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Summary

In a Norwegian context, the cultivation of oilseed rape (OSR; *Brassica napus* and *Brassica rapa*) is limited and challenged by geography, climate, insects and fungus-related pathogens.

Quantitatively, the cultivation of OSR in Norway is rather small when compared to the yearly production and cultivation in Europe. In Norway, OSR is mainly used in feed (animals and fish) and there is also interest in its use as "local biomass" for the production of biofuels. The production in Norway is, however, too small to satisfy domestic demand, thus, much of the OSR used today is imported.

Future potential growth of genetically modified (GM) OSR in Norway would have to meet some, if not all, of the demands/needs and challenges to cultivation. One option may be to introduce fungus resistant OSR. Today, most GM OSR crops on the market are herbicide-resistant.

This report aims to examine the knowledge gaps and research needs in this area, with a focus on environmental issues related to the potential use and introduction of fungus resistant GM OSR in Norway.

We intend to map these knowledge gaps, as well as reveal potential new knowledge gaps related to cultivation of OSR in Norway in general and GM OSR in particular.

The objectives of this report are to:

- Map and document knowledge gaps and research needs related to the potential introduction of fungus resistant GM OSR, in particular environmental risks and biodiversity impacts by using scientific literature and reports;
- Evaluate different future development scenarios of the introduction and use of GM OSR in Norway;
- Present findings from a workshop with invited experts from academia and key persons from the authorities that aimed to map knowledge gaps with emphasis on a Norwegian context; and
- Synthesize the results of a questionnaire survey carried out among Norwegian farmers to obtain their views, needs and knowledge on GM OSR.

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Norsk sammendrag

I norsk sammenheng er dyrking av raps og rybs (*Brassica napus* og *Brassica rapa*) begrenset av geografiske, klimatisk og biologiske forhold. Kvantitativt er dyrkingen ganske liten i forhold til den årlige produksjon og dyrking i Europa. I Norge brukes raps og rybs hovedsakelig i dyre-og-fiske fôr og er også interessant som en "lokal biomasse" for produksjon av biodrivstoff. Produksjonen i Norge er imidlertid for liten og innenlands etterspørsel løses med import. Målet er imidlertid å øke produksjon av raps/rybs i Norge for i større grad å imøtekomme etterspørselen.

Noen av de største utfordringene for raps/rybs dyrking er skader og sykdom forårsaket av insekter og soppangrep. For å møte disse utfordringene kan genmodifisert (GM) raps/rybs være en potensiell løsning.

Vi ser derfor på miljørisiko knyttet til potensiell innføring og dyrking av soppresistent GM raps i Norge. Dette gjør vi ved å:

- Kartlegge og dokumentere kunnskapshull og forskningsbehov ved en eventuell innføring av sopp resistent GM raps/rybs – med fokus på miljørisiko og konsekvenser for biologisk mangfold
- Beskrive potensiell fremtidig utvikling ved innføring og bruk av GM raps/rybs
- Presentere funn fra litteraturstudier for å kartlegge kunnskapshull
- Presentere funn fra workshop med inviterte eksperter med intensjon om å kartlegge potensielle kunnskapshull
- Presentere funn fra spørreundersøkelse sendt til norske bønder for å identifisere deres tanker rundt GM generelt og raps/rybs spesielt

1. Introduction

Oilseed rape (OSR), *Brassica napus* (*B. napus*) and *Brassica rapa* (*B. rapa*), is an important oil crop in Europe and the rest of the world. The leading producers of OSR are Europe, Canada, the United States of America (USA), Australia, India and also China. With regard to biofuels, OSR oil is the source of oil in Europe, due to the high oil content of the plant. Another important issue is the fact that industrial OSR makes a biofuel that freezes at lower temperatures than many other vegetable sources (Peterson et al. 1997), and hence will be more adapted to colder climates.

In Norway, the aim is to increase OSR production in total as well as in the area used for cultivation, as OSR is an important contribution to the "oilseeds" that are used in animal and fish feed. An expected increase in the demand for biofuels is also increasing the demand for production. The production in Norway is at present too low to meet domestic needs, thus, much of the OSR used in Norway today is based on import from OSR-producing countries.

Future trends in genetically modified (GM) crop development show that the upcoming applications for experimental releases in the USA and the European Union (EU) are improved resistance against fungal and bacterial diseases, among others (see for example, GMOinfo[1], Information Systems Biotechnology (ISB)[2], etc.). In total, there have been 24 approved releases of fungus resistant GM crops in the EU, the majority being fungus resistant GM maize, potato and soybean (Collinge et al. 2010).

In this report, "Environmental risks of fungus resistant GM oilseed rape", we aim to identify the main challenges to current OSR production, map the knowledge gaps related to OSR cultivation, including in relation to its wild relatives which could be potential hybridization partners, and identify potential consequences of different scenarios connected to the use and/or production of fungus resistant GM OSR in Norway. Environmental risks of transgene spread and hybridization, as well as monitoring, together with attitudes of the farmers growing OSR today will be examined and used to discuss their potential relevance in Norway. The focus in this report is on OSR and the knowledge that we have for cultivation of OSR in a Norwegian context. Especially, the challenges such as fungal diseases and other factors that are special for Norwegian OSR farmers as compared to those elsewhere and the potential environmental risks related to the spread of the GM trait of fungus resistance into the environment will be elucidated.

This report is a continuation of the report "Monitoring of GMOs released into the Norwegian environment: A case study with herbicide resistant GM rapeseed" (Quist, 2013).

The report is based on the following material and methodologies:

- Literature-based studies, including scientific papers and reports, to perform theoretical analysis of import/growth and production of OSR as well as GM OSR;
- Previous report on monitoring of OSR (Quist, 2013);
- Workshop/seminar presentations and discussions;
- Questionnaire answered by Norwegian grain farmers; and
- Case study analysis.

[1] GMOinfo at http://gmoinfo.jrc.ec.europa.eu/
[2] ISB at http://www.isb.vt.edu/

Our previous report (Quist, 2013) emphasized that detailed knowledge on the ecology of *Brassica napus/rapa* ecology in a Norwegian context is lacking and highlighted the knowledge gaps that require further insight. This report will look further into these aspects and also aims to investigate relevant aspects of the distribution and cultivation of the relevant OSR crops in a Norwegian context. It seeks to provide insight on the potential knowledge gaps related to the production of OSR and its challenges in Norway. It also seeks to highlight the potential invasiveness and "weediness"[3] of these species and the potential environmental risks of the introduction of fungus resistant GM OSR or other relevant GM OSR crops into Norwegian agriculture and the surrounding environment.

Knowledge on plant species cultivated in Norway and the baseline level of growth of their wild relatives are important in order to assess the potential environmental risks by the introduction of GM plants in Norway. Direct and indirect effects on cultivation schemes, surrounding environments and biodiversity need to be understood to be able to look at the effects of gene spread. GM varieties of potentially interesting plant crops could behave differently in a Norwegian context due to factors that are particular to the country. The latter is with regard to climate and biodiversity, and the fact that genes are differently expressed depending on the surrounding environment and factors influencing it.

1.1. Oilseed rape (OSR) species in Norway

1.1.1. *Brassicas* and their relatives

It is estimated that 49 of the *Brassica* species are represented in the Norwegian flora. These are called "The *Brassica* complex" (Asdal, 2012). All of these species can potentially cross and hybridize with the Norwegian varieties of OSR and produce viable and more or less fertile offspring.

1.1.2. Origin of *B. napus* and *B. rapa* (syn *B. campestris*)

B. napus (in Norwegian: *raps*) is thought to originate from an interspecific hybridization between *B. oleracea* and *B. rapa*. Wild forms of OSR are not known. *B. oleracea* is originally from areas around the Mediterranean, and it is assumed that *B. napus* originated from southern Europe.

B. rapa (in Norwegian: *rybs*) is also thought to originate from Europe, but there are on-going discussions as to whether distinct varieties originated from Asia as well.

The origins of *B. napus* and *B. rapa* and general background information on these species are well documented on the webpages of the Canadian Food Inspection Agency (CFIA)[4].

[3] Weediness: A plant acting (or behaving) as a weed.

[4] http://www.inspection.gc.ca/plants/plants-with-novel-traits/applicants/directive-94-08/biology-documents/brassica-napus-l-/eng/1330729090093/1330729278970

1.1.3. OSR and related species

OSR has several related species in Norway that are either cultivated, are weeds or are growing outside agricultural fields in Norway. Most of these have hybridization barriers preventing the production of hybrids, but some can hybridize and produce fertile hybrids. In a report by Finne (2006), the hybridization potential of the OSR species is given according to their ability to cross with *B. napus.* In this report, *B. rapa* and *B. juncea* are the two species with the highest ability to produce hybrids.

Table 1. Relative rating of species according to their ability to produce offspring after hybridization with *B. napus*

Species	F_2-offspring	Offspring after back crossing	Rating
Brassica rapa	+	+	1
Brassica juncea	+	+	2
Brassica oleracea	+	+	3
Brassica nigra	+	+	5
***Brassica adpressa* (syn. *Hirschfeldia incana*)**	-	+	6
Raphanus raphanistrum	-	+	6
Diplotaxis eruciodes	-	+	7
Diplotaxis muralis	-	+	7
Sinapsis alba	-	-	8
Sinapsis arvensis	-	-	8
Diplotaxis tenuifolia	-	-	9
Rapistrum rugosum	-	-	9
Raphanus sativus	-	-	9

(Source: Scheffler and Dale 1994, ref. Treu and Emberlin 2000 referenced in Finne (2006)). Rated with declining ability to make offspring (1= greatest ability).

It must be noted that *B. napus* is somewhat contested due to its strong ability to cross-breed/cross-pollinate with wild relatives and its ability to form populations in the wild (feral). This is of importance when looking at the potential cultivation of GM OSR and the potential for cross-pollination and establishment in the wild, especially if selected for, as is the case with herbicide-resistant GM OSR and spraying with selective herbicides outside fields to fight weeds (as is commonly practiced in other parts of the world).

Hybridization with wild and compatible relatives is influenced by several factors (Andersson and de Vicente (2010), p.82), such as:

- Climatic conditions;
- Selective advantage;
- Insect movements;
- Which species is the pollen donor and which is the acceptor; and
- Chromosome numbers.

Hybridization/crosses between *B. napus* and *B. rapa* are more fertile and have been found and reported in Canada and also in Scandinavia (Halfhill *et al.* 2004, Jørgensen and Andersen 1994; Landbo *et al.* 1996, Warwick et al 03).

PHOTO: 1 (MAUNZEL 64479984 DOLLARPHOTO.COM)

To our knowledge, there are no OSR crops that exist as wild plants in natural conditions. However, as ferals[5], they exist frequently outside cultivation areas, as reported elsewhere (Elling et al 09, Pessel et al. 2001, Schulze et al 14). These plants have "escaped" cultivation.

It is therefore not a question of whether hybridization between GM ORSs and wild relatives will occur if GM ORSs are cultivated in Norway, but rather a question about "to what extent" and "where" this will occur as there are wild relatives of the OSRs growing as far north as Finnmark county (Lid and Lid. 2005, Store Norske Leksikon[6], 2014).

1.2. Production of OSR in the Norwegian context

"The Norwegian Official list of varieties"[7] which is an overview of Norwegian cultivar varieties, records 23 registered varieties of *Brassica* (including registered oilseed, tubers and cabbage) in Norwegian cultivation.

The registered OSR varieties as of July 2014 are six varieties of *B. rapa* subsp. *Campestris* (*rybs*) and four varieties of *B. napus (raps)* (Norwegian Food Safety Authority, 2014) (see Table 3 below). *B. napus* is by far the main OSR produced in Norway as of 2013. This is based on the actual sales of seed and is an estimated number (personal communication, Norwegian Agricultural Extension Service).

The area used for cultivation of OSR crops was around 34600 daa in 2013 and 41100 daa[8] in 2014 (Statistics Norway) with an estimated ratio of 64:36 (in %) for "raps":"rybs". As climate change may result in earlier spring, the "raps" part is thought to be even higher (communication with Norwegian Agricultural Extension Service). This is also described in the master thesis by Ingvild Evju (2011).

5 Feral: Existing in a wild state (not domesticated or cultivated) (Dictionary.com).
6 https://snl.no/åkerkål
7 http://www.plantesortsnemnda.no/offisiell-sortsliste
8 http://www.ssb.no/207411/jordbruksbedrifter-med-areal-av-korn-og-oljevekster.areal-av-de-ulike-kornslaga.fylke

Table 2. List of *B. napus* and *B. rapa* varieties approved and certified for production in Norway

B. napus varieties	*B. rapa* varieties
Barcoli	Agena
Solan	Kulta
Marie	Marco
Sheik	SW Petita
	Tuli
	Valo

Source: Norwegian Food Safety Authority, The Plant Board, Norwegian Official list of varieties, 2014.

1.2.1. OSR species cultivated in Norway

Two species of OSR are cultivated in Norway. These have both spring and winter varieties. The majority of cultivated OSR at present are the spring varieties of *B. napus* (subspecies *oleifera*), which are grown in southern Norway, and *B. rapa* (subspecies *campestris*), which has a wider geographical range. The production is limited by geographical, climatic and biological conditions.

The winter varieties are sown in the autumn, hibernate (as a small plant) over winter and are harvested the following summer. Spring varieties are sown in the early spring and are harvested late in the following summer.

Whereas the winter variety of *B. napus* predominates in Europe and the USA, Canada mainly grows the spring varieties of *B. napus* and *B. rapa*. This is because the winter varieties are less resistant to very low temperatures. This is also the case for the production in Norway, where almost all OSR crops grown are of the spring varieties.

The yield of the OSR crops will depend on the following:

- Climate;
- Variety of OSR crop;
- Pests[9]/insects;
- Soil fertility;
- Intensity of production; and
- Fertilizer input.

The yield of OSR crops will thus vary each year due to these factors and their built-in variation.

Norway does not conduct its own OSR breeding programmes. There are however large breeding programmes where breeding is carried out on both spring and winter varieties of OSR. As Europe mainly cultivates winter varieties of OSR, the availability of spring varieties is less predominant. The spring varieties are also mainly used as rotational crops, bringing with them the challenge of volunteers[10] emerging the following year. This is in turn controlled by the use of herbicides to control growth. Organic cultivation of OSRs is thus considered to be almost impossible in Norway.

[9] Pests: here; organisms that cause disease and nuisance / damage to the OSR plants
[10] Volunteer: self-set plant from the previous year's crop becomes a weed in the following year's crop.

1.2.2. Yield

In Norway, the autumn varieties of *B. napus* gives the higher yields, followed by autumn varieties of *B. rapa* and spring varieties of *B. napus* and *B. rapa* (Abrahamsen et al. 2006). According to Abrahamsen et al (2006) it is common practice in Norway to assume that the difference is about 30 kg/daa greater yield for *B. napus*. Ten years ago, the average productivity of OSR in Norway was estimated to 156kg/daa[11] (Statistcs Norway figures for 1990-2002, in Abrahamsen et al. 2006).

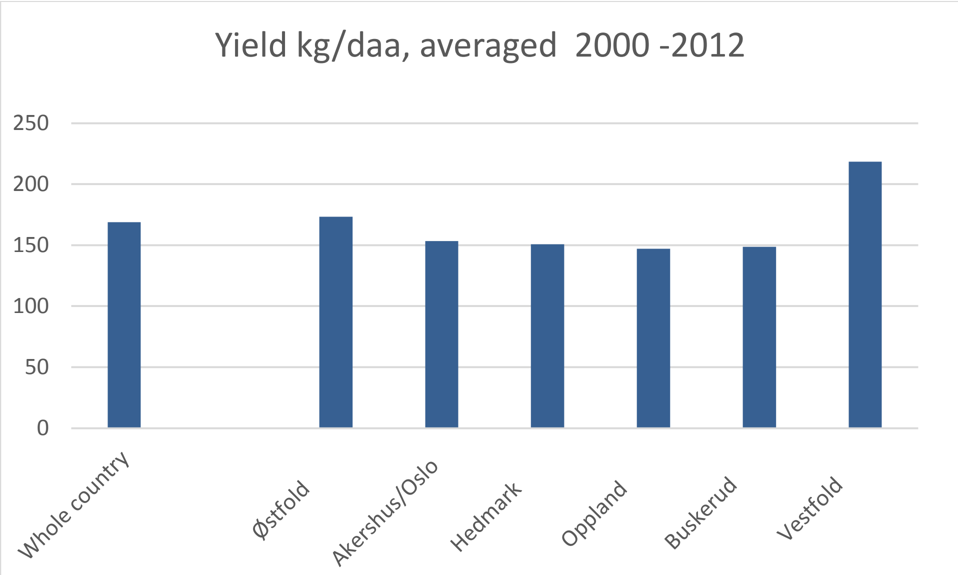

Figure 1. Average yield of oilseed in Norway.

Sources: Delivery Register for Grain and Oilseed (Norwegian Agriculture Agency) and "Total population of rural businesses" (Statistics Norway) (data received from Norwegian Agricultural Extension Service).

The production of OSR has shifted from *B. rapa* as the major Norwegian domestic oilseed produced in 2006-2007, to *B. napus*. The reasons for this shift have been the greater availability of *B. napus* seed varieties on the market and that *B. napus* mainly is used when it comes to breeding.

Abrahamsen et al. (2006) estimated that the cultivation of OSR in Norway could be increased from 70 000 daa (2004) to approximately 450 000 daa, increasing the annual domestic production of OSR to an estimated maximum of 40-50 000 tons. It is not clear if this drastic increase would only come at the expense of reduced production of grain (since the total area in agricultural production is not envisaged to expand) and with additional associated risks of increased occurrence of severe plant pathogens such as *Sclerotinia sclerotiorum* (*S. sclerotiorum)*.

The factors contributing to the relatively low (modest) production of OSR in Norway at present seem to be the following:

- Low yield of varieties;
- More profitable to produce wheat/barley;

[11] Daa= decare, used for area (not a SI unit). 10 daa equals 1 hectare (ha).

- OSR crops are mainly used as rotational crops - they are good plants for improving the soil (in Norwegian= forgrøde), resulting in better yields of barley and wheat in the following years;
- Pests and pathogens;
- Large amounts of seeds that are left behind in/on the soil after harvest and the consequent volunteer problems the following year;
- Decrease in area used for overall plant production; and

Practical issues such as:

- Establishment and germination of seed in the fields are more difficult than with wheat and barley;
- Seeds are not coated with a dressing of antifungal/antimicrobial agents causing vulnerability to pests and diseases; and
- The same equipment is used as for wheat, making it impossible to prevent the occurrence of OSR seeds in the wheat.

1.2.3. Imports of oilseed

In Norway, OSR is an important contributor to the production of so-called "oilseed", which is primarily used in feed for animals and fish. OSR is also seen as an important factor in the production of biofuels. However, the production in Norway is too low to meet domestic needs, thus much of the OSR used in Norway today is based on imports.

The production rate in Norway as of 2013 was 0.01 million tons, while Denmark's production rate was 0.67 million tons (Table 5). The production rate is relatively "modest", compared to the total yearly production of OSR in Europe.

The cheapest and most readily available oilseed alternative in the world market is soybean, which at present constitutes 85 per cent of Norwegian imports of oilseed. The remaining 15 per cent consists of mainly imported OSR, cottonseed and sunflower seed.

Table 3. Imports of oilseed into Norway

	2010	**2011**	**2012**
Total oilseed imports	439	458	428

Annual Norwegian imports of oilseed, 1000-ton (Statistics Norway 2013)

1.2.4. Area used for OSR cultivation and crop rotation

The area used for OSR cultivation in Norway varies annually. This is due to the variability of the growing season, where a late spring leads to a refrain of seeding out OSR seeds and the farmer instead chooses to sow out something else. This is also a result of OSR crops being used as rotational crops, where they are only cultivated in the same field every 6th year to avoid diseases.

An important factor is that Norwegian OSR cultivation mainly is carried out by farmers who use OSR as a rotational crop and not as a “cash” crop/the main crop. Crop rotation is traditionally practiced to fight diseases in the main cultivated crop, by mitigating the build-up of pathogens (and pests) in the field, but also to increase the nutrients in the soil and improve its structure. In general, OSR is cultivated on only a small part of the overall area used for wheat/barley production.

The expansion in OSR growth has not been as large as initially foreseen. This is partly due to the decrease in the number of Norwegian farmers as a whole. The trend in Norway is towards fewer, but bigger, farms and farmers with leased land (many land plots leased at the same time). According to Statistics Norway (2014), the agricultural area has dropped by around 70 000 daa from 2002/2003 to 2013/2014.

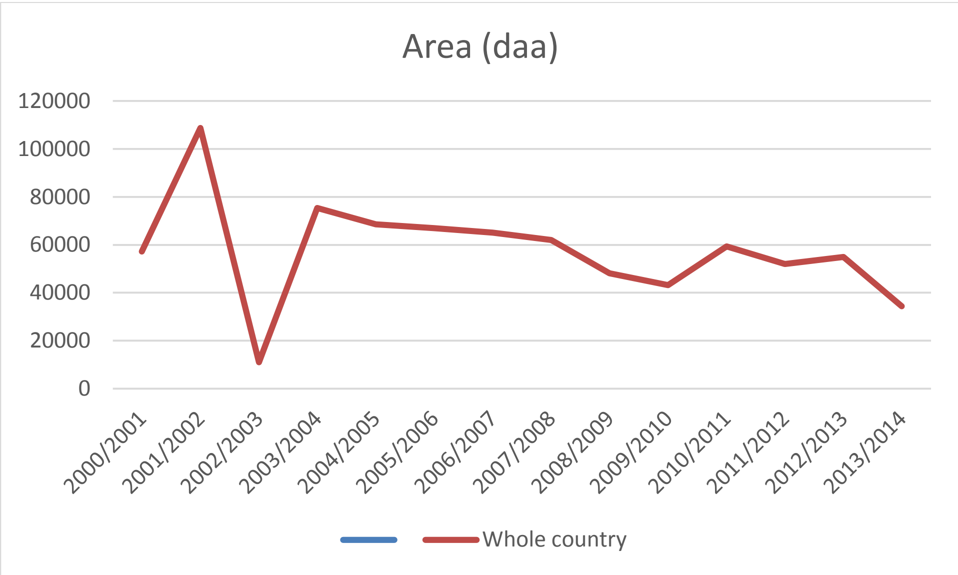

Figure 2: Area used for oilseed cultivation by year
Source: Statistics Norway.

The area used for OSR cultivation was increasing between 2009-2010, where Østfold, Akershus and Oslo had the largest area of production. However, this area has declined since then (see Figure 2).

Recent data from Statistics Norway estimate that an area of 41 000 daa was used for cultivation of oil-producing crops in 2014. This includes the production units that applied for production subsidies that year. This number is far lower than the long-term goal envisaged for area used for OSR crops that for “Felleskjøpet Agri” (www.felleskjopet.no) is to cultivate more than 100 000 daa (referred to in Hivju, 2011).

It is an overall goal for Norwegian agriculture to be self-supplied on food that it is possible to produce, given the climatically conditions and geography. However, the present situation is that the degree of self-sufficiency in Norway is actually going down each year and that we only produce 40 % of the food resources that we need (article in Norwegian Farmers Union website[12]). We also import the ingredients

[12] http://www.bondelaget.no/nyhetsarkiv/dramatisk-klimarapport-article77600-3805.html

for animal and fish feed, although to a lower degree. Thus, to increase the self-supplement of plants that are used for food and feed must be an aim.

Scientists in "Nofima" (The Norwegian Institute on Food, Fisheries and Aquaculture Research) claim that there is great potential for the production of OSR for the purpose of producing vegetable oils (article in Nationen[13]). However, there are major challenges when it comes to the weediness of the plant species involved and the factors affecting the actual yield of the plants, such as pests and diseases.

Future national agricultural priorities on oil crops in Norway will thus potentially lead to increased cultivation of OSR. In this context, new varieties of GM OSR that are climate-tolerant (stress-tolerant) or varieties that are resistant to serious plant pathogens and/or insects might be relevant in the future. Field trials with GM OSR crops that are resistant to fungi and herbicide-resistant varieties have been performed in Europe (Belgium) previously by Plant Genetic Systems NV (1998 and 1999) and Aventis Crop Science NV (2000) (GMOINFO – Joint Research Centre, The European Commission`s in-house science service). However, there has been no new approvals for commercialization of such GM OSR varieties in Europe.

1.2.5. Future scenarios of OSR production

Future scenarios of domestic OSR production include increasing the area used for OSR cultivation, increasing the yield by growing more B. *napus* as compared to *B. rapa* and increasing the focus on OSR as a crop that improves soil structure.

However, the following are some assumptions that have to be first met:

- The availability of varieties that can be sown earlier and give better yields or more robust varieties;
- More control of pests and fungi, which are currently done by spraying synthetic pesticides and fungicides, and use as a rotational crop;
- The seed left in the field after harvest capable of germinating the following year and the herbicides used on the germinated seeds to avoid this problem must be evaluated. Would less processing of the soil prevent these seed from germinating?
- The productivity of the crop plants and price of yield must be increased.

1.2.6. Alternative varieties

In a Norwegian context, it could be of relevance to investigate the potential use of alternative varieties of OSR obtained through breeding or potentially by genetic modification.

Such modifications could be envisaged to have three main objectives:

a) To expand the geographical range of mainly *B. napus* production by development of varieties adapted to colder climates;

[13] http://www.nationen.no/tunmedia/forsker-stort-potensiale-for-a-dyrke-raps-rybs-og-oljedodre-til-oljeformal/

b) To solve challenges related to weed control by introduction of herbicide- resistant varieties of *B. rapa* and *B. napus;* and

c) To improve resistance of OSR to plant pathogens such as *S. sclerotiorum*

Existing GM OSR varieties available do not represent plants that are able to cope well with the Norwegian climate and distinct stresses.

1.2.7. Challenges to OSR cultivation in Norway

Due to the geography of the country, and the fact that some parts of Norway are above the "Arctic Circle", the climate places limits to the cultivation of OSR. It is mainly the counties of Østfold, Vestfold, Akershus and Oslo that have the highest production of oilseed products (see Figure 1), however, the kind of oil crop produced is not specified.

Apart from the climate, there are other challenges, such as pests and diseases caused by microorganisms, fungus and the like.

In a Norwegian context, the main challenges are the following:

Table 4: Major challenges to OSR cultivation caused by pests, insects and microorganisms

Species	Norwegian name	Taxonomic group	Damage	Reference
Meligethes spp	Rapsglansbille	Insect	Eats buds, lays eggs in buds	Andersen et al. 2009
Sclerotinia sclerotiorum	Storknolla råtesopp	Fungus	Causes damage to stems, mycel and sclerotia in stems, damage on leaves	Brodal et al. 2009
Phyllotreta spp	Jordloppe	Insect	Eats seeds that have not started to germinate yet	Lyhagen, 2008
Plutella xylostella	Kålmøll	Insect	Eats leaves	Plantevernleksikonet[14]
Plasmodiophora brassicae	Klumprot	Paracite	Roots damaged due to increased cell division	Brodal et al. 2009

[14] Plantevernleksikonet: http://leksikon.bioforsk.no/

Figure 3: Plasmodiophora *brassica*

Source: http://www.cals.ncsu.edu/course/pp728/Plasmodiophora/Plasmodiophora.html

The abovementioned list of pests/fungi has been developed after communication during the workshop[15] held as part of this project and also based on the factors mentioned in Hivju (2011). There are other insects/fungi/microorganisms that can affect OSR cultivation as well, but these will not be mentioned here.

For OSR cultivation, insects have far more effect and impact on the yield than fungal or fungal-like diseases. The damage caused by these pests and disease factors results in yield losses each year for the farmers.

The different pests can affect the plants throughout the whole growing season and farmers have to watch their fields carefully to be able to combat the pests at an early stage.

According to the literature (Andersen et al. 2009), the "Rapsglansbiller" are the most damaging insects for *B. napus/rapa* in Norway. These insects feed on the flower buds and later on the pollen itself and are very resistant to pesticides. The farmer has to do an early treatment with a highly efficient pesticide in order to knock them out. Even then the insects are weakened, but do not die.

Another important and damaging disease is the infections caused by the fungus *S. sclerotiorum*. This fungus causes rotting of leaves, stems and pods and is hard to manage as it can remain in the soil (as sclerotia) for many years after an attack. It has many host plants and the massive attacks on and in the tissue of plants result in high yield losses. To fight this, the crops are treated with fungicides during flowering. However, there are knowledge gaps related to the presence and diversity of *S. sclerotiorum* in Norway. In other parts of the world, a high degree of genetic diversity of S*. sclerotiorum* has been found (Atallah et al. 2004, Attanayake et al. 2013), and one could expect the same in Norway. A major challenge would then be to develop OSR plants that are resistant towards *S. sclerotiorum*.

At present, there are no OSR cultivars that are resistant or immune to attacks from *S. sclerotiorum* or other fungi. Chemical control and crop rotation, physical and mechanical means are thus the ways this pest is controlled.

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[15] Workshop held in Oslo, Gardermoen on 20-21 August 2014 called "Miljørisiko ved soppresistent GM raps" (eng: "Environmental risks of fungus resistant GM OSR").

There is, however, on-going work to assess natural resistance in young OSR plants, using methods that quantify resistance to plant pathogens. This will help researchers, and eventually breeders, to identify "stable quantitative resistance for control of crop diseases" in young plants (Huang et al. 2014).

The winter varieties OSR are dependent on the time of sowing and the hibernation period during the winter (as mentioned previously). To get a good establishment/germination of the winter varieties, the crop has to be sown early in the autumn. Too much moisture will increase the chance of damage by pests and snails.

The spring varieties of OSR are dependent on the time of sowing and consistent and rapid germination. They are vulnerable to pests, diseases and weeds. To get an acceptable yield from the spring varieties, the plants should be of equal size and experience no attacks from pests during the germination period. OSR production, especially of the spring varieties, is also dependent on uniform sowing depth, temperature and moisture in the soil. Soil that is too moist will increase the potential for damage by pests/insects. This is a particularly a challenge in Norway as the OSR seeds are not coated with anti-microbial and anti-fungal chemicals.

The factors mentioned above show that herbicide-resistant varieties would not meet the challenges to cultivation of OSR in Norway, namely the losses caused by plant pathogens and the climatological constraints.

PHOTO: 2 (STEFANHOLM 65034309 DOLLARPHOTOCLUB.COM)

1.2.8. Applicable OSR varieties in Norway

If varieties with disease resistance and tolerance to lower temperatures and shorter growing season could be developed through conventional breeding or GM, it could potentially represent solutions to the main limitations and challenges for the expansion of Norwegian cultivation of OSR.

The GM OSR GT73 (*B. napus)* with glyphosate [16] herbicide resistance (developed by Monsanto Company) was banned in Norway in 2012 (regjeringen.no).

The factors leading to this ban were:

- Import and use of this OSR may lead to stray seed that potentially can germinate in Norway;
- OSR seed can germinate several years after lying in the soil;
- If established, pollen can spread over wide distances with insects and wind; weeds can thus be herbicide-resistant or the OSR itself can act as a weed in other crops;
- Spread of this GM OSR may threaten and affect the biodiversity in Norway;
- There is no demand for GT73 in Norway, thus there is no social utility;
- Norwegian consumers, agricultural producers and the majority of consultative bodies are sceptical to trade of GT73;
- There are other conventional OSR crops that meet the needs in Norway; and

[16] Glyphosate: A herbicide used to kill weeds. Traded under the name Roundup.

- There is no basis for a conclusion saying that the production and use of GT73 would contribute to sustainable development internationally.

Environmental aspects have clearly been important in justifying the ban of this GM OSR in Norway. GT73 has also been banned in Austria (Bundesministerium für gesundheit und frauen, 2006).

Many of the factors included for the ban of GT73 will also apply for fungus resistant GM OSR varieties. Thus, if such GM OSR are evaluated for commercial release the envisaged advantages must be compared with potential risks.

It must also be noted that conventional breeding of OSR is performed at a high level where varieties with herbicide resistance are developed based on "classical breeding methods" and without the techniques involved in GM plant breeding.

1.2.9. Alternatives to OSR

The oilseed cultivar *Camelina sativa* ("Oljedodre") has been suggested as an alternative or as an addition to existing OSR production in Norway. This is because it contains high amounts of healthy fatty acids (such as omega-3 acids) and anti-oxidants, according to Bente Kirkhus, Project Manager at Nofima[17].

C. sativa also contains other fat-soluble components such as plant-sterols[18] and is interesting as a "healthy" plant for use in oils.

The plant is robust and is more resistant to diseases than *B. napus* and *B. rapa* and also has a shorter crop rotation time. The plant species can still be found sprawling, but is until now a resource that has not been very much in use.

This plant has its origin in Eastern Europe and West Asia and is cultivated in Europe and the USA due to the high content of oil in the seeds. The plant can be grown in large parts of Norway and was previously frequent in use (up to the year 1900) as far north as Finnmark (Artsdatabanken[19]). The plant is thought not to displace other species or to establish elsewhere and is not known to transfer genes (introgression) or parasites/diseases to indigenous species (Artsdatabanken) and is thus not thought to pose any risks to the environment.

[17] http://nofima.no/nyhet/2012/02/fettforskning-store-muligheter/
[18] Plant sterol: blocks absorption of cholesterol in the intestine.
[19] Artsdatabanken: http://www.artsdatabanken.no/

1.3. Potential for spread and crossing with wild relatives in the Norwegian context

1.3.1. Potential for spread of GM pollen in Norway

B. napus, which is the OSR variety mostly cultivated in Norway, is a cross-pollinator and self-pollinator (autogamous) depending on the variety and environment (referred to in Pascher et al 10). Pollen of *B. napus* is spread both by wind and insects. In several countries it has been shown that pollen has been spread up to 4 km from the fields, and according to VKM (Norwegian Scientific Committee for Food Safety, 2006) one must expect that pollen can be spread up to 10 km by certain insects (bumblebees).

Based on the description above, one must expect that pollen from varieties of OSR might be spread and transported into the Norwegian environment the same way.

This means that there is a high potential for the spread of the GM traits into the environment, depending on the available species of OSR, the size of donor and acceptor species populations, field and landscape forms, pollen barriers, environmental conditions (temperature, speed of wind, direction of wind, humidity), and density of insect populations (Warwick 2004 and Mêssean et al. 2006). It is therefore extremely important to map the distribution of OSR-related species in Norway, to be able to foresee the potential spread of transgenes. The most relevant species would be the first three in Table 1 (p.11) describing the species that can produce fertile offspring after hybridization with *B. napus*. These are *B. rapa, B. juncea* and *B. oleracea* (Store Norske Leksikon[20])*:*

- *B. napus*: grows in the southern part of Norway up to Trøndelag county;
- *B*. rapa ssp. *campestris* ("Åkerkål") grows up to Troms county;
- *B. rapa* ssp. *oleifera* ("Åkersennep") grows up to Finnmark county; and
- *B. rapa ssp. rapa ("nepe")* grows across the whole country*.*

Potentially, GM pollen can spread and hybridize throughout the whole country as long as appropriate species for hybridization are present.

The VKM reports from 2006 and 2012 (06/305 and 12/306) discusses pollen flow and of OSRs and the potential for spread of transgenes through this. They also comments on the species with the highest potentials of creating offspring and their expected viability (see Table 1).

It is to be expected that hybridization with related species will occur due to pollen flow, and therefore the potential spread of transgenes through this route is a major issue that should be thoroughly evaluated.

Important questions to consider are therefore: What effects would this potential spread of pollen and transgenes have on the environment? Is there a possibility that this new GM trait will benefit the GM plants and potential hybrids in such a way that they will have increased fitness and invasiveness?

GM plants acting as weeds has been an issue of concern, and OSR relatives have been shown to act as weeds through the acquirement of transgenes resistant to herbicides, for instance (Daniels et al. 2005,

[20] https://snl.no/korsblomstfamilien

report to DEFRA, England). The worst-case scenario would then be if a weed acquired genes that would make it even fitter and weedier.

The EFSA Guidance document on Environmental Risk Assessment of GM plants (EFSA Journal 2010) goes through the steps in risk assessment, where certain factors should be involved in the evaluation of "Persistence and Invasiveness including plant-to-plant gene flow" (p.40). Gene flow is an issue of concern and applicants are asked to describe what risk management measures are required. In their evaluation of the "prohibition of placing on the market of genetically modified oilseed rape event GT73 for import, processing and feed uses in Austria" (EFSA Journal 2013), EFSA concluded that the occurrence of occasional feral OSR GT73 plants, pollen dispersal and cross-pollination did not pose any harm.

1.3.2. Potential for spread of GM seed in Norway

Recent data show that spread and spillage by seed, rather than pollen, is a more significant source of contamination than pollen. Spread of seed results in the establishment of volunteers and ferals that further can results in spread of pollen. Data suggest that up to 10000 seed/m2 is lost), (Lutman et al 2005).

Spread of GM by seed is thus considered as an important issue due to the following (Finne, 2006):

- High production of seed of OSRs;
- Great seed losses during harvest (pods that shatter) with seed that potentially can survive for many years;
- Seed size is small and makes it difficult to contain; and
- Seed lost during handling and transport.

PHOTO: 3 (GILLES PAIRE 8651724 DOLLARPHOTOCLUB.COM)

In addition, the seed can be spread by birds and wind.

These factors imply that it is almost impossible to control spread of OSR seed. Thus, this would be a considerable factor in the spread of transgenes when it comes to potential import and/or cultivation of GM OSRs in Norway.

In the report by Finne (2006) distinct models for spread of transgenes in seed are also given, showing the decrease in amount of transgenes the further away from the field the seed is located.

The "Bundesministerium für Gesundheit und Frauen" (bmgf) in Austria consider accidental spillage of GT73 as a major risk due to the rise of feral "patches" into the wild and establishment of "self-dispersing, cultivation-independent populations ". In Austria, the high import of OSRs is seen to pose a risk for establishment of feral GM OSR plants alongside transport routes. Also, they consider coexistence of GM and non GM OSRs as impossible without interference between them (from "Scientific arguments for an import ban of herbicide resistant rape GT73" by bmgf).

The same risks are relevant to consider in a Norwegian context when it comes to future import or cultivation of GM OSRs.

1.3.3. Scandinavian production of OSR

OSR has a long tradition in agriculture in the Scandinavian countries (Norway, Sweden and Denmark). Geography, geology and climatic conditions are very different, especially if comparing the most Northern part of Norway with the Southern part of Denmark. There are also differences with respect to the OSR varieties that are cultivated, cropping systems, use of agrochemicals in the different regions etc., due to environmental conditions and farm size (Wallenhammar et al. 2014, OECD 2012, Vintersborg and Pedersen 2007).

The world production of OSR was approximately 72 million tonnes in 2013 (FAOSTAT 2014[21]). Table 5 gives an overview of the total production and import of OSR in the world, in Europe and also in the Scandinavian countries. The production of *Brassicas* in a world context is 36.8 million hectares (FAOSTAT, 2014). Even in the EU, the production is too small to meet the European demands, leading to increased imports from other countries.

Compared to the total amount of OSR production in the world, Scandinavian production is rather low. The total amount of oilseed production in Sweden and Denmark is higher compared to the Norwegian production of OSR (Table 5)**.**

Table 5. Total production and import quantity of OSR in the world compared with the Scandinavian countries (FAOSTAT 2014).

	Production of OSR		Import Quantity of OSR	
	Million tonnes 2003	Million tonnes 2013	Million tonnes 2003	Million tonnes 2011
World	36,8	72,5		
Europe	11,5	25,6	2,5	9,9
Denmark	0,35	0,67	0,2	0,16
Sweden	0,1	0,33	0,09	0,05
Norway	0,01	0,01	0,001	0,01

1.3.4. GM OSR cultivation in Scandinavia

In general, Scandinavian agriculture is more or less free from GMOs. There is no commercial production of GM OSR but different GM OSR events are in the pipeline for commercialization in Europe. At present, five herbicide-resistant (HT) oilseed rape events (GT73, MS8, RF3, MS8xRF3 and T45) are approved for import and processing for food and feed uses in the EU (Schulze et al. 2014). None of these events can be grown for commercial purposes in the EU but some have been grown for experimental purposes, e.g. in Sweden (EU SNIF Database[22]).

[21] http://faostat3.fao.org/
[22] http://gmoinfo.jrc.ec.europa.eu

1.3.5. Field trials with GM OSR in Scandinavia

There are several GM plants that have been experimentally released in Sweden and Denmark (http://gmoinfo.jrc.ec.europa.eu/gmp_browse.aspx). In the Scandinavian countries, field trials with GM OSR were conducted from the 1990s onwards. Many multi-year and large-scale field trials were performed and for many years these field trials were conducted under conditions that made escape from the fields possible (Vintersborg and Pedersen, 2007).

Since the 1990s, Sweden and Denmark have authorized a number of GMO field trials, under Directive 2001/18/EC (after 17 October 2002). An historic overview of all data submitted since 1991 is available from the Joint Research Centre (http://gmoinfo.jrc.ec.europa.eu/overview/). A total of 122 summary notifications in the period 1995-2012 was listed for Sweden. The list summarizes all applications submitted and covers various lines of GM OSR, 40 in total.

From Denmark, a total of 57 summary notifications was listed in the period 1992-2012, where four applications were for various lines of GM OSR. In this historic overview, OSR, winter/autumn OSR, summer/spring OSR and swede rape are all classified as OSR and the main trait introduced was herbicide resistance (resistance to gluphosinate[23] and glyphosate). In addition, some other traits that have been field-tested are resistance to fungi, tolerance to drought, alteration of composition, increased oil content, restoration of male sterility, etc. Even though field trials have been conducted for many years, there has been no systematic attempt to determine the consequences of these field trials in terms of the possible persistence of GM OSR in the environment.

Norway, Sweden and Denmark operate under the concept that the farmer introducing GM crops is responsible for assuring coexistence with conventional and organic farming (Vintersborg and Pedersen, 2007). All three countries are working on cultivation distances for GM crops but the distances are not necessarily identical (Vintersborg and Pedersen, 2007). There are also some common rules in the Scandinavian countries when it comes to, for example, cleaning of equipment when handling GM crops and for storage and transportation (Vintersborg and Pedersen, 2007). Further, when it comes to liability – who is responsible if GM material is found to be present in conventional or organic crops close to the GM field – there are different approaches.

1.3.6. Experience with contamination and resistance development issues in Scandinavia

Some of the main concerns when it comes to GM OSR are the environmental and agronomic concerns associated with the escape of herbicide resistant (HT) trait(s) to wild relatives and to other OSR cultivars (GM and non-GM) (Devos et al. 2004, Devos et al. 2012, Schulze et al. 2014). The escape of the GM plants has raised concerns that the build-up of herbicide resistance in feral OSR could make it more difficult to manage these plants using herbicides.

In a Danish study from 2007 (Jørgensen et al. 2007), the purity of certified seed lots, the abundance and origin of volunteers, and longevity and origin of seeds in the soil seed bank were investigated. A relatively high frequency of impurities was found in both the certified seeds and in the OSR fields.

[23] Glufosinate: herbicide *2-amino-4-(hydroxy-methyl-phosphoryl) botanic acid.*

Against the background of the presumed long-term survival of seeds and a high degree of volunteers with an unknown origin, these findings were discussed in the context of the coexistence between GM and non-GM OSR. In the conclusion, the authors urge caution when it comes to cultivation of GM OSR.

Research conducted under the EU SIGMEA project[24] across five sites in four European countries over 16 years, among them Denmark, concluded that the potential risk of contamination from GM ferals depends on whether the GM traits bring a benefit to plants containing the modified gene. For example, if the GM ferals were resistant to a specific herbicide and that herbicide was widely used on waysides and field margins, then they could increase volunteer populations in nearby fields (Squire et al. 2011).

Another example from Sweden demonstrated that OSR seeds in the soil were still viable ten years after the end of a field trial with GM OSR. The Swedish scientists found OSR plants on the former release site that still carried the inserted gene (D`Hertefeldt et al. 2008). The GM OSR contained a gene (bar gene) that made it resistant to the herbicide gluphosinate. A total of 15 GM OSR plants that had almost certainly germinated from ten-year-old seeds from the field trial was reported in this study. The study demonstrates the fact that OSR seeds can survive for a long time in the soil and can emerge as volunteer plants in subsequent crops.

The spillage of seed during import, transportation, storage and handling and processing of GM OSR is also a major concern and cannot be prevented totally by cultivation or import bans. In 2000, Sweden, by mistake, received GM OSR from Canada (Jordbruksverket 2007:21). Conventional OSR from Canada (canola) sold by Advanta had become contaminated with Monsanto Roundup Ready OSR. The contamination happened by cross-pollination with a batch of conventional hybrid OSR. Advanta-contaminated OSR was detected in the UK, Sweden, France and Germany. In Sweden, 500 hectares of the contaminated OSR were sown. Initially, the government said that about one per cent of the seed had been contaminated. However, the Swedish authorities later reported that in one batch up to 2.6 per cent of the seeds were contaminated. The Swedish Agriculture Ministry suggested destroying the crop.

PHOTO: 4 (PHILIPPE DEVANNE 41381525 DOLLARPHOTOCLUB.COM)

1.3.7. Canada

Canada is the largest producer of GM OSR in the world. The Canadian authorities have established a unique regulatory system for GMOs, which focuses on the novelty of a trait, rather than the process used to add to or change the trait. Plants with novel traits (that is "a plant containing a trait not present in plants of the same species already existing as stable, cultivated populations in Canada, or is present at a level significantly outside the range of that trait in stable, cultivated populations in Canada") are

[24] EU SIGMEA: Sustainable introduction of GMOs into European Agriculture (SIGMEA) was supported by the European Commission under the Sixth Framework Programme. http://www.inra.fr/sigmea

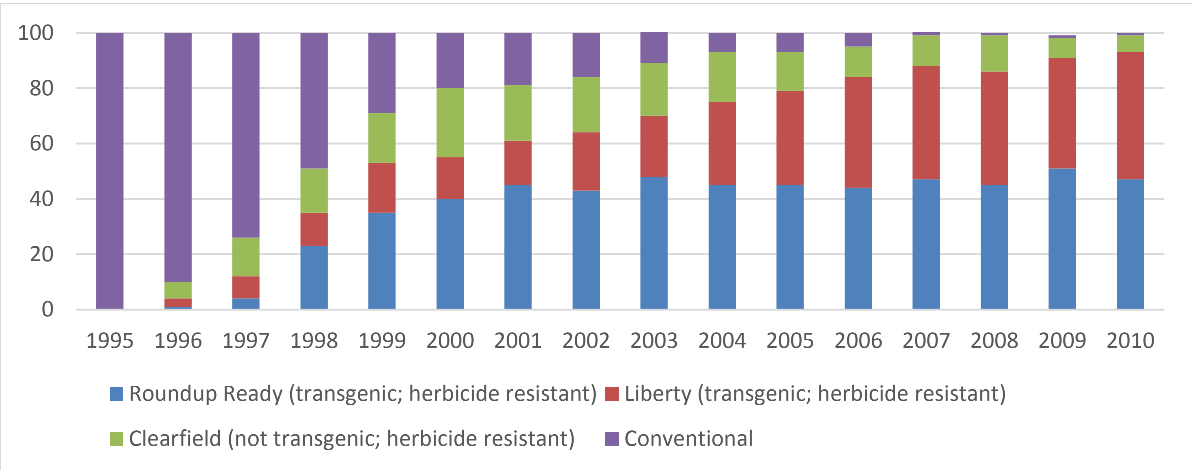
regulated based on substantial equivalence and the nature of the novel trait, and may have been modified through conventional breeding, mutagenesis or recombinant technology (CFIA[25]). Genetically modified organisms (GMOs) that are to be used in food or feed must be approved by Health Canada and the CFIA. Environment Canada is also involved in the approval process of novel products that are intended for environmental release, together with CFIA. Genetic engineering and GM food products are classified as novel foods, and are thus regulated under the Food and Drugs Act by Health Canada. CFIA regulates the environmental release of GM plants, and also oversees field trials.

Canada has no system for monitoring GMOs after a general release permit has been issued, or after the GMO has entered the food production system. There are no requirements for labelling of products derived from GMOs unless there is a health or safety concern related to the product (nutritional composition, allergens) (Library of Congress, Canada).

1.3.8. GM *Brassica* cultivation in Canada

Canada grows three *Brassica* species, namely *B. rapa* -, *B. napus* - and *B. juncea*. After the GM herbicide resistant *Brassica* varieties were released in 1995 it took only 5 years before they constituted more than 50% of production. And only a few years later the GM herbicide resistant varieties dominated the OSR production. The herbicide resistant canolas occupies more than 80% of the area cultivated to herbicide resistant crops (Beckie et al. 2006). Other herbicide resistant crops are soybean, corn and wheat. A non-GM herbicide resistant variety held substantial marked shares in the early 2000's but now production is marginal, together with the conventional canola (see Figure 4 below).

A) Estimated percentage of acres being grown herbicide resistant or conventional



[25] CFIA: Canadian Food Inspection Agency

B) Canola production in Canada

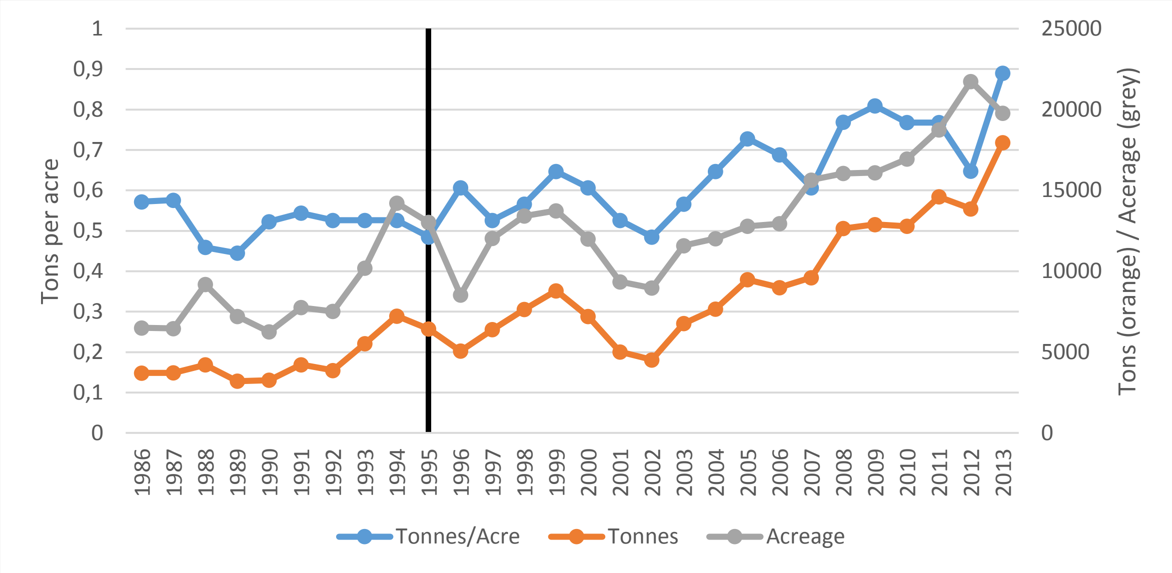


Figure 4: Diagrams showing A) *Estimated percentage of acres*[26] *being grown to herbicide-resistant or conventional crops*: Bars showing the estimated percentage of acres being grown to conventional, non-GM herbicide resistant, and two varieties of GM herbicide resistant crops, since the introduction of GM canola in 1995 and **B) *Canola production in Canada*:** Showing the development of yield per acre (blue line, left vertical axis), total tons produced (orange line, right vertical axis), and acreage (grey line, right vertical axis) used for growing canola since 1986. Notice the black bar marking the introduction of GM canola in 1995. All data from Canola Council of Canada (canolacouncil.org).

As can be seen from the diagram above, canola production is close to have quadrupled since the acceptance of GM canola (orange line) in 1995. Both total production and yield per acre (blue line) started to increase steadily after the GM herbicide resistant varieties became dominant (in the early 2000s, see Figure 4 above). Land use for canola (grey line) has also increased, and about double that of the last decade. The large increase in production is probably connected to the increase in land use. However, since production per acre has increased, it can be assumed that this is not only due to the increased land use, but could also be connected to better agricultural practices, better land being used, better climatic conditions (longer season, climate change?) and perhaps related to the use of herbicide-resistant varieties in weed management. Behind the rapid adoption of herbicide-resistant canola by Canadian farmers are several perceived advantages to herbicide-resistant canola as compared to non-resistant canola.

Among the benefits claimed are (Beckie et al. 2003, Beckie et al. 2006):

- increased yield;
- improved weed management and control; and
- less use of tillage and the opportunity for post-emergence application of herbicides.

[26] Acre: measure of land in "Imperial Units" 1 acre=4.05 daa (based on international acre)

A 2006 review paper by Beckie et al. reported on the observed impact of herbicide-resistant crops being grown in Canada since the mid-90s. Here they report that farmers are experiencing higher economic returns due to better yields, improved quality and reduced input costs with regard to crop management (Beckie et al. 2011). They also report reduced carbon dioxide (CO_2) emissions from the use of herbicide-resistant crops compared to conventional crops due to less fuel use (fewer tillage and spraying operations) and soil carbon sequestration due to less tillage. It has previously been reported that Canada has experienced major reductions in herbicide use after the introduction of herbicide-resistant canola due to reduced application rates and a decreased need for herbicide combinations (Beckie et al. 2006). However, the intensity of herbicide use has not declined substantially since herbicide-resistant canola became the dominant crop, and the environment experiences the same herbicide load as before (Beckie et al. 2006, Leeson and Beckie 2014). This is because non-tillage farmers tend to use more herbicides than tillage farmers.

It took more than a decade before the first weeds resistant to glyphosate and gluphosinate ammonium appeared. However, their appearance remains sporadic, and resistance has only been found in field populations of three species (weedsecience.org). This resistance is thought to have developed through natural selection and not hybridization. In order to avoid further development of resistant weeds it is important that appropriate management practices are performed, such as a good crop rotation system where the type of crop and type of herbicide used is varied together with tillage.

1.3.9. Field trials with GM OSR in Canada

Field trials are overseen by the CFIA's Plant Biosafety Office (PBO), the entity which evaluates applications for field trials and sets out the rules and conditions. *B. napus* is the most commonly used plant among the field trials for the *Brassicas* and the most common traits such as herbicide resistance, yield and stress tolerance have been tested. However, there have also been trials of GM OSR expressing traits of water use efficiency, male sterility, oil composition and nitrogen use efficiency.

Table 6. Number of field trials in Canada 2007-14

Year	2007	2008	2009	2010	2011	2012	2013	2014
Number of field trials	662	204	244	651	726	830	145	90

Source: CFIA. Includes all GM and otherwise modified plants.

1.3.10. Resistance development issues in Canada

The development of resistance to herbicides is not uncommon. The last few years have provided reports on weeds becoming resistant to glyphosate (resistance has been documented in populations of at least three species of weed, (International Survey on herbicide resistant weeds, weedscience.org), a central herbicide when growing Roundup Ready canola. This resistance implies that a different herbicide with a different mechanism of action has to be used in conjunction with glyphosate, as a pre-or-post emergence herbicide depending on its impact on glyphosate. In other words, the emergence of glyphosate-resistant weeds removes most of the advantage of using herbicide-resistant crops (i.e. less herbicide use, no tillage etc.).

1.3.11. Experience with contamination

Canola is an outcrossing species, and in Canada several studies have documented that volunteers with multiple herbicide resistance genes can develop in and around fields (Beckie et al . 2003, Beckie et al . 2006). The same studies also indicate that there is a high degree of contamination, above threshold values, of certified seed material. Beckie et al. (2011) state that herbicide-resistant canola volunteers can be controlled well by applying alternative herbicides with other modes of action. And if the volunteers are taken care of in the first season before seeds are set, the level of volunteers in the field the following seasons will be below the economic threshold. Although gene flow occurs on a large scale, no economic or environmental impacts have been observed in Canada according to Beckie et al. (2011).

1.3.12. Examples of experience with contamination

GM herbicide-resistant OSR was approved for commercial cultivation in Canada in 1995 (Knispel et al. 2008). Since then, two *B. rapa* and ten *B. napus* GM events have been approved for either food, feed, and/or production (CFIA). Most of these events have been modified to be herbicide-resistant, though some contain additional traits. *B. juncea* is also grown in Canada, however not as a GM crop (though cross contamination from *B. rapa* or *napus* might have occurred). Currently, GM herbicide resistant OSR is grown on eight million hectares in Canada (ISAAA).

The GM OSR plants have spread, and this became public knowledge when a study claimed that nearly all of the conventional Canadian seed supply of OSR contained transgenes at varying levels (Friesen et al. 2003).

Canada is the country with the largest export of *B. napus*. Here, the main GM varieties are the herbicide-resistant ones which constitute 87 per cent% of the cultivated area (OECD 2011). In Canada there have been major problems with the spread of the GM-containing events to the “wild”. It has been found that up to 93-100 per cent of the *B. napus* growing by the roads are GM herbicide resistant varieties in some parts of the country (Knispel and Mclachlan, 2010). From the literature it is well known that GM herbicide resistant OSR varieties have been found in locations were herbicides have been used for weed control, thus selecting for the GM herbicide resistant variety. This is also the case in Canada.

1.4. Current diversity and status of GM OSR: Relevance to the challenges of OSR production in Norway

The existing GM varieties of OSR are mainly approved for cultivation in Canada, USA, Australia and Mexico. There is no commercial cultivation of GM OSR in Europe. However, several varieties of GM OSR are approved for import and processing into the EU.

There are a few varieties that have altered lipid profiles for use in feed (for agriculture and aquaculture purposes). Previous assessments of GM OSR in Norway have concluded that viable seed from GM varieties of GT73 (herbicide-resistant) should not be approved for import into Norway.

1.4.1. GM events of *Brassica napus*

For *B. napus,* the ISAAA[27] website lists 30 commercialized GM events. A few of these varieties have modified contents of lipids, such as the CGN-89111-8 event (Monsanto Company), which has modified content of oil/fatty acid and antibiotic resistance.

However, most of the commercialized GM events of *B. napus* are classical herbicide-resistant varieties, such as events with EPSPS[28] pathways circumventing glyphosate toxicity. There are also GM events with alternate pathways, such as the DP-Ø73496-4 event (Pioneer Hi-Bred International Inc.), which has improved resistance to glyphosate herbicides.

1.4.2. GM events of *Brassica rapa*

For *B. rapa,* the available GM varieties are limited, with only two commercialized varieties approved for cultivation, both being herbicide-resistant traits. One is a glyphosate-resistant event called ZSR500 (University of Florida) which is a stack with two transgenes. This event is produced by conventional breeding and the GM traits are introduced through cross-hybridization and selection involving GM donor(s). The other is a gluphosinate-resistant event called HCR-1 (Bayer Crop Science).

1.4.3. Fungus resistant GM OSR

The development of the first fungus resistant GM OSR took place as far back as 1991 (Brogue et al. 1991) where *B. napus* was genetically modified to be fungus resistant through the introduction of a *chitinase*[29] gene. In 1995 (Thompson et al. 1995), an *oxalate oxidase*[30]-encoding gene was introduced into the same OSR species, thus making plants that expressed enzymes that could withstand the secretions from the fungal pathogens or could also attack their structures and be resistant to their attacks. The first field trials of fungus resistant GM OSR took place in 1998-2000. These trial were performed with stacked events having both fungus resistance and herbicide resistance. These events have however not been placed on the market or commercialized.

27 ISAAA: International Service for the Acquisition of Agri-biotech Applications. www.isaaa.org
28 EPSPS: 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase. Enzyme participates in biosynthesis of aromatic amino acids. Target for herbicides such as glyphosate.
29 Chitinase: hydrolytic enzyme that breaks down glycosidic bounds in chitin, which is a cell wall component in fungi.
30 Oxalate oxidase: enzyme that oxidizes oxalate to hydrogen peroxide and carbon dioxide.

Several factors could have caused this, as for instance:

- Varying expression levels of the transgenes; and
- Resistance not 100 per cent effective due to the complexity of mechanisms involved in a fungal attack on plants.

The defence mechanism of a plant undergoing fungal attacks must not be underestimated. It involves structural mechanisms, neutralization of fungal toxins, anti-fungal gene activation etc. This indicates that the "one gene–one solution" scheme might not be effective enough. If one was to succeed in developing fungus resistant GM OSR, this would be an important area of research. One could also consider the ability to develop increased natural resistance toward the most infectious pathogens and fungi by combined crosses of OSR varieties with such increased natural resistance.

A GM OSR (*B. napus)* line that has increased resistance towards *Plutella xylostella* and *S. sclerotiorum* has recently been developed (Liu et al. 2010). These two pests are also considered as two of the main challenging factors affecting OSR cultivation in Norway.

The genes they introduced to increase the resistance are the *sporamin*[31] gene from sweet potato and *chitinase* gene from *Paecilomyces javanicus*. This group is working with different combinations of genes in order to enhance resistance to insect and fungal diseases. Also, the *WRKY33*[32] gene from *Arabidopsis thaliana* has recently been inserted into OSR lines and has been found to give increased resistance to infection by *S. sclerotiorum* (Wang et al. 2014), showing that there is increasing interest in work in the area of fungus resistant GM OSR.

An increasing proportion of the OSR crops grown globally are genetically modified, which raises several issues relating to risks/consequences, including the likelihood that imported OSR oil to Norway might contain transgenes. Today, the majority of commercialized GM OSR varieties are primarily equipped with genes encoding herbicide resistance (glyphosate and gluphosinate ammonium). These types of GM *Brassica* are of little/less relevance to Norwegian agriculture due to the fact that gluphosinate ammonium was banned in Norway from the 1st of January 2010. All use was also forbidden from the 1st of January 2011. This was based on risk evaluations of the herbicide in question, related to health damage aspects of the chemical.

1.4.4. Potential benefits of GM OSR to farmers

Globally, the use of GM crops in agriculture is increasing. The potential benefits to the farmer of using GM crops are:

- Increased management flexibility as the farmer finds the GM crop with the traits he/she wants to cultivate easily;
- Improved weed control through the use of herbicide-resistant plants;
- Less pest damage due to introduced genes that manage the pest (viral, microbial, insecticidal or fungal); and
- Less spraying of pesticides.

[31] *Sporamin*: defense role as a protease inhibitor, storage protein in sweet potato, trypsin inhibitory effect.
[32] *WRKY33*: encodes a transcription factor in pathogen-induced defense signaling (Wang et al 2014).

All these points can be analysed from many different perspectives. However, just looking at these factors without considering the associated potential risks, would imply that GM crops seem to be a good solution for the farmer to improve farming and obtain higher yields due to lower losses from weed competition in the field, pests and other means.

In the Norwegian context, there are few available GM varieties of *B. rapa* and *B. napus* that would be suitable as cultivars. These GM varieties are primarily produced to be herbicide-resistant and it seems that only a few other functional properties have been successfully developed.

The biotech industry has delivered diverse stress-tolerant varieties of cultivars, for instance drought-tolerant varieties. Fungus resistant varieties have so far not been prioritised. However, up to 10 per cent of the total field trials performed over the last five years have been with traits related to disease resistance against fungi, viruses and bacteria (Collinge et al. 2010). Increased focus on OSR as oilseed cultivars together with climate change and increasing damage caused by pathogens in the agro ecological system are probably some of the reasons for renewed interest in these GM OSR plants.

2. The legal framework applicable to GM OSR in Norway

2.1. Norwegian regulations and monitoring of GM plants, with OSR as a case study

2.1.1. Regulations and guidelines

In Norway, the Gene Technology Act (GTA) of 1993 regulates all types of use and development of GMOs, whether for commercial import for food, feed or processing (FFPs), for contained use in approved laboratories, greenhouses or other facilities, or for any type of deliberate release into the environment. Processed, not viable and non-living material originating from GMOs are regulated under different regulations, e.g. as food, feedstuff, medicinal products etc.

The first section of the Norwegian Gene Technology Act states the purpose of the Act as follows:

"*The purpose of this Act is to ensure that the production and use of genetically modified organisms and cloned animals takes place in an ethical and socially justifiable way, in accordance with the principle of sustainable development and without detrimental effects on health and the environment*" (GTA, 1993).

Many parts of the Act, with regard to any application for deliberate release, whether as FFPs or for production and cultivation in agriculture, are further regulated under the Impact Assessment Regulation (IAR). In Norway, risks to health and the environment as well as ethical, social justification and sustainable development considerations must be assessed as part of an application for deliberate release of GMOs.

The Act is broad in its approach and includes therefore aspects of relevant information that are difficult to incorporate and collect, and which are not usually found in risk assessments under other countries' regulations. There are therefore guidelines to parts of the IAR in Annexes 1, 2, 3 and 4 with regard to risk assessment, monitoring and information requirements on the issues of ethics, social justification and sustainable development.

It is mandatory to release all applications for deliberate release of GMOs for public hearings. In this process any organization, institution or citizen can raise their concerns and opinions regarding a specific GMO application.

Another important aspect of the GTA and its underlying regulations is that all GMOs, or development of GMOs, that are not approved by the authorities as contained use within an approved confined facility, are per definition considered deliberate release and therefore need approval as deliberate release in compliance with the Act. An experiment with e.g. GM oilseed rape in greenhouses is therefore considered a deliberate release (unless the greenhouse facility and the modified oilseed rape have both received approval for contained use by the authorities) and will therefore need an approval for deliberate release before the experiment is started.

The aims of the GTA and its IAR are represented in Figure 5, where the overall assessment as a basis for the authorities' decision regarding a specific GM OSR application is presented as an interlinked assessment between natural science issues of risks and hazards related to health and the environment, and social science issues related to ethics, social justification and sustainable development.

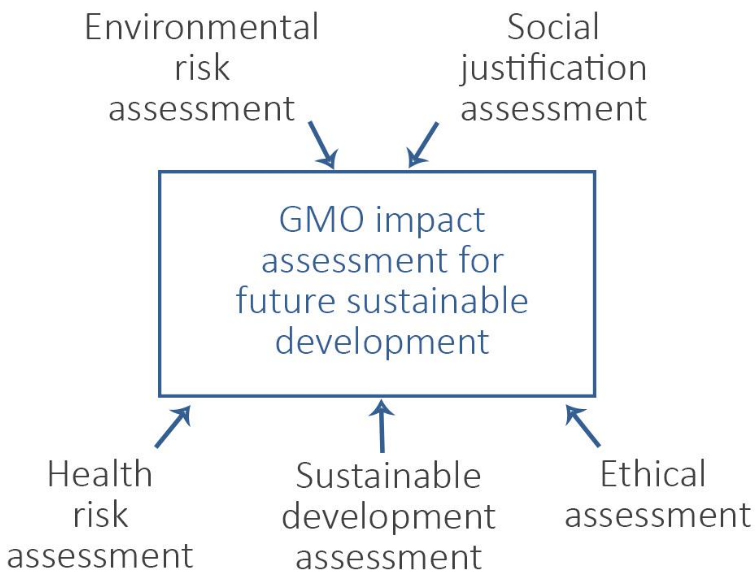


Figure 5: Purpose of the Norwegian Gene Technology Act

After J. Husby (2006) "The role of Precaution in GMO Policy".

All types of monitoring or general surveillance regarding GMOs, whether imported as FFPs, for placing on the market, or for deliberate release into the environment, e.g. in agriculture, forestry, aquaculture or other types of usage, are regulated by the IAR under the Act. The IAR specifies many aspects of monitoring, in which objectives, general principles and the design of the monitoring plan are outlined in Annex 3. Suggestions for a monitoring plan, in line with this regulation, should always be a part of an application for marketing and deliberate release of GMOs in Norway.

Due to the European Economic Area (EEA) agreement with the EU, many aspects of regulating and managing GMOs in Norway are harmonized with relevant EU directives and their management procedures. This is also the case for monitoring plans outlined in Annex 3 of the IAR, which is only a translation into Norwegian of the EU Annex VII on monitoring plans under the Directive 2001/18/EEC on deliberate release of GMOs. In the EU, Annex VII regarding the monitoring plan is further elaborated (Council Directive 90/220/EEC, 2002), which establishes the EU guidance supplementing Annex VII to Directive 2001/18/EEC. This EU guidance will also be of importance when designing monitoring plans in relation to marketing and deliberate release of GM plants in Norway, and therefore of high relevance regarding any applications for use of GM OSR in Norwegian agriculture or in the processing industry. In addition, the European Food Safety Authority (EFSA) has developed "Guidance on the Post-Market Environmental Monitoring of genetically modified plants" in 2011 (EFSA, 2011). It is also especially useful to understand the importance of other EU regulations and management tools that may have effects in relation to monitoring, e.g. regulations and guidelines on coexistence, and those on traceability and detection of GMOs.

In addition to the harmonization with the EU regulations, there are obligations and guidelines under the UN Cartagena Protocol on Biosafety that are also of relevance to the monitoring of GMOs, due to the fact that Norway is a Party to the Cartagena Protocol. The guidance on risk assessment and monitoring under the Cartagena Protocol does not have the same level of obligation as the EEA agreement, being merely "soft" guidelines and not strict binding obligations, in addition they are being neither as comprehensive nor as applicable as the EU regulations and guidelines. Nevertheless, they are of high importance in the global context.

2.1.2. Responsible authorities and decision procedures

The Ministry of Climate and Environment (MCE) has the overall management responsibility for the marketing and deliberate release of GMOs in Norway, while the Ministry of Health and Care Services has the responsibility for contained use of GMOs. Both ministries have to conduct their responsibilities and decisions under the GTA in compliance with other relevant ministries, e.g. Ministry of Trade, Industry and Fisheries or the Ministry of Agriculture and Food, thereby ensuring that sectorial knowledge, opinions and responsibilities are considered before any decisions are taken. Ideally, consultations, input and collaboration involving all relevant ministries and their underlying entities should take place before any decisions on e.g. marketing, use or release of GMOs are made.

Under the MCE, the Norwegian Environment Agency (NEA) is the authority responsible for receiving GMO applications, conducting hearings and managing the application procedures. The public hearings regarding deliberate release of GMOs should ideally be also open for comments on the monitoring plans. The NEA gives their final recommendations to the MCE, which takes the decisions. This is often a political decision taken at the Minister or Government level. Norway also has a Biotechnology Advisory Board that is mandated through the GTA, and which makes recommendations to the Government, Parliament and authorities on each GMO application in relation to social, ethical, sustainability and risk issues. In addition, the Norwegian Scientific Committee for Food Safety under the Ministry of Agriculture and Food makes recommendations regarding risk assessments on health and the environment to relevant authorities. The opinions and recommendations from all these entities are always publicly available, and may in many instances also be of high relevance for monitoring plans related to specific GMO decisions.

2.1.3. Environmental monitoring

In the Norwegian environmental and agronomic context we can establish that due to many specific factors, the deliberate release of GM OSRs represents a "worst case scenario" predicted for GM plants. Some of the specific factors are listed in the following bullet points, and are further discussed and elaborated on in other parts of this report:

- OSR survives very well in Norwegian climate conditions, especially in the southern and central parts of the country, and can establish feral populations in "wild/semi-wild" nature outside agricultural fields;
- OSR has many small seeds that disperse easily and that can survive and remain viable for years in the soil seed bank, and can easily be spread over longer distances by different types of natural vectors, e.g. insects, birds, mammals and through waterways;
- OSR has pollen that can be easily transported, e.g. by wind and insects, and remains viable and can cross-pollinate over long distances;

- OSR has a tendency to establish volunteers in crop rotation systems and can thereby become a weed problem in the following year's crops, and therefore is also able to disperse seeds over longer time periods; and
- OSR has natural wild relatives in Norway with which it can hybridize through cross- pollination, and thereby spread genes and new modified traits, and possibly establish wild hybrid populations.

Due to the small, light seeds of OSR, we expect that safeguarding dispersal through harvesting equipment, transport and storage places will be an issue for the monitoring plan. In general, when developing a monitoring plan for any GM crop variety, it will follow case-by-case procedures, in which each GM transformation event will have an individual dossier and risk assessment, and a specific monitoring plan for that application and its suggested use. All the points above will be of importance in a risk assessment of GM OSR, and will in addition be points of generally high concern in a monitoring plan context. In addition, the modified traits, the stability of the genome, knowledge of the farming system and the surrounding environment, including proximity to wild related species and other OSR fields, will be important aspects in the risk assessment, and therefore of concern when establishing the monitoring plan. Most of the detailed aspects of monitoring GM OSR are described in detail in the GenØk report; "Monitoring of GMOs released into the Norwegian environment: A case study with herbicide-resistant GM OSR" (Quist, 2013), and will therefore not be further elaborated in this report, with the exception of some relevant aspects which were not discussed in that report.

In general, it can also be noted that due to the biology and nature of OSR, monitoring during and after release will need to have a long-term perspective in relation to the wider release areas and the established protection goals, and also in relation to possible unforeseen effects. Established protection goals and possible adverse impacts in relation to these should usually be identified during the risk assessment procedures. It should therefore be relatively easy to identify monitoring methods for those identified hazards within a monitoring regime. The unforeseen unexpected impacts that may happen, those with no indications from the risk assessments and the scientific literature, are more difficult to comprehend, and may fall outside a monitoring plan. The intention of the regulations and monitoring guidance is that such possible adverse impacts should be taken care of under general surveillance regimes of release areas and identified monitoring indicators.

2.1.4. Costs and benefits of monitoring

In a marginal agricultural system with low income, which is often the case in Norwegian agriculture, a relevant question will be, who is going to pay the extra costs for the monitoring and general surveillance (compared to growing conventional OSRs without these costs)? Will it be the applicant, the farmers, the consumers, the Government or others? These types of "speculative", but relevant questions, will undoubtedly be raised by the taxpayers, consumers and farmers in relation to monitoring plans for all types of GMO releases, also in relation to any GM OSR applications. We can therefore determine that the relations between different elements of the Norwegian GTA, especially those that refer to sustainability, socio-economic considerations and social justification, are interlinked with costs of producing any new GM OSR variety under Norwegian conditions, especially in comparison to conventional OSR varieties. The questions of who pays for the monitoring, who should conduct the monitoring and general surveillance, and who will receive the benefits of switching from conventional

OSR production to GM OSR, are therefore of high relevance in the Norwegian context. In accordance with the Norwegian GTA, these types of issues may have to be identified and models for solutions decided upon before any decisions on release and marketing are taken. See also section with regard to survey among farmers in Norway.

3. Target and non-target organisms, indicator species relevant to the introduction of fungus resistant GM OSR

The environmental effects of GM OSR are dependent on the type of trait incorporated and released into the recipient environment. A good understanding of the interactions and structure of the plants' associated community of organisms is also required. This will include potential target organisms if the incorporated trait aims to control pests or diseases, and non-target organisms, i.e. organisms that are not the target of the expressed novel trait (e.g., anti-fungal compound, Bt[33]-toxin) or of the required cultivation practice (e.g., pesticide application).

Islam (2006) listed the following strategies in a review of GM approaches to fungal resistance in plants:

1. Over-expression of genes that produce compounds e.g. pathogenesis-related proteins (PR proteins) and phytoalexins[34], which are directly toxic to pathogens or reduce their growth;
2. Expression of genes, e.g. polygalacturonase[35], oxalic acid[36] and lipases[37] that destroy or neutralize the components of pathogens;
3. Expression of gene products e.g. peroxidases[38] and lignin[39], that can potentially enhance structural defence in the plants;
4. Expression of gene products, e.g. elicitors[40], hydrogen peroxide (H_2O_2)[41], salicylic acid (SA)[42] and ethylene (C_2H_4)[43] that regulate signals to control plant defences;
5. Expression of the resistance gene (R) products involved in hypersensitive response (HR) for their interaction with the avirulence (Avr) gene;
6. Binding or inactivation of fungal toxins, thus stopping invasion of the fungus by expression of an R gene; and
7. Other strategies are production of RNAi, RNase and lysozyme. In such cases genes isolated from sources apart from plants are exploited. Available reports include introduction of double-stranded RNA from viruses found in fungi and genes of lysozymes cloned from human tissues.

[33] Bt: *Bacillus thuringiensis*
[34] Phytoalexin: antimicrobial substance produced by plants.
[35] Polygalacturonase: enzyme produced in plants (involved in ripening) and fungi/bacteria (involved in rottening).
[36] Oxalic acid: organic acid present in nature.
[37] Lipase: enzyme that hydrolyzes fat.
[38] Peroxidases: family of enzymes known to increase defense mechanisms in plants.
[39] Lignin: polymer, part of cell walls of plants and some algae.
[40] Elicitor: compound that signals activation or synthesis of other compounds.
[41] Hydrogen peroxide: signaling molecule in many biological processes.
[42] Salisylic acid: organic acid, functions as a plant hormone.
[43] Ethylene: natural plant hormone.

All of these strategies have the potential to alter features in GM plants, including when transferred to OSR, that in turn could affect the performance and fitness of plant-associated entomofauna[44] or other fungal organisms associated with OSR. In particular, alterations of lignin content or expression of substances which are also shared with insects have the potential to influence fitness features of the OSR-associated entomofauna.

As a starting point for risk assessment, the ecological functional categories relevant for biodiversity services and that are relevant to the OSR system should be identified (Andow and Hilbeck 2004, Birch et al. 2004, Hilbeck et al. 2006, EFSA Guidance 2010).

In an agricultural context, species assemblages fulfil a variety of ecological functions such as biological control, transfer of pollen, or recycling of organic material, which help to sustain soil fertility (Jax 2005, Fontaine et al. 2006). Any change in these assemblages can possibly harm the agro-ecosystem and impact farming success and activities.

Assessing the consequences of the incorporated trait within GM OSR fields and also following transgene flow to recipient wild or weedy relatives, for example from fungus- or insect-resistant OSR to wild relatives of the *Brassica* family, involve an understanding of different functional groups at various levels. Firstly, flower-visiting insects are potential pollen vectors delivering the service of pollination not only between OSR plants, but also to its wild relatives (Saure et al. 2003).

Secondly, whether a transferred fungus or insect resistance gene confers an ecological advantage to the wild relative will depend on the functional relationships between the plants and their associated herbivores including, in this case, fungal diseases (Hails 2000, Johnston et al. 2004). Thirdly, once a fungus resistance transgene has successfully invaded a new population, it inevitably exerts non-target effects on organisms associated with the new recipient plant population, including fungal pathogens (Johnston et al. 2004). Therefore, it is critical to know the main functional groups and the dominant species within these groups, associated not only with the GM plant but also with the potential wild/weedy or cultivated mating partners of OSR.

Because the insect fauna associated with a particular plant species vary with both time and region, adequate information for assessments needs to be obtained by direct observations made in the intended target region. During our literature and Internet database search, we found that there is only little and patchy information on insect diversity in OSR fields in Norwegian production regions. The workshop held during this project and the presentation held by the participants from Bioforsk and the Norwegian University of Life Sciences gave a good overview of the most challenging insects and fungi for OSRs. The most important ones are listed in Table 4 (p.16). Prior to a release of GM OSR for field trials or commercial production, a thorough survey should be carried out to help identify and select the most relevant arthropod[45] organisms that should be subjected to testing prior to release and/or monitoring following field release of GM OSR in Norway. For the remainder of this section, we rely upon and report about insect diversity studies from other OSR-producing regions in Europe, north of the Alps.

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[44] Entomofauna: a fauna of insects, the insects of an environment or a region.
[45] Arthropod: invertebrate animal with external (exo) skeleton. Insects are in this class.

3.1. Entomofauna diversity in OSR fields

OSR fields normally host a quite diverse, associated arthropod fauna including fungal microorganisms. Most published literature, however, deals with the entomofauna of OSR fields. In Europe, the most common pest species of OSR are pollen beetles (*Meligethes aeneus*, *M. viridescens*), cabbage seed weevil (*Ceutorhynchus assimilis*), cabbage stem weevil (*Ceutorhynchus pallidactylus*), rape stem weevil (*C. napi*), *brassica* pod midge (*Dasineura brassicae*), cabbage stem flea beetle (*Psylliodes chrysocephala*) and flea beetles (*Phyllotreta nemorum*, *P. undulata*, *P. diademata*) (Free and Williams 1978, Free and Williams 1979, Tarang et al. 2004). However, little data could be found on entomofauna in Norwegian OSR fields in the published English scientific literature. Hence, we draw from published literature in other OSR-producing European countries.

In 2002, Tarang et al. (2004) studied potential pests (phytophagous[46] insects specialized on cruciferous plants) and their natural enemies (hymenopterous[47] parasitoids and carabids[48] as predators) in organic autumn OSR in Estonia, a country also at similar latitudes of Europe as the most south OSR-producing regions of Norway. The following is a summary of their findings.

Herbivore[49] species: The authors reported eleven species of crucifer-specialist insects (caught in the yellow traps): *Meligethes aeneus, M. viridescens, Ceutrhynchus assimilis, C. floralis, C. rapae, C. pleurostigma, P. undulata, P. vittata, P. atra, P. armoraciae, and P. nemorum.* Although of all these potential pest species, *Meligethes aeneus* and *Ceutorhynchus assimilis* were the most numerous, they found that these species only fed on the OSR plants but did not reproduce there. This explained the absence of larvae of both species and the absence of their typical damage. In contrast, *Meligethes* spp. can become significant pests in OSR fields in more southern growing regions of Europe like Switzerland and Germany (Meier 2007). *Meligethes ssp*. is also found in most of Norway.

Parasitoid species: Hymenopterous parasitoid species from 16 families were recorded, including the following six parasitoids of target phytophagous insects:

Phradis morionellus (Holmgren) (Ichnemonidae, Tersilochinae) an endoparasitoid of *Meligethes aeneus* larvae; *Diospilus morosus*, *Mesopolobus morys, Stenomalina gracilis, Trichomalus perfectus* (Walker) (Pteromalidae, Pteromalinae) ectoparasitoids of *C. assimilis* larvae; *Omphale clypealis* an endoparasitoid of *Dasineura brassica* larvae.

Predator species: Furthermore, 41 taxa of carabids were recorded in the Estonian organic OSR field. Prevalent genera of carabids were *Pterostichus, Amara, Agonum, Harpalus* and *Carabus*. Among them, the genus *Pterostichus* dominated, with *P. cupreus* and *P. melanarius* being the most numerous species. Most carabids are polyphagous predators, especially those of the genera *Carabus, Calathus, Trechus, Bembidion* (Goldschmidt and Toft, 1997). All carabid larvae are predators.

[46] Phytophagous: feeding on plants.
[47] Hymenopterous: insects having two pairs of membranous wings and an ovipositor.
[48] Carabids: family of beetles (Carabidae).
[49] Herbivore: plant-eating species.

In an extensive, multi-year study in Swiss OSR fields, Meier (2007) found that across all three study years and across all OSR fields, the category of "flower visitors/pollinators" was consistently the most abundant functional insect group, both in terms of numbers of individuals and species. The functional group "herbivores" was the next dominant group with a clearly assignable function. The third important functional category was "predators". The temporal distribution of the numbers of species within these three dominant groups (flower visitors/pollinators, herbivores, and predators) showed a quite uniform pattern with low and only slightly fluctuating levels of species richness before mass flowering.

The onset of mass flowering of OSR had a massive effect on species diversity and abundance. The average numbers of species per field doubled within the three functional groups compared to the numbers prior to flowering. After flowering, the numbers of species decreased, only to increase again continuously until the end of the sampling period when the highest levels were observed. When analysed separately for each functional group, two functional groups basically followed that described pattern - the numbers of total species would multiply in numbers during the beginning of mass flowering, followed by a decrease during the peak and end of flowering and an increase again towards the end of the sampling period. Only the functional group of flower visitors departed from that pattern, with a peak during flowering followed by a steady decrease without a subsequent increase towards the end of the observation period, which is clearly explained by the absence of flowering plants.

Amongst the flower visitors/pollinators, the two dominant groups during the flowering period across all six oilseed rape fields were always the Anthomyidae flies, which were represented by at least four species, and *Meligethes anaeus* beetles (Nitidulidae). The only other primary species within this functional group were *Meligethes viridescens* and the honey bee *Apis mellifera*. Furthermore, at least four wild bee species *Andrena haemorrhoa*, *Andrena nitida*, *Andrena flavipes*, and *Andrena lagopus* and the syrphid fly species *Xylota segnis* made up a measurable portion of the flower visitors/pollinators (Meier 2007).

PHOTO: 5 APIS MELLIFERA (AZUR13 69488734 DOLLARPHOTOCLUB.COM)

In Meier (2007) analyses revealed that there was a remarkable uniformity in insect community structure between different OSR fields. Even across different periods of oilseed rape phenology[50], the relative composition of functional groups remained fairly constant. Despite the fact that half of the fields studied were sprayed with insecticides just before the start of the sampling period, he did not find that this had a significant influence on the number of species and individuals present.

However, likewise uniformly, the beginning of mass flowering of OSR triggered the movement of millions of insects into OSR fields. Thus, with the onset of mass flowering, the total number of insects

[50] Phenology: study of insect and animal life cycle events and how variations in climate and season influences these.

recorded increased by a factor of four (Meier 2007). Such a mass movement of insects into particular locations may influence the local distribution of insects across a whole region, especially in cases where OSR field densities are high and constitute the predominant food source for many insects. However, this is confirmed for autumn OSR fields but not for spring OSR (Westphal et al. 2003), although in the very northernmost regions, the dynamics in spring OSR fields may function like autumn OSR fields in more southern regions as it also represents an early season crop. Finally, Meier (2007) also concluded that the high abundance of flower visitors and herbivores attracts predators and parasitoids, which also increased significantly in numbers of species and individuals during OSR flowering.

3.1.1. Entomofauna diversity on related *Brassicaceae* species

In the context of transgene flow, identifying potential pollen vectors that could transfer pollen from OSR to related species is critical (Saure et al. 2003).

On all three *Brassica* species monitored by Meier (2007), the dominant insects were always the *Meligethes* spp. beetles with average relative abundances between 82 and 97 per cent per plant. Further, except for *Sinapis arvensis,* weevils of the genus *Ceutorhynchus* were relatively frequently observed on the related *Brassica*. Some wild bees were observed on *Raphanus raphanistrum* and *S. arvensis*.

Anthomyidae[51] flies and *M. anaeus* were the dominant species not only among flower visitors but also in the overall sample. Little is known about the Anthomyidae flies and their ability to transfer pollen from OSR to related species. However, even though their movement between OSR and related species during flowering is probably rather marginal, their great abundance increases the chances of them transferring pollen. More research is needed to know whether they are likely to transfer pollen from one species to another. Besides, Anthomyidae flies were not recorded during the visual inspections of related *Brassica* species.

The pollen beetle *M. anaeus* is known to support pollination within OSR crops. This species is rather sessile, making a transfer from OSR to related plants during the flowering period of oilseed rape unlikely. However, it moves from oilseed rape to other flowering plants – preferably *Brassica* – towards the end of the flowering period, and pollen transfer could occur at this stage (Saure et al. 2003). *M. anaeus* beetles carrying OSR pollen could be detected several hundred meters from OSR fields (ZALF 1998). Among the insect species detected on the related *Brassica* species monitored, pollen beetles were always the most dominant insects, making it a key species in the system studied in terms of a potential pollen vector at the end of the OSR flowering period and in terms of a common herbivore shared by OSR and related species (see Meier, 2007).

Two further groups that merit special attention as pollen vectors between OSR and related *Brassica* are the syrphid[52] flies and bees (Apiformes). Because of their high mobility, these two groups can also transfer pollen from OSR to related species during the entire flowering period. Even though only few syrphid fly species were caught in the yellow pan traps and their dominance was relatively low in the fields studied, they are known to be pollinators and are much attracted by *Brassica* (Proctor et al. 1996). Conner et al. (1995) describe syrphid flies as an important group of pollinators for *Raphanus raphanistrum*, a close wild relative of OSR that is known to hybridize with it and that co-occurs with

[51] Anthomyidae: Diverse family of flies. Some can act as agricultural pests.
[52] Syrphid: Family of flies. They feed on nectar and pollen.

OSR in our study areas. Although syrphid flies are not obviously adapted to pollination, the probability of them causing pollen transfer from OSR to other species is relatively high since many of them are migrating species, moving between habitats several kilometres apart (Salveter and Nentwig 1993).

Meier (2007) identified several wild bee species in OSR fields. Increasingly, wild bee species are being recognized as important pollinators within agricultural crops, in particular with colony collapse disorder diminishing honey bee abundance significantly in many regions (Kremen et al. 2002, Fontaine et al. 2006, Hayter and Cresswell 2006). In contrast to *A. mellifera*, which usually revisits the same plant species over and over again, wild bee species including bumble bees often switch between different pollen sources (Westrich 1989). Therefore, the wild bees have a high potential to transfer pollen from OSR to wild relatives.

In summary, a high diversity of all studied categories executing important ecological functions, flower visitors/pollinators, herbivores (including pests), and predators/parasitoids was identified in OSR fields in Europe, including at latitudes similar to those of Norwegian OSR production regions. While not all flower visitors are necessarily pollen vectors, coincidental pollen transfer may occur and increase in particular with those species that exhibit great mobility between fields and habitats. Due to the mass movement of insects in and out of OSR fields depending on OSR flower phenology, the critical period for pollen transfer from OSR to related *Brassica* species occurs towards the end of flowering. The pollen beetles *Meligethes* spp. are especially key species during this period because of their high abundance in OSR fields and on related *Brassica* species. As expected, *A. mellifera* constituted the most abundant single species among the pollinators. However, high numbers of wild bee species were also observed, which, due to their migrating and mobile foraging behaviour, are possibly a more critical pollen vector to related *Brassica* than honey bees. In this regard, little is known to date and more research must elucidate their pollen transfer capacities and distances, in particular in Norway. These issues are of utmost importance not only in relation to unwanted transfer of transgenes from GM crops to related species, but also in the context of seed purity and coexistence.

4. Environmental risks and ecological considerations in the cultivation and production of OSR

Seed dispersal during harvest of OSR results in substantial losses of viable mature seed. Such seed loss due to shattering of seed pods is estimated at 2-5 per cent of the yield (Price et al. 1996). These seeds additionally have strong ability for dormancy, especially when the soil is tilled post-harvest. Viable seed thus constitute a soil “seed bank” from which volunteers will germinate into crops cultivated in consecutive seasons. Persistence of *Brassica* seed in such dormant seed banks is considerable and although most potential volunteers can be expected to have germinated and thus been purged from such OSR fields within the first five years following harvest, evidence documents volunteer *Brassica* oilseed rape emerging more than 10 years after harvest (D` Hertefeldt et al. 2008, Jørgensen et al. 2007).

It should also be noted that the issue of seed shattering and subsequent loss of produce as well as potential for volunteers in future crops are addressed by the agrochemical industry which has solutions for farmers, as in the use of chemicals (herbicides). One such chemical aid is produced by the company Novokem and trademarked as *Iskay pod protector*. Iskay is synthetic polymer glue used in a mixture of Roundup glyphosate herbicide. The herbicide acts as a desiccant ensuring homogenous ripening of the OSR crop, whereas the polymer glue aids in entangling the seed pods in a “lattice” or mesh, which keeps the pods closed during seed maturation and subsequent harvest. According to industry estimates, OSR harvest potentials thus increase from 2 900 kg/ha to 3 450 kg/ha (Novokem 2013). However, other reports indicate that the use of glyphosate-based desiccants can decrease yields compared to untreated OSR crops (Pits et al. 2008).

4.1. “Worst-case scenario”: Spread, hybridization with wild relatives and “weediness”

If GM OSR is a potential future agricultural crop in Norway, its ability to spread and persist in a given environment, together with its outcrossing potential, are features that must be considered so as to foresee what might happen in a Norwegian context.

In order to adequately consider the ecological impacts of GM crops, we need to examine the hybridization potential of the crop. As we know, the hybridization potential for the distinct OSR crops is extant and varying.

According to “Feral OSR- Investigations on its potential for hybridization” (Bundesministerium für Gesundheit und Frauen, Austria), ecological risk assessment necessitates looking into and investigating areas of:

- Seed dispersal;
- Frequency of feral OSR;
- Persistence outside cultivation, i.e. fitness; and
- Invasiveness in natural habitats.

What we do know about the *Brassica* species are the following:

- Species of *Brassica* are well-adapted colonizers of new environments;
- Large areas of Norway are susceptible as suitable receiving environments for species of *Brassica*;
- Some species, sub-species and varieties of the *Brassica* complex hybridize and interbreed readily, producing viable and fertile offspring;
- Viable seed of *Brassica* species such as *B. napus* can persist dormant in soil up to 10 years;
- Normal seed spillage during harvesting of *B. napus* in agriculture is estimated up to 10 000 seeds/m^2 (Lutman et al. 2005);
- Agriculture logistics and other transportation of *Brassica* seed create substantial spillage at handling facilities and along transport corridors, mainly roads and railway lines;
- Animal vectors, mainly bird-mediated transport, are important contributors to the spread of seed, accelerating invasiveness and establishment of feral populations; and
- Outcrossing frequencies at field level are theoretically known through simulation studies (Colbach et al. 2009).

Another important issue is the fungal status on wild *Brassica* in the Norwegian environment. How diverse is it, how does it affect the wild *Brassicas*?

Would a potential introduction of fungus resistance through spread of transgenes to wild OSR relatives cause a change in the natural balance of the fungus on the *Brassicas*?

We believe that the import of viable OSR seed should be considered as an example of a case for analysis of potential environmental effects of GM OSR in Norway.

4.2. Exposure to fungus resistant GM OSR in Norway: Analysis of four scenarios

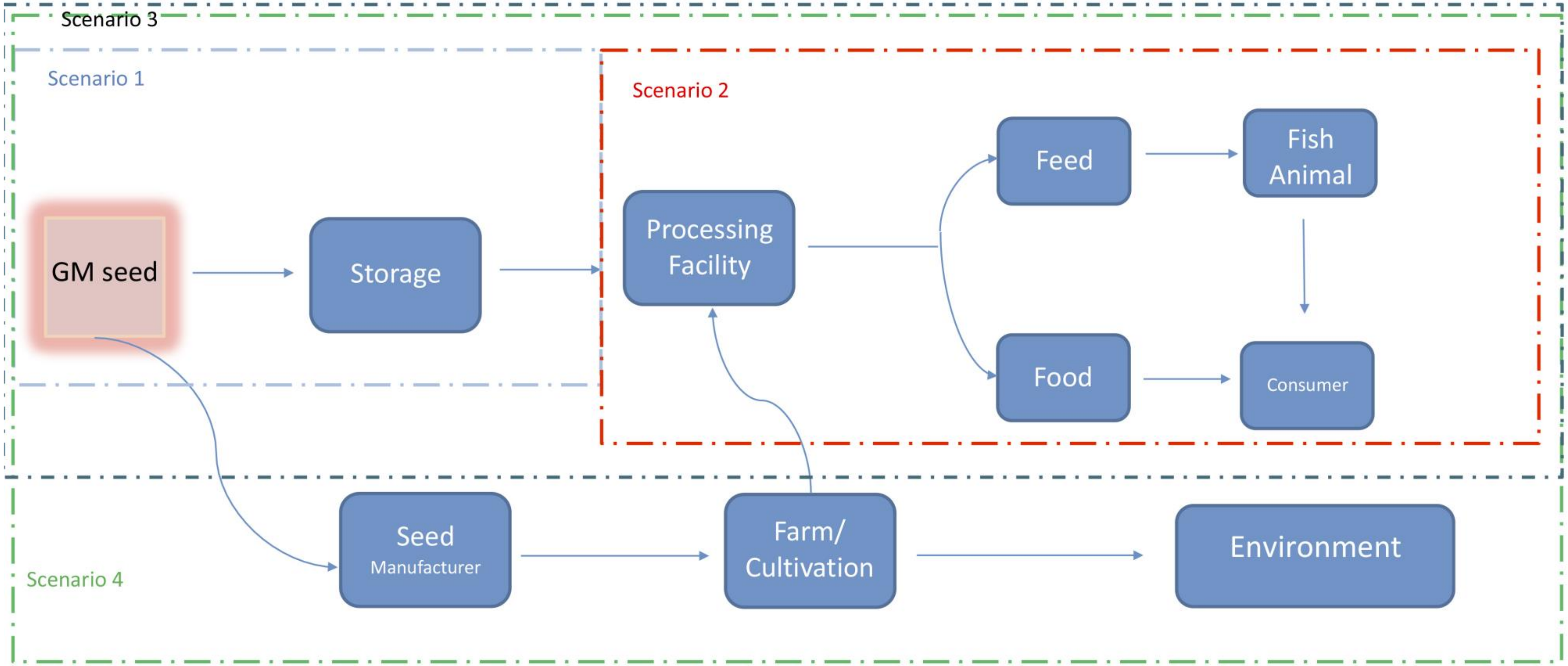
In this part of the report we will go through different scenarios of potential exposure to fungus resistant GM OSR in Norway. The scenarios range from "no import or cultivation" to "large scale cultivation of fungus resistant GM OSR".

In our previous report (Quist, 2013), we wrote that due to the expansion in use of GM OSR globally, and the extensive import of OSR, GM OSR might enter Norway through transport and "accidental" mixing of imports.

This report explores different scenarios of the potential introduction of fungus resistant GM OSR in Norway. Thus, **the focus will be on scenarios 3 and 4,** focusing on viable GM OSR. Scenarios 1 and 2 will be briefly presented.

We highlight the potential exposure pathways and risks to environment (Figure 6), as well as point out the potential knowledge gaps and factors (Table 7) that require further investigation.

Figure 6. Overview of different scenarios regarding import of (fungus resistant) GMO



Scenario 1: No approved import or cultivation of fungus-resistant GM OSR
Scenario 2: Approval of import of processed fungus-resistant GM OSR
Scenario 3: Import of viable fungus-resistant GM OSR, but no cultivation
Scenario 4: Cultivation of fungus-resistant GM OSR

Important factors to consider are listed in Table 7 below.

In the following, the scenarios to be described further involve fungus resistant varieties of GM OSR approved for import only (Scenario 3) or for import and cultivation (Scenario 4). These GM OSR crops are viable and can, by spread and spillage, establish in the wild if the right conditions are present.

The Norwegian Food Safety Authority is responsible to oversee that Norwegian regulations are followed, while the overall control of food/feed for potential presence of GMO is done by the Norwegian Veterinary Institute. They are responsible for the surveillance and mapping program of GMs called: "Tilsyn med genmodifisering i såvarer, fôrvarer og næringsmidler" ("Supervision of genetic modification in seed, feed and food"). Which institution that would have the overall responsibility for surveillance of GM and non-GM OSR seed storages and detection of contaminations between them is an issue that should be clarified in advance of the allowance of this import.

The same authorities could perhaps also have responsibilities regarding the regular control of the seed retailers and seed manufacturers marketing seed to the farmers cultivating OSR.

Overall monitoring and regulations connected to this are described in the chapter called "The legal framework applicable to GM OSR in Norway" on p.32 onwards. See also report by Quist (2013).

An important issue for these scenarios is the transport of the fungus resistant GM seeds between the different facilities, seed retailers, farmers etc. How much OSR seed is spilled during transportation? In Norway, the transport routes are long and mostly by road (today's scenario). Are there selective advantages for spilled GM seed along the roads? If these GM OSR crops are stacked with herbicide resistance genes, the herbicide used to kill weeds by roads and railway tracks would be an important factor to evaluate further.

The factors listed in Table 7 for the distinct scenarios needs further investigation, with special emphasis on the factors that could be special in a Norwegian context due to our way of performing agriculture, handling seed, harvesting, transport etc.

Table 7: Important factors to consider in the different scenarios regarding fungus resistant GM OSR in Norway

	Storage	Seed bank / Manufacturer	Processing	Feed	Food	Farm / cultivation	Environment
Scenario 1 ***No approved import or cultivation of fungus resistant GM OSR***	Control of imported seeds for illegal presence of GM seeds.	Regular control of seed for cultivation.	Accidental spillage from processing and "garbage" checked for GM content	Random testing	Random testing	Not an issue.	Obtain baseline data on wild *Brassica* species. Monitor for pollen flow from neighboring countries.
Scenario 2 ***Approval of import of fungus resistant GM OSR for processing***	Maintain containment between GM and non GM OSR. Control of imported seeds for illegal presence of GM seeds.	Control of GM and non-GM OSR seeds. Maintain containment. Control non-GM seed lots regularly	Controlled processing. No spillage to surrounding environment. Segregation of GM and non-GM during processing Regular control of process.	Regular testing of feed. Labelling.	Regular testing of food. Labelling.	Not an issue.	Monitoring for accidental spread by transport (spillage) and potential hybridizations with wild relatives.
Scenario 3 ***Import of viable fungus resistant GM OSR, no cultivation***	Maintain containment between GM and non GM OSR. Control of imported seed for GM content.	Control on GM and non-GM OSR seed regularly. Maintain containment	Controlled processing. No spillage to surrounding environment. Segregation of GM and non-GM during processing Regular control of process. Regular control of process.	Regular testing of feed. Labelling.	Regular testing of food. Labelling.	Randomized control/monitoring of OSR cultivation to detect potential spillage and hybridization with non-GM OSR.	Monitoring for accidental spread by transport (spillage). Monitor environment for potential hybridizations with wild relatives.
Scenario 4 ***Cultivation of fungus resistant GM OSR***	Maintain containment between GM and non GM OSR. Control of imported non- GM seeds illegal presence of GM seeds.	Control on GM and non-GM OSR seed regularly. Maintain containment	Controlled processing. No spillage to surrounding environment. Separate GM and non-GM during processing Regular control of process.	Regular testing of feed. Labelling.	Regular testing of food. Labelling.	Coexistence issues of GM and non-GM OSR. Measures taken to secure coexistence and segregation (detection, monitoring)	Monitoring for accidental spread by transport (spillage). Monitor environment for potential hybridizations with wild relatives. Evaluation of potential weediness of these. Selective advantage due to GM trait? Biodiversity issues.

5. Questionnaire: What do Norwegian farmers think about the relevance of fungus resistant GM OSR?

Norwegian farmers cultivating grain (i.e. wheat, barley, oat, rye) or OSR (i.e. either *B. napus*, *B. rapa* or both) were invited to respond to an online questionnaire on the challenges related to OSR cultivation and the use of GM OSR in Norway. The questionnaire was approved by the Data Protection Official for Research, Norwegian Social Science Data Services.

The questionnaire contained 15 questions regarding:

i) challenges related to OSR cultivation in Norway;
ii) relevance of different traits in GM OSR under Norwegian growing conditions;
iii) farmers' interest in growing GM OSR;
iv) environmental risks related to the cultivation of GM OSR; and
v) considerations of social utility, sustainability and ethics related to the cultivation of GM OSR in Norway.

The Norwegian Agricultural Extension Service (Norsk Landbruksrådgiving) distributed the questionnaire to grain and/or OSR farmers in the eight counties in Southern and central Norway (Akershus, Buskerud, Hedmark, Nord-Trøndelag, Sør-Trøndelag, Telemark, Vestfold and Østfold). They sent an email with an invitation and link to the online questionnaire to individual farmers. The questionnaire was open to respondents from the 13th to 27th October, 2014.

The eight counties included in the survey represent the counties in Norway where we usually find OSR cultivation. In Norway, OSR is used as a rotational crop in grain production. The intention of the Norwegian agricultural authorities is to increase OSR production through increased use as a rotational crop. We therefore also included farmers that currently only produce grains in the survey. According to statistics from the Norwegian Agriculture Authority[53] (2014), there are currently 9 998 grain producers in the counties selected for the survey. In total, 100 grain producers responded to the survey (however, each respondent did not necessarily respond to every question of the survey). Most of the respondents were from Akershus (34) or Østfold (34) and Vestfold (20). Additionally, there was one respondent from Hedmark and two from Buskerud, while no farmers from the three remaining counties responded to the questionnaire. The majority of the respondents (87 per cent) cultivated either *B. napus or B. rapa,* or both of these crops. Among these, 50 per cent cultivated *B. napus*. Only 13 per cent of the respondents produced grains only. A summary of the results from the questionnaire is presented below.

[53] https://www.slf.dep.no/no/en

OSR cultivation in Norway: Challenges, explanations for low adoption rate of OSR and suggestions for factors that could contribute to an increased adoption

Pests (insects) and pathogens, unfavourable climatic conditions and a short growing season were described as the main challenges to OSR production in Norway. These problems result in yield loss and low productivity. Establishment of seeds (germination) and the need to sow seeds early in the growing season (for spring OSR) were particularly mentioned as challenges, due to the climatic conditions in Norway. Some respondents also mentioned economic constraints and the lack of access to appropriate equipment for harvesting and drying of seeds as other challenges.

Low yield, economic constraints and unfavourable climatic conditions were considered as the main reasons for the low adoption rate of OSR cultivation in Norway.

Improved knowledge about OSR cultivation and the benefits of OSR as a rotation crop for grain producers were mentioned most frequently as factors that could help to increase the cultivation of OSR in Norway. Besides this, OSR varieties suitable for Norwegian growing conditions, climatic change, improved productivity and increasing price of the crop were often mentioned as factors that could contribute to increased future production. Some of the respondents highlighted the need for more and cheaper pesticides (to fight insect pests and pathogens) and improved systems (equipment, handling and storage) for OSR harvesting.

Cultivation of GM OSR in Norway: Attitudes, knowledge and possible environmental impacts and societal, ethical and sustainability considerations

When asked whether Norwegian authorities should allow cultivation of GM OSR, half of the respondents answered “no”, while only 10 per cent answered “yes”. Almost 32 per cent of the respondents were unsure (Figure 7). The participants who responded “other” expressed that an approval of GM OSR had to be based on proper environmental risk assessment, and that it could be a competitive advantage to produce non-GM OSR, but that this production should be compensated through better prices for non-GM OSR.

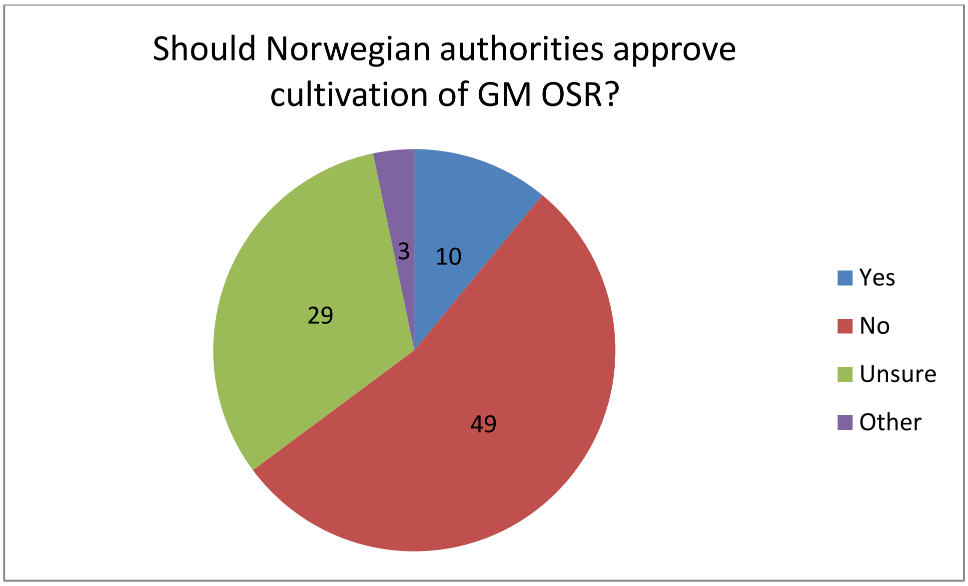


Figure 7: Respondents' views on potential approval of GM crop cultivation in Norway (Number of respondents given).

Similar attitudes were expressed when the farmers were asked if they would cultivate GM OSR if Norwegian authorities were to approve it. Figure 8 shows that the share of farmers responding "no" or "I do not know" are almost the same and constitute more than two-thirds of the responding farmers. The share of farmers responding "yes" is one-fifth of the responding farmers.

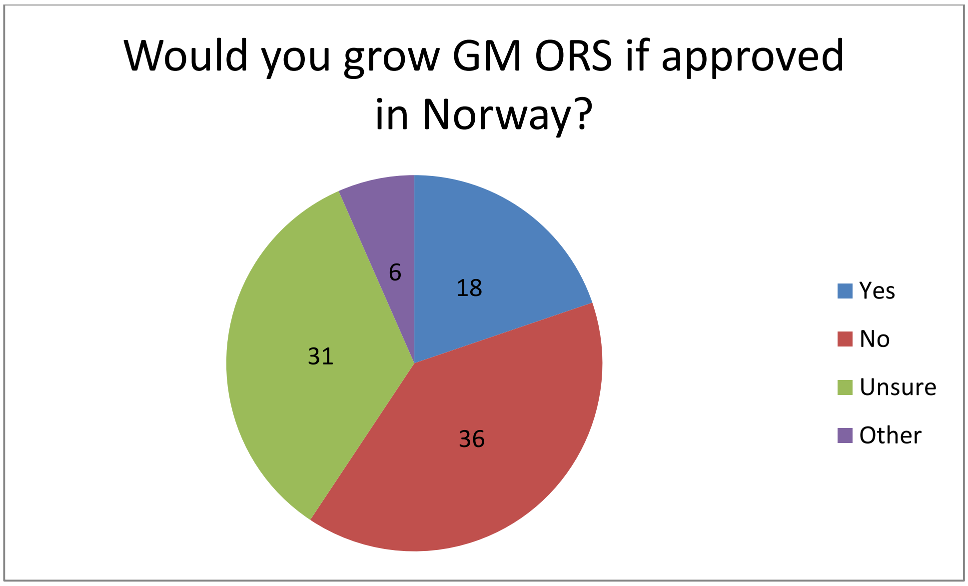


Figure 8: Respondents' views on whether they would cultivate GM OSR (Number of respondents given).

The farmers who wanted to cultivate GM OSR considered higher yield, better economic conditions, more stable crops and less herbicide use as the main benefits. The main concerns among the farmers who did not want to grow GM OSR were uncertainty about long-term consequences, risk of unintentional spread of GM OSR to the surrounding environment and increased problems of herbicide resistance in weeds. Concerns regarding the interest of multi-national companies developing GM crops and their ownership of the technology and seeds were also mentioned. The farmers who were unsure mainly wanted more information about possible long-term, unwanted effects, particularly with regard to environmental risks.

The six respondents who answered “other” issues, had the following type of concerns: i) this is a political question, ii) yes, if there are no antibiotic resistance genes involved, iii) more knowledge is required, and iv) yes, if GM OSR is more suitable as a rotation crop for farmers cultivating other *Brassica* species/varieties.

The participants were asked to rank four types of GM OSR crops according to their relevance and suitability for cultivation under Norwegian growing conditions. The GM OSR crops proposed had the following traits: (i) fungus resistance, (ii) pest resistance, (iii) herbicide resistance, and (iv) altered fatty acid composition. As shown in Figure 9, there was a small tendency among the respondents to rank GM OSR with fungus resistance and pest resistance as more relevant than GM OSR with herbicide resistance or altered fatty acid composition.

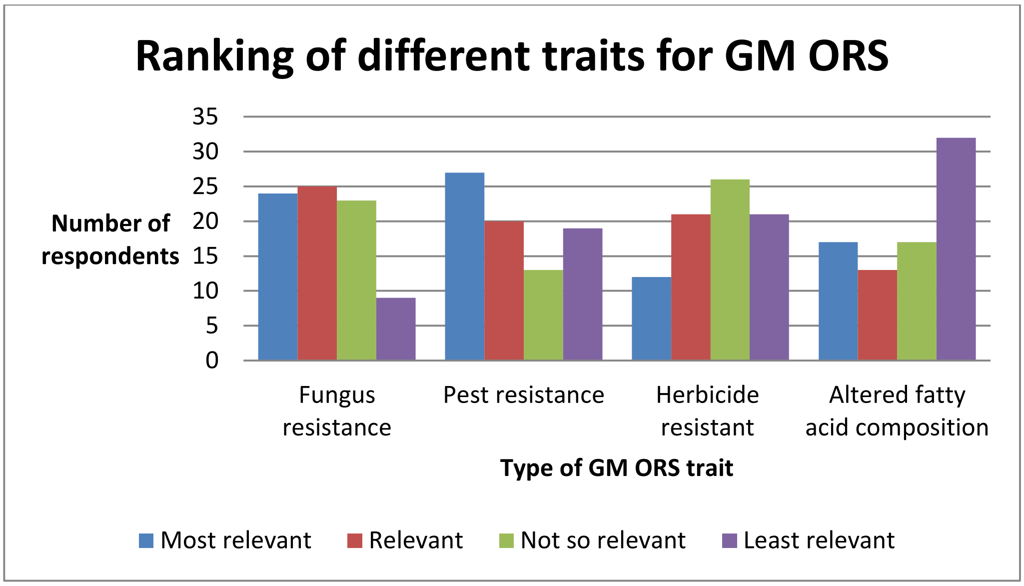


Figure 9: Respondents' ranking of the relevance of different GM traits for OSR cultivation in Norway

The farmers were also asked to rank their knowledge about GM plants. Figure 10 shows that more participants considered their knowledge on this topic as "poor"/"very poor" than "good" / "very good". One-third of the farmers ranked their knowledge as intermediate.

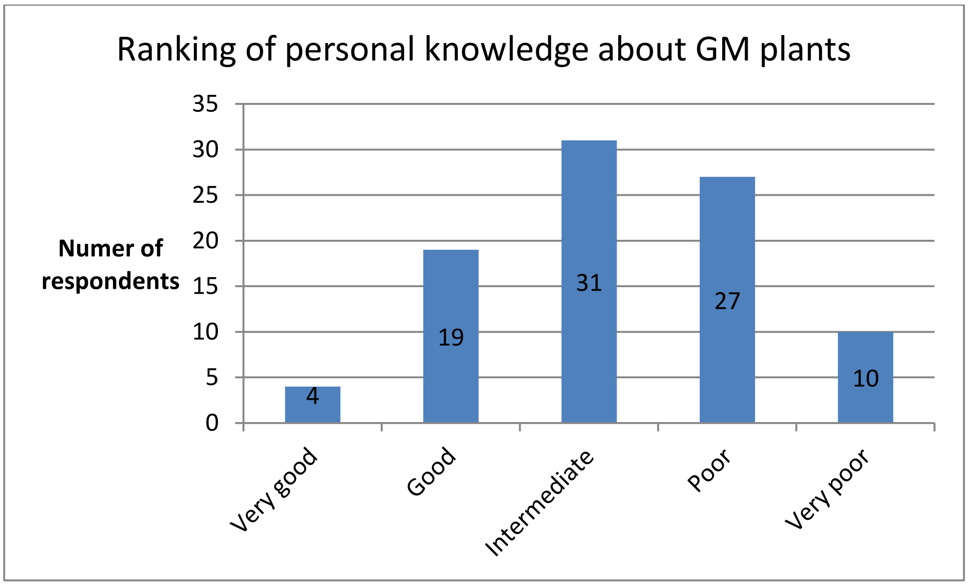


Figure 10: Respondents' ranking of personal knowledge about GM plants

The respondents were asked to describe what they considered to be the main environmental risks related to GM OSR cultivation in Norway. Many factors came up, and the ones most frequently mentioned were: (i) long-term adverse effects on non-target insects, animals and humans, (ii) hybridization and unintentional spread of the transgene(s), and (iii) development of herbicide resistance in weeds. Other factors mentioned (less frequently) were: little knowledge about the issue, the potential of cultivated plants to become weedy, increased use of herbicides, other ecological consequences, unknown risks, spread of antibiotic resistance, selection of other pests, spillage of seeds, that transgenes cannot be removed once they are introduced, less biological diversity and the loss of control on what is GM and what is not.

Finally, the respondents were asked to describe their considerations regarding societal utility, ethics and sustainability related to GM OSR cultivation in Norway. Broad viewpoints were expressed. Some respondents expected that the cultivation of GM OSR could contribute to societal utility, for instance through increased production, improvement in the quality of the crop and reduced need for pesticides. Along these lines, other pointed out that GM OSR cultivation in Norway could contribute to improved food security and lower the dependency on import of OSR as a feed resource. Many, on the other hand, argued that there are no reasons to expect that the cultivation of GM OSR would benefit society and farmers in the long term. Some expressed concerns regarding potential long-term environmental impacts, such as development of herbicide resistance in weeds due to hybridization, or increased use of herbicides/pesticides. Others emphasized that the development of GM OSR could reduce the diversity of available OSR varieties. Finally, many pointed to the fact that OSR production in Norway is currently at a very low level, hence few farmers would benefit from the introduction of GM OSR. Some participants expressed the idea that GM OSR would be more beneficial to society if Norwegian and European consumers become more positive to GM food and feed.

With regard to ethical considerations, many of the respondents expressed concerns regarding patents on GM seeds and corporate control over seed markets. Some advocated for the use of the precautionary principle due to lack of knowledge about gene regulation and the function of the transgenes in GM plants. A concern raised by some respondents was that GM OSR could potentially lead to long-term adverse impacts on the environment and human health. Many argued that uncertainty about long-term challenges raises ethical concerns. One respondent, however, emphasized that methods used in conventional breeding are also associated with uncertainties, which could be equally ethically questionable. Some expressed that short-term economic benefit is often highly valued at the cost of dealing appropriately with ethical concerns. Finally, others argued that it remains important that Norwegian agriculture does not allow cultivation of GM plants and only limited use of pesticides and antibiotics.

Some respondents argued that the use of GM plants in principle is not in accordance with sustainable development, without stating why this is so. Further, concerns regarding potential long-term environmental impacts, such as the spread of transgenes and the development of herbicide-resistant weeds leading to increased use of herbicides, were frequently mentioned as concerns with regard to sustainability. Others emphasized the value of promoting organic agriculture and many highlighted that it would be important to maintain a diversity of OSR varieties and traditional breeding methods to secure sustainability. Along these lines, some argued that it would be more important to further develop and invest in the methods and technologies applied in conventional breeding than to use genetic modification in breeding. Finally, many pointed to the need for further research to investigate possible unintended adverse effects, and some commented that there could also be more research to confirm that GM OSR is not associated with many potential risks.

5.1. Key findings and reflections

This farmers' survey is not intended to be a representative survey among grain producers in the selected counties in Southern Norway. It is important to recognize that the response rate was low. Nevertheless, the survey gives an indication about the attitudes and viewpoints among a group of grain/OSR producers on the production of GM OSR. Not surprisingly, climatic conditions, low productivity as well as yield losses due to pests and pathogens were considered as the main limitations to OSR cultivation in Norway. Hence, the dominant traits in GM OSR currently cultivated or under development (i.e. fungus resistance, pest resistance, herbicide resistance and altered fatty acid composition) do not offer any "solution" to the main challenges to Norwegian OSR cultivation. Interestingly, however, the farmers considered fungus and pest resistance as the most relevant and suitable traits for Norwegian growing conditions. The majority of the respondents did not think that Norwegian authorities should approve GM OSR for cultivation in Norway, and moreover, they would not like to grow it if it was approved. This is in accordance with the policy of the main farmers' associations in Norway (organisations which are all members of the network for GM-free food and feed in Norway), and may also be related to the limited perceived benefit for farmers of growing GM OSR in the future. There were however many respondents who were unsure about whether GM OSR should be approved and whether they would grow it. Moreover, most of the respondents felt they had an intermediate or poor knowledge about issues related to GM OSR cultivation. This underlines the importance of public debates and knowledge exchange among farmers and other interested parties on these issues. It is also interesting to note that the farmers expressed a broad range of considerations related to societal benefit, ethical and sustainability aspects, which also underlines the importance of recognizing that cultivation of GM plants raises concerns beyond environmental and health risks, issues highlighted in the Norwegian Gene Technology Act.

6. Knowledge gaps and uncertainties in the use and production of GM OSR in Norway: Points from the workshop

The workshop on "Environmental risks of fungus resistant GM OSR" took place in Oslo, on 20-21 August 2014. Participants were from the Norwegian University of Life Sciences (NMBU), Bioforsk, Technical University of Denmark (DTU), Norwegian Environment Agency, Norwegian Agriculture Extension Service, Norwegian Scientific Committee for Food Safety and GenØk- Centre for biosafety.

This project on fungus resistant GM OSR was undertaken because there was a lack of knowledge on fungus diseases and OSR, the potential for spread of transgenes, direct and indirect effects on the environment, monitoring plans and relevance of fungus resistant GM OSR for Norwegian farmers.

6.1. First day of workshop

The workshop participant from the Agricultural Extension Service presented the various form of OSR that are cultivated in Norway and how this differs with our neighbouring countries. The main difference was that spring forms of OSRs are mainly cultivated in Norway. Reason for this was mentioned as problems with having areas ready for the autumn varieties early enough to get a got establishment of the seedlings.

Factors that affect cultivation with regard to climate, size and number of farms in Norway, and the challenges regarding volunteers were discussed. It was mentioned that OSR in general is cultivated on a small part of the area used for grain (wheat and barley).

The reason for the shift in cultivation from *"rybs"* (*B. rapa)* to *raps* (*B. napus)* was attributed to the much higher yield obtained with "*raps"*. It was clear that one would want to encourage an increase in "*raps"* production over that of "*rybs"*.

The representative from Bioforsk went through the challenges to cultivation of OSR in Norway with regards to climate and insects, pests and fungi. These issues are discussed in previous chapters.

In addition the work done to control *S. Sclerotiorum* with improvements of the "forcasting service" ("varslingsmodellen") and new techniques for earlier discovers of the infections are important. It was also added that with climate change it is likely that problems caused by other fungal diseases and infections will increase due to warmer climate and more rainfall during the growing season.

Questions were raised concerning natural tolerance present in the OSR plants towards diseases and pests and it was discussed whether it would be "easier" to develop fungus resistant GM plants instead.

The present status of fungus resistant GM OSRs were presented by a representative from GenØk, where genes involved in making plants fungus resistant (until now) were described.

The representative from the Agricultural Extension Service focused on what would be the needs for Norway in the future for the agriculture. What should the farmland be used for: Fuel or feed? What would be most important? It was mentioned that there is little development of the spring varieties of OSR because the majority of Europe cultivates the autumn varieties.

The representative from the Technical University of Denmark presented issues related to the potential for the spread of genes and asked questions related to changes in agriculture and how it would be changed in the future, as well as asking if the spread of transgenes to the environment would be an important consideration at all. These issues were emphasized as those that should be further taken up collectively, such as mapping of how widespread *B. campestris* is in Norway (to be able to estimate potential for hybridization and spread of transgenes throughout the country).

6.2. Second day of workshop

The second day of the workshop started with a presentation from the representative from the Norwegian University of Life Sciences. The presentation was on fungal diseases of OSR. The different types of fungi/fungal diseases and how they attack the plants were explained. Important issues concerning the complexity of their epidemiology were discussed (survival and spread) which are important in the context of developing fungus resistant GM OSR.

The last presentation was on monitoring issues of GMOs, presented by a representative from GenØk. Here, regulations such as the Norwegian Gene Technology Act, EC/EEA agreements, EFSA guideline on post-market monitoring and the Cartagena Protocol on Biosafety were presented.

6.3. Final discussion

The final discussion was on the following themes:

- Which other countries would be good comparators regarding OSR cultivation? In Norway, OSR is cultivated in the southern parts, as such, Denmark might be a good comparator. However, Norway mainly cultivates spring varieties of OSR while Denmark cultivates autumn varieties.
- Is the potential for spread/proliferation the same for spring and autumn varieties? It most probably is. We have to look into what is different or special for Norway.
- Are the social benefits from OSR cultivation and whether production of this crop is profitable in Norway the most relevant issues to discuss?
- How will the OSR itself be affected by inserting multiple genes to obtain resistance to disease and pests?
- Due to the complexity of the diseases, it would probably not be possible to control the disease by inserting one gene only. Would this affect the growth rates of the plants?

Questions were also raised regarding what kind of research is needed to map the potential environmental risks and other issues connected to the cultivation of fungus resistant GM OSR in Norway. The following themes and issues for further investigation where highlighted:

- Investigate the resistance mechanisms introduced into the OSR and if they have effects on non-target organisms
- Potential effects on decomposition and the organisms involved
- Potential for increased fitness in weeds if transgenes are transferred

- Prevalence of fungal diseases on wild relatives of OSR
- Potential for better yields with GM OSR
- Would there be increased infection pressure on OSR if the extent and scale of OSR cultivation are increased?
- Would climate change affect the need for GM OSR? Would there be other needs than just fungus resistance?
- If GM OSRs are cultivated, what kind of changes would this impose on the farmer regarding production form?
- Are some GM traits worse than others in relation to their potential to spread in the environment and their impacts?

In summary, the workshop provided knowledge and information on OSR cultivation in Norway, current challenges for Norwegian OSR farmers, research needs and interesting questions regarding what potentially would be challenging when cultivating GM OSR.

7. Conclusions and recommendations

The literature review, experiences from other countries and issues that were discussed during the workshop clearly point out that cultivation of GM OSRs would be a challenge regarding spread, hybridizations with wild relatives and survival in nature. This is because OSRs have wild relatives in Norway growing as far north as Finnmark county. Theoretically, transgenes would then spread across the whole country with the right environmental conditions and selection pressure in place. With regards to the knowledge that we have on OSR growth, spread and hybridization potentials, the question is not if hybridization t will happen, but to what extent. This is however influenced by several factors (as mentioned in a previous chapter) and is not easy to predict and must be seen, case by case.

There are implications on potential climate changes in the future with higher temperatures and more rainfall in our part of the world. An important issue is that this will impact agriculture practice and the need for new plant varieties to meet challenges by more rain and warmer climate.

Higher temperatures and more rainfall would also possibly potentially benefit the fungus and theoretically result in more disease. This may also cause an increased interest among Norwegian farmers to use OSR as a rotation crop for reducing pests and fungus among wheat and barley.

In the future, there may also be new demands of products from agriculture as for example to meet the need for feed for an growing aquaculture sector and the increasing demand for biofuel in the future as the amounts and availability of fossil fuel decreases. Are we then going to increase OSR production due to this alone?

An interesting issue is whether or not Norway is able to increase OSR production to meet these demands and if the availability of OSR varieties are suitable to meet these.

An overall question will therefore be; what type of GM transformation event of OSR will cause such an increased value for the farmers, such a benefit for the society, with the possible highest safety level in relation to risks, and thereby minimal costs for monitoring, that the society and its authorities are willing to accept the potential risks and burdens? In this context, it is also of interest as to whom the developers of GM varieties are aiming their development towards, what are the agronomic challenges they try to solve, and for which main market the varieties are intended. Norway, being the marginal climatic and agronomic north of Europe where OSR can be grown, will probably not be a future market of high interest for GM OSR developers. In other words, possible benefits for GM OSR farmers in Norwegian agriculture will be a “spin-off effect”, e.g. if the GM variety has beneficial traits that may also work well and maybe solve some agronomic challenges in Norway. The main market will be the central European OSR-producing countries and Canada, which in general obtains much higher yields and also uses other varieties than Norway.

The risk for spread of the transgenes are also highly present. Reports show that “unintentional stacking” of herbicide resistance genes in *B. napus* has taken place in the volunteers due to intraspecific pollen flow in and from the cultivation areas (Warwick et al 2004). This means that the volunteers detected have multiple herbicide resistant traits present in the same plant. Also spread of transgenes to wild relatives takes place naturally (Cogem advisory report CGM/130402-01). Spread of transgenes will thus not only happen through spillage of OSR seeds but also along transport routes to and from cultivation areas, transport from the machinery involved in harvesting and by other routes (Pascher and Dolezel 2005).

Moreover, OSR seeds are very persistent in the soil and are able to germinate after many years. If these seeds contain transgenes, they could become a source for transgene spread to wild relatives, and also to conventional crops.

The central question would then be: what would be the consequence of spreading transgenes in to the Norwegian environment although it is possible to draw on experiences from Scandinavian countries and Canada?

Moreover, it is crucial that monitoring strategies are elaborated before any approval of cultivation of GM OSR are given in Norway. There is also a need to get more information on insect diversity in OSR fields in Norwegian production regions as well as to identify insects of relevance and their pollen transfer capacities and distances. Such information is also of importance for monitoring strategies. There is also a need to elaborate who should pay for the monitoring and who shall conduct the monitoring and general surveillance.

Another issue is whether it is possible to make fungus resistant GM OSRs that are totally resistant to fungal attacks? What we do know is that the pattern of attack from fungi and the disease development is very complicated, and this may make it challenging to obtain this. This needs to be explored further in field trials in the Norwegian environment to identify if these GM OSR meet the proposed benefits.

How are fungi controlling natural populations of *Brassicas* and how will an introduction of fungus resistant OSRs influence this? This is something we know too little about, and which need further investigation.

In general, knowledge about different species and their conditions in Norway is important to get an understanding of how a potential introduction of a “new” species, as a GM species, would impact the “baseline” of these species (here, the *Brassica* species). That is, if the natural biodiversity of these will be affected through the introduction of a GM that potentially can spread throughout a large geographical area, if conditions are favorable.

This report has pointed to several important issues regarding OSRs that should be considered before a potential introduction of GM OSR in Norway.

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8.1. Webpages/links

Artsdatabanken: http://www.artsdatabanken.no/

Canadian Food Inspection Agency (CFIA): http://www.inspection.gc.ca/plants/plants-with-novel-traits/approved-under-review/field-trials/eng/1313872595333/1313873672306

Canola Council of Canada: http://canolacouncil.org

EU SIGMEA: http://www.infra.fr/sigmea

FAOSTAT, 2014. http://faostat3.fao.org/

FAOSTAT (2014) http://faostat.fao.org/site/291/default.aspx

Forskning.no: http://forskning.no/mat-og-helse-planteverden/2010/09/gamle-vekster-gir-god-olje

GMOinfo: http://gmoinfo.jrc.ec.europa.eu/

Greenpeace: GM Contamination register: http://gmcontaminationregister.org

International Survey on herbicide resistant weed: http://weedscience.org

ISAAA GM approval database. International Service for the Acquisition of Agri-biotech Applications. http://www.isaaa.org

ISB: http://www.isb.vt.edu/

JRC: Deliberate release and placing on the EU market of GMOs – GMO register: http://gmoinfo.jrc.ec.europa.eu/overview/DK.asp

Nofima: http://nofima.no

Nationen: http://nationen.no/

Norwegian Agriculture Agency: https://www.slf.dep.no/no/en

Plantesortsnemda: http:// plantesortsnemda.no/offisiell-sortsliste

Plantevernleksikonet: http://leksikonet.bioforsk.no

Regjeringen: http://regjeringen.no

She net: http://www.shenet.se/vaxter/raps.html

Statistics Norway (SSB): http://www.ssb.no

Store Norsk Leksikon (SNL): https//www.snl.no

The Norwegian Farmers Union (Norges Bondelag):

http://www.bondelaget.no/nyhetsarkiv/dramatisk-klimarapport-article77600-3805.html