Germination
- 1 - Seeding growth
- 2 - Tillering
- 3 - Stem elongation
- 4 - Booting
- 5 - Awn emergence
- 6 - Flowering (anthesis)
- 7 - Milk development
- 8 - Dough development
- 9 - Ripening

Each primary growth stage is divided into 10 secondary stages, extending the scale from 00 to 99. The early growth stages (1, 2 and 3) are referred to most frequently. The scale does not run chronologically from 00 to 99. For example, when the crop reaches three fully unfolded leaves (13) it begins to tiller (20), before it has completed 4, 5 or 6 fully unfolded leaves (14, 15, 16).

Table 14 Zadok's growth scale

Growth stage	Development
0	Germination
00	Dry seed
01	Start of water absorption
03	Seed fully swollen
05	First root emerged from seed
07	Coleoptile emerged from seed
09	First green leaf just at tip of coleoptile
1	Seedling growth
10	First leaf through coleoptile
11	First leaf emerged
12	Two leaves emerged
13	Three leaves emerged
14	Four leaves emerged
15	Five leaves emerged
16	Six leaves emerbed
17	Seven leaves emerged
18	Eight leaves emerged
19	Nine or more leaves emerged
2	Tillering
20	Main stem only
21	Main stem and one tiller
22	Main stem and two tillers
23	Main stem and three tillers
24	Main stem and four tillers
25	Main stem and five tillers
26	Main stem and six tillers
27	Main stem and seven tillers
28	Main stem and eight tillers
29	Main stem and nine or more tillers
3	Stem elongation
30	Pseudo stem (youngest leaf sheath erection)
31	First node detectable
32	Second node detectable
33	Third node detectable
34	Fourth node detectable
35	Fifth node detectable
36	Sixth node detectable
37	Flag leaf just visible

39	Flag leaf ligule just visible
4	Booting
41	Flag leaf sheath extending
43	Boots just visible swollen
45	Boots swollen
47	Flag leaf sheath opening
49	First awns visible
5	Ear emergence from boot
51	Tip of ear just visible
53	Ear quarter emerged
55	Ear half emerged
57	Ear three quarters emerged
59	Ear emergence complete
6	Anthesis (flowering)
61	Beginning of anthesis (few anthers at middle of ear)
65	Anthesis half-way (anthers occurring half way to tip and base of ear)
69	Anthesis complete
7	Milk development
71	Kernel water ripe (no starch)
73	Early milk
75	Medium milk
77	Late milk
8	Dough development
83	Early dough
85	Soft dough
87	Hard dough
9	Ripening
91	Grain hard, difficult to divide
92	Grain hard, not dented by thumbnail
93	Grain loosening in daytime

94	Over-ripe straw dead and collapsing
95	Seed dormant
96	Viable seed giving 50% germination
97	Seed not dormant
98	Secondary dormancy induced
99	Secondary dormancy lost

Appendix 2. Recognition fungi/diseases

2.1. Fusarium

Fusarium is a collective noun for a numerous fungi. The most well-known are snow mold (Gerlachia nivalis) and head blight (Fusarium spp.).

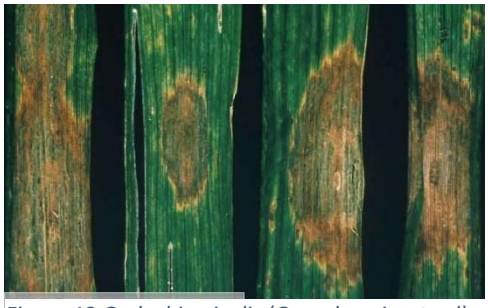

Figure 12 Gerlachia nivalis (Groenkennisnet, sd)

Recognition

Snow mold is recognizable at the heart of the plant with white mycelium that later turns leafs in watery spots and later on to brown. During ripening the fusarium species are recognizable at the recolored chaffs. The spike is damaged and the sap movement is interrupted, that causes dead ear tops and smaller grains.

Life cycle

The disease stays in the form of a spore on stubble and straw rests. These can be transported by wind and splashing rainwater. Spores can appear on young leafs and cause foot rot. Each specie has his own temperature optimum. Snow mold easily spread in cool summer (appears at 3 degrees, (Gardena, sd)and to low potassium) other fusarium species grows quicker by higher temperatures. Rainy weather helps spreading the spores due the splashing water on the healthy plants.

Fusarium in the ear occurs especially in wet summers and causes small grains and a low thousand grain weight. Beside that fusarium fungi (except snow mold) toxics like mycotoxins. If the content of mycotoxins is too high the cereal is not suitable for human consumption or animal feed.

Control

To prevent it is important that a good doses of potassium is given.

2.2. Net blotch barley

Net blotch (Rynchopsporium secalis) is most common in summer and winter barley, rye and grasses.

Figure 13 Rynchopsporium secalis (Groenkennisnet, sd)

Recognition

This disease is recognizable at the watery grey spots with a sharp black-brown border.

Life cycle

The spores stay over on stubble and straw rests. The plants get infected by splashing rain. The fungi is active by not too high temperatures and high moisture content. The contamination can come with the seed to the next crop.

Control

A fast germination by higher temperatures gives a lower change of infection. It is also important to do a good soil-turning cultivation to bury the previous crop as good as possible to avoid contamination.

2.3. Net blotch wheat

Septoria (Zymoseptoria tritici) is most common in wheat. After winter round, oval light colored stains can be seen. The leaves die (almost) complete in spring and blurred with fruiting bodies (pycnidiën).

Figure 14 Zymoseptoria tritici, pycnidiën visible (Groenkennisnet, sd)

Recognition

The fruiting bodies are present as black dots in the contaminated stains. From these fruiting bodies spores are formed that can contaminate healthy plants.

Life cycle

The spores stay over on stubble and straw rests. The plants get infected by splashing rain or trough contact with contaminated plants. Infection find place in autumn and the fungi is present during winter. The contamination is most likely if the leaves are wet for a long period. The optimum temperature is between 20 and 25 degrees Celsius.

Control

To prevent infection it is important to do a good soil-turning cultivation to bury the previous crop.

2.4. Brown leaf rust

Especially wheat and rye are getting infected by this rust (Puccinia recondita). This fungi likes warm weather so it can appear till late in the growing season.

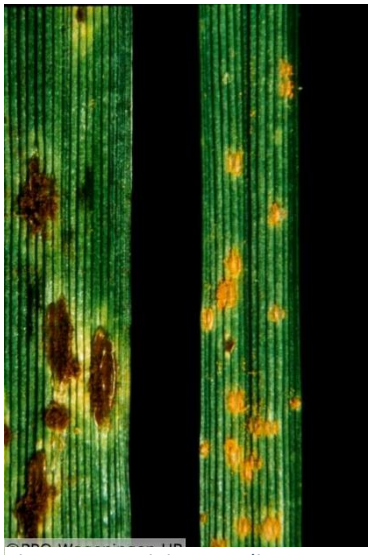

Figure 15 Puccinia recondita (Groenkennisnet, sd)

Recognition

The brown spore piles are spread on the leaf. These piles are bordered with a lighter circle. In these places the black fruiting bodies for the next generation are formed.

Life cycle

Brown rust stays over on the previous hostplant and can infect the healthy plants already in autumn, this can be prevented by a good soil-turning cultivation. When temperatures rises the fungi grows explosive.

Control

To prevent infection it is important to do a good soil-turning cultivation to bury the previous crop.

2.5. Dwarf rust

Especially barley and some grasses are getting infected by this rust (Puccinia hordei). This fungi likes warm weather so it can appear till late in the growing season.

Figure 16 Puccinia hordei (Groenkennisnet, sd)

Recognition

The brown spore piles are spread on the leaf. These piles are bordered with a lighter circle, the same as visible at brown rust. In these places the black fruiting bodies for the next generation are formed.

Life cycle

Brown rust stays over on the previous hostplant and can infect the healthy plants already in autumn, this can be prevented by a good soil-turning cultivation. When temperatures rises the fungi grows explosive.

Control

To prevent infection it is important to do a good soil-turning cultivation to bury the previous crop.

2.6. Yellow rust

Yellow rust (Puccinia striiformis) can appear in different cereal crops and in grasses. The most recognizable are the spore piles that are in rows on the leaves.

Figure 17 Puccinia striiformis (Groenkennisnet, sd)

Recognition

The disease can be recognized at the spore piles in rows on the leaves. Contaminated plants loses green leafs and don't give much yield. The ears can also get infected, this makes it a ripening-disease as well.

Life cycle

The spores stay over on previous host plants. The spreading is optimal at temperatures between 10 and 15 degrees Celsius.

Control

A good soil-turning cultivation can help prevent the spreading of the disease. Drilling not too early can keep the disease less.

2.7. Yellow blotch disease

Drechslera tritici-repentis (DTR) is a fungi that is recognizable by the yellow-brown leafspots with a dark core.

Figure 18 Drechslera tritici-repentis (DTR) (Groenkennisnet, sd)

Recognition

A dark core with a lighter circle is typical for DTR. There aren't any dark dots as by Septoria. In a later stage of the disease the small spots grow together till most of the leaves die.

Life cycle

The disease can come over with the seeds but most of the contaminations comes from previous host plants. Barley, rye and couch grass (Elytrigia) are host plants but the contamination is mostly visible in winter barley.

In autumn the crop can get infected. Most of the times it is first visible in the spring. In the dark cores spores are formed and spread by water or wind. The disease grows best in a wet period. It increases strong by temperatures from 10 degrees Celsius and above.

Control

Good soil-turning cultivation. Later drilling date lowers the change of contamination.

2.8. Septoria nodorum blotch (SNB)

SNB is a ripening disease that occurs when the plant is flowering or ripening.

Figure 19 Septoria nodorum (Groenkennisnet, sd)

Recognition

The fungi is most recognizable by leafspots, these can be confused with net blotch wheat (Septoria tritici) but SNB does not have the black dots of fruiting bodies. In the ear the disease gives a characteristic brown coloring.

Life cycle

The disease stays over at old host plants. The fungi makes year round new spores and spread these. The fungi pulls up in the plant till it affect the ear. Contamination is caused by water, wind and direct contact.

Control

Good soil-turning cultivation gives a lower disease pressure.

2.9. Mildew

Mildew (Blumeria graminis) can appear in all grasses and cereals. In cereals especially in barley and wheat.

Figure 20 Blumeria graminis (Groenkennisnet, sd)

Recognition

Early infection is a white fungi-fluff. Later the affected spots die and turn brown-yellow. On barley the affected spots can die faster without forming any fungi-fluff or spore piles.

The ear can get infected as well, in that case the mildew is a ripening disease.

Life cycle

The fungi stays on the previous host plants. In autumn the drilled winter cereals can get infected from these plant remains. The fungi stays on the plants during the winter. On the fungi-fluff spores, black fruiting bodies, are formed that spread the disease. The infection starts under the plant and goes to the ear where it takes away the light for the plants.

Control

Good soil-turning cultivation to bury the stumble and straw remains. This helps keeping the disease pressure low. A high doses of Nitrogen has to be avoided in order to avoid massive crop where micro-climate can occur.

The grower have to be careful with resistance for chemicals.

2.10. Eyespot

Eyespot (Pseudocercosporella herpotrichoides) is one of the foot diseases in wheat, rye and barley.

Figure 21 Pseudocercosporella herpotrichoides (Deutsche Saatveredelung, sd)

Recognition

The disease can be recognized by the eye-looking spots at the foot of the plant. The spots are oval with a light-brown border and a lighter center.

Life cycle

The fungi stays over on previous host plant remains and affect the vulnerable crops from the soil. A heavy infection can cause lodging. Most of the time one eyespot can be found per stem.

Control

A big crop rotation with non-cereals and not too early sowing can keep the pressure low. Microclimate have to be avoided so not too much nitrogen before drilling and use of growth regulators. When spraying against eyespot it is important to use a technic that the chemicals can reach the spots.

2.11. Loose smut (Ustilago)

Wheat, barley and oats can get infected by this disease (Ustilago nuda and Ustilago avenae).

Recognition

In the fields it is recognizable at the black ears that appear at the start of the flowering. The black color are the spores from this fungi. When these spores are blown away or rained of the only remaining part is the stem of the ear. When there is a spread infection in the field it is a sign that the drilled seeds already where infected by this disease. The actually problem is that no grains are fully formed in the ears.

Life cycle

The contamination stays over in the seeds. The infected plants are flowering earlier than the others and spread the disease. The disease penetrate in the grains and will rest till next growing season.

Control

To prevent this disease it is possible to disinfect the seeds with a treatment. If there are plants find in the field they have to be removed directly without spreading the spores. This have to be recorded in the field book because it is a fungi that easily travel with the seeds to the next generation where it will expand quickly.

2.12. Crown sheath rot

This fungal pathogen produces extensive damage on the sheath of the stem.

Figure 22 Infected plant on the right, Gaeumannomyces graminis (Groenkennisnet, sd)

Recognition

The disease is visible at the black spot on the sheath. It severely damages the stem and roots.

Life cycle

The infection starts from the soil. It comes from remaining plant parts from previous crops. Due to the fungi the nutrient

transport in the plant is blocked so the ears and the grains cannot develop very well.

Control

There are no chemicals against crown sheath rot so the best thing to do is start with a broad crop rotation. The disease is most seen on spots where the soil structure is not good so a good soil preparation is key.

Appendix 3. Recognition of viruses

3.1. Barley Yellow Dwarf Virus

This virus is mostly brought by aphids.

Recognition

BYDV is seen through yellow discoloration, this start at the top of the leaf and spread to the base of the plant. This virus can appear in wheat and barley. Infected plants do not develop well or even die.

Figure 23 Infected plant on the left, BYDV (Kundu, 2009)

Life cycle

Early drilled wheat or barley can get infected in a relative warm autumn due to the still active aphids. The infection is not very visible in autumn. If the temperatures rises in the spring the disease spread in the field. The infections can be seen in (small) areas on the field.

Control

To prevent the crop for aphid damage it is important to drill not too early in autumn, when the crop germinate in November the aphids are not very active anymore and the change of contamination is low. Also previous host plants have to be avoided.

In spring a chemical that contains pyrethroid can be applied against aphids to prevent damaging.

Appendix 4. Recognition of pests

3.1. Aphids

The cereal aphids can appear in an early growing stage, through direct feeding damage the yield can reduced.

Figure 24 Sitobion avenae (Groenkennisnet, sd)

Recognition

In winter cereals there are three different aphids: the English Grain Aphid (Sitobion avenae), the Bird Cherry-Oat Aphid (Rhopalosiphum padi) and the Rose-grain Aphid (Metopolophium dirhodum).

- The English Grain Aphid is dark-green, sometimes brownish, with black legs. This aphids stays over the winter as an egg in grass- and cereal crops. This aphid stays on the leaves till the ear appears, then it will move to the ears.
- The Rose-grain Aphid is light-green with light-colored legs. This aphid stays the winter over on a rose. These aphids are most of the times on the leaves and barely on the ears.
- The Bird Cherry-Oat Aphid stays the winter over on the Bird Cherry tree and is mostly seen on the stem of the plant. In spring and summer the flying aphids fly from the winter host plant to the cereal crop. These population grows fast at sunny and warm weather conditions.

Life cycle

The plants can get sticky because of the honeydew they left. And due to the damage the aphids causes the plants are viable for the Barley Yellow Dwarf Virus (BYDV).

Control

Chemicals can applied if 30% of the ears is occupied before flowering or 70% after flowering (Groeipartners, sd). Selective pesticides are preferred because these do not kill natural enemies like ladybugs, wasps or beetles.

Appendix 5. Recognition of symptoms of deficiency of nutrients:

In this paragraph an overview of nutrients deficiency in cereals based on (Prescott, et al., 1986).

5.1. Nitrogen (N)

Nitrogen is necessary for producing vegetative parts of the plant. It is also responsible for the protein production, so kernel growth. In seed production, kernel growth, is not always desired because it gives bigger seeds and not necessarily better/more seeds. When applied to much there is a higher risk of lodging.

Pale green/yellow tinting of entire leafs, reduced plant height and fewer tillers. Can drastic affect the yield.

Figure 25 Lack of Nitrogen (Scanlan, Critical tissue nitrogen concentrations for diagnosis of nitrogen deficiency in wheat, 2017)

Figure 26 Lack of Phosphate (kali-gmbh, 2017)

5.2. Phosphate/Phosphorus (P)

Phosphate is responsible for the growing of the root system, seed setting and ripening.

Hues of red or purple colors at the stem base and thin leaves. Show up at an early growing stage.

5.3. Potassium (K)

Potassium activates reactions with enzymes. Potassium also maintain the pressure on the cells.

Always visible in old leafs, the whole plant can be affected with all leaves having a spindly appearance.

Figure 27 K-deficiency (Canolawatch, 2016)

Figure 28 Lack of magnesium (kali-gmbh, 2017)

5.4. Magnesium (Mg)

Magnesium is an element for chlorophyll and it is an important part for photosynthesis of the plant. It is necessary to convert nitrogen into protein by enzymes.

Young leaves are pale in contrast with older leaves. The new leaves become chlorotic and remain unopened, resulting in twisted leaves that looks like drought stress. The symptoms looks the same as Potassium (P) deficiency, the difference is that a lack of Mg appears in the young leafs and a lack of K appears in the old leafs.

5.5. Sulphur (S)

Sulphur produces proteins, enzymes and vitamins in the cell membrane. It also helps the plant sty strong against fungi.

Pale green (new) leafs that fail to green-up when more N is applied. Lack of S usually occurs on sandy soils low in organic matter.

Figure 29 S-deficiency (Scanlan, Diagnosing iron deficiency in cereals, 2015)

Figure 30 Manganese deficiency (Scanlan & Brennan, Diagnosing manganese deficiency wheat, 2017)

5.6. Manganese (Mn)

New leafs become pale and limp. Light grey flecking and striping then appears at the base of the young leafs.

5.7. Zinc (Zn)

Pale green stripes on either side of the leaf's mid-rib. On older leafs, these stripes become necrotic and changes to muddy grey/green.

Figure 31 Zinc deficiency (Wilhelm, 2016)

Figure 32 Lack of Copper (Prescott, et al., 1986)

5.8. Copper (Cu)

Tip whitening in young leaves, typical spiral twisting and bending over at right angles to the stem. Ears can be misshapen and underdeveloped. Crop maturity can also be delayed by a weak or two.

5.9. Calcium (Ca)

Calcium maintains strong cell wand and promotes the cell functions.

Young leaves do not become chlorotic with Ca deficiency. Old leaves retain their dark green colour.

Figure 33 Calcium deficiency (CIMMYT, sd)

Appendix 10.

Checklist Report Writing 2018

Name: Ton Boers Group: 4TA

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*The assessment criteria marked with a * are 'killing points'. If the assessor has ticked more than five of them, you must improve the report on all insufficient parts. No killing points are allowed in the thesis/report*

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1. Use of English
- ☐ Contains no more than three grammatical, spelling and typing errors per thousand words; the report is then rejected*.
- ☐ Has an active writing style*
- ☐ Is professional, formal and objective *
- ☐ Is coherent (referral and linking words)*
- ☐ Contains correct punctuation*
- ☐ Does not contain the personal pronouns 'I/me/me, you/you/you, you, you, we/we/us' *
- ☐ Is attuned to the chosen target group*
- ☐ Has a uniform style*

2. The organisation
- ☐ The report has a logical structure
- ☐ Each chapter has a logical paragraph structure
- ☐ Each chapter has an introduction (except ch.1)

3. The report/ thesis
- ☐ Is free of plagiarism*
- ☐ The pages are numbered*
- ☐ Has a uniform format

4. The cover
- ☐ Displays the title
- ☐ Author(s) is/ are mentioned

5. The title page
- ☐ Title is specific*
- ☐ Author(s) is/ are mentioned in alphabetical order*
- ☐ Date and place of publication are mentioned*
- ☐ The sponsor/client of the report is mentioned*

6. The preface:
- ☐ Contains personal reason for writing
- ☐ Contains acknowledgement (”I” form permitted in the preface)

7. Table of contents:
- ☐ All parts of the report are numbered*
- ☐ The summary and appendices are included
- ☐ Table of contents is clear/ structured
- ☐ Page numbers are consistent

8. The summary:
- ☐ Is a concise version of the entire report
- ☐ Contains the conclusions
- ☐ Includes suggestions for further research
- ☐ Does not contain personal opinions
- ☐ Directly after the table of contents

9. The introduction:
- ☐ Is chapter 1*
- ☐ Describes the context, problem demarcation and justification*
- ☐ Provides content relevant background information*
- ☐ Contains the problem definition/research question*
- ☐ Includes the objective(s) of the research
- ☐ Contains a report

10. **Material and method**
- ☐ Describes the research method used
- ☐ Justifies the choice of the research method used
- ☐ Matches/is in line with the problem definition/research question*
- ☐ Describes the research variables/units
- ☐ Describes the method of data analysis

11. The (construction of the) core
- ☐ The chapters and the (sub)sections with a maximum of three levels are numbered *
- ☐ Chapters and (sub) paragraphs have a fitting title
- ☐ A chapter covers at least one page
- ☐ New chapters start on a new page
- ☐ Sentences are typed in sequence, without hard return within the paragraph
- ☐ Figures are numbered and have a fitting title, which is put below the figure.*
- ☐ Tables are numbered and have a fitting title, which is put above the table*
- ☐ Tables and figures can be understood independently
- ☐ Figures and tables are referred to in the text*
- ☐ Each appendix is specifically referred to in the content
- ☐ The text can also be understood without references

12. The discussion of results
- ☐ Includes the interpretation(s) of the results
- ☐ Contains a comparison with relevant literature
- ☐ Contains a review of relevant sources
- ☐ Valid argumentation is provided
- ☐ Contains a critical evaluation of own findings

13. The conclusions and recommendations
- ☐ Contains answer(s) to the research question
- ☐ are based on relevant facts and / or discussion
- ☐ Does not contain any discussion or information that does not appear elsewhere in the report text*

14. References
- ☐ References in the text are in accordance with APA standards*
- ☐ The source list conforms to APA standards *

15. The Annexes
- ☐ Are all numbered
- ☐ Each annex has an appropriate title
- ☐ Do not contain the author’s own analyses
- ☐ Are clearly structured/displayed