Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

Opinion of the Panel on plant health of the Norwegian Scientific Committee for Food Safety 12.02.08

Pest risk assessment of the *Cucumber green mottle mosaic virus* in Norway

SUMMARY

In 2007, after many years of absence, *Cucumber green mottle mosaic virus* (CGMMV) reoccurred in Norwegian cucumber production. The Norwegian Authority for Food Safety is considering whether or not to regulate CGMMV as a quarantine pest. On this basis the Authority, in a letter of 20 July 2007, requested a PRA on CGMMV in Norway. To answer the request from the Authority, the Norwegian Scientific Committee for Food Safety (VKM) commissioned a draft PRA report from Bioforsk Plant Health and Plant Protection Division. VKMs Panel on Plant Health (Panel 9) has used the report as a basis for their opinion.

Panel 9 gives the following main conclusions of the PRA: 1) Both recent and previous presences of CGMMV in the PRA area indicate that the pest is able to establish itself in the PRA area. Successful establishment of CGMMV has only been recorded in greenhouses in the PRA area. The probability for establishment and damage in field production is regarded as low. 2) CGMMV has probably not been present in Norwegian cucumber production since 1983, and the four cases found in greenhouse production in 2007 should be regarded as new introductions. CGMMV should currently be regarded as of limited distribution and under voluntarily eradication. 3) The most probable pathway for long distance spread into Norway is seed transmission. Infected seedlings, people, water and soil are more probable pathways for short distance spread. The probability of further spread from location to location is high. 4) Due to the potential for high yield loss in modern cucumber production, rapid spread when first introduced and the difficulties and costs connected to controlling the virus, CGMMV is a threat to the modern, highly intensive greenhouse production of cucumber in Norway. The potential damage consists of yield loss, direct costs in controlling the virus (labour, chemicals, and periods with no production) and the indirect costs due to difficulties in cooperation with other growers and uncertainty regarding the market situation. 5) Increased waste from the cucumber production is a potential negative environmental consequence. 6) Dry heat treatment has probably been the most effective measure to prevent the spread of CGMMV. 7) New cultures must start with healthy seed or healthy seedlings. Tools, trays, or people coming from potentially infected greenhouses must be avoided. 8) In the case of a crop infection, there has to be strict destruction of infected plant material, washing and disinfection of greenhouses, equipment, tools and clothes. It is important to handle healthy plants before infected ones. To safeguard the new crop there should be a stop in cucumber production

before starting a new cucumber crop. 9) There is a moderate level of uncertainty regarding the pathway for entry of CGMMV into the PRA area. There is a low degree of uncertainty regarding the pathogen, its survival and its possibility for transmission, establishment and spread in Norwegian greenhouse cucumber production. There is a high degree of uncertainty about whether CGMMV is able to become established and spread in field cucumber cultivation in the PRA area. The degree of uncertainty is moderate regarding the impact and economic losses

KEYWORDS

CGMMV, *Cucumber green mottle mosaic virus*, cucumber, intensive greenhouse production, additional artificial light, yield loss

ASSESSED BY

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ACKNOWLEDGEMENTS

VKM has asked the Norwegian Institute for Agricultural and Environmental Research (Bioforsk), Plant Health and Plant Protection Division, to make a draft pest risk assessment (PRA) report on *Cucumber green mottle mosaic virus* in Norway. VKM has used this report (Blystad et al. 2008) as a basis to answer the request from the Norwegian Food Safety Authority.

Dag-Ragnar Blystad, Brita Toppe and Trond Rafoss are acknowledged for their valuable work with the draft PRA report.

CONTENTS

1. BACKGROUND

In February 2007 *Cucumber green mottle mosaic virus* (CGMMV) was found at two growers in Rogaland County. The Norwegian Food Safety Authority consulted Bioforsk on the matter. Bioforsk prepared a short risk analysis (Blystad, 2007), in which a complete eradication of the pest was recommended. In a survey of a representative selection of cucumber producing growers (greenhouse and field) performed by Bioforsk in 2007, CGMMV infection was detected at two more greenhouse growers.

CGMMV is known to have occurred in Norway earlier. The pest has so far not been listed as a quarantine pest in Norway, and is therefore not listed in attachment 1 or 2 in the Regulations relating to plants and measures against pests (Landbruks- og matdepartementet 2000). No countries in Europe consider CGMMV as a quarantine pest. Based on these facts and in accordance with earlier practice with other plant pests, the Norwegian Food Safety Authority decided that § 40 of the regulations relating to plants and measures against pests should not be put into use in these new CGMMV cases. However, the Authority recommended the growers to follow the advice given by Bioforsk concerning eradication of the pest.

A resolution with authorization in § 40 will set off a payment of compensation to growers that are covered by the regulations relating to compensation in production of plants and domestic animals (Landbruks- og matdepartementet 2004). The Authority's decision resulted in no compensation to the four involved growers. Their expenses and possible losses in connection with eradication of the pest were not covered.

In a letter to the Norwegian Food Safety Authority, dated 14 March 2007, the Norwegian Horticultural Growers Association asked the Authority to reconsider the matter. The Authority is now considering whether or not to regulate CGMMV as a quarantine pest in Norway. On this basis the Authority, in a letter of 20 July 2007, requested a PRA on CGMMV from VKM.

To answer the request from the Authority, VKM commissioned a draft PRA report from Bioforsk Plant Health and Plant Protection Division (Blystad et al. 2008). The report has been used as a basis for this opinion of VKMs Panel 9.

2. TERMS OF REFERENCE

The Norwegian Food Safety Authority is considering whether or not to regulate CGMMV as a quarantine pest in Norway. A PRA from VKM is needed to ensure a satisfying basis for a decision by the Authority. On this basis the Authority requests a risk assessment of CGMMV as a plant pest in Norway. The PRA should be made according to ISPM No. 11 (FAO, 2004).

The Authority wishes VKM to assess the following aspects in particular:

1. The probability that the pest is already established in both greenhouse and field production in Norway.

2. The probability of entry and establishment of the pest via import of plants, plant parts, and other contagious materials according to current regulations of plant health (i.e. seeds, plants, fresh fruits etc.), from countries where the pest is established. An assessment of other possible pathways should be included.

3. Economic consequences and consequences in production for both field and greenhouse production, and possible environmental consequences, resulting from a possible entry, establishment and spread in Norway. The following should also be included: A description of

experiences in other European countries, and an assessment whether there are special conditions in Norway that indicates that the pest might represent a higher risk in Norway than in the rest of Europe.

4. The effect of different risk reducing options, both in production and trade.

3. INITIATION

3.1. Initiation points

3.1.1. PRA initiated by the review or revision of a policy

This assessment was initiated by the Norwegian Authority for Food Safety as a basis for a review and possible revision of a policy, after reoccurrence of CGMMV as a harmful plant pathogen in Norwegian cucumber production after many years of absence.

3.2. Identification of PRA area

The PRA area is Norway.

3.3. Information

Information sources utilised for this PRA are published material available in international scientific journals, books and/or reports, and personal communications and geographic data that have been made available to the risk assessors. Where these information sources have been used, this is indicated in the text by references enclosed in brackets.

This PRA is made in accordance to the international standard ISPM No. 11 (FAO, 2004).

3.3.1. Previous PRA

There is one previous PRA (in Norwegian) for the pest *Cucumber green mottle mosaic virus* in the PRA area (Blystad, 2007). Other PRAs for *Cucumber green mottle mosaic virus* are not known.

3.4. Conclusion of initiation

The pest of concern in this PRA is *Cucumber green mottle mosaic virus*, CGMMV. The initiation point for this PRA is the review or revision of a policy by the Authority. The PRA area is Norway. At the time of initiation CGMMV had been found in greenhouse cucumber at four growers in the PRA area.

4. PEST RISK ASSESSMENT

4.1 Pest categorization

4.1.1. Identity of pest, name and taxonomic position

4.1.1.1 Name

Cucumber green mottle mosaic virus, CGMMV

4.1.1.2 Synonyms

Cucumber virus 3

Cucumis virus 2

4.1.1.3 Common names

Norwegian: Agurkgrønnmosaikkvirus

Swedish: Gurkgrönmosaikkvirus

Danish: Agurk-grønmosaikkvirus

Dutch: Komkommerbontvirus

English: *Cucumber green mottle mosaic virus*

4.1.1.4 Taxonomic position

Genus: *Tobamovirus*

The genus *Tobamovirus* has 22 definitive members (Fauquet et al. 2005).

Four species in the genus *Tobamovirus* infect plants in the family *Cucurbitaceae*.

These are:

- *Cucumber fruit mottle mosaic virus*, CFMMV. This is a virus described from Israel (Antignus et al. 2001). It is not yet detected in other countries.
- *Cucumber green mottle mosaic virus*, CGMMV. This was the first tobamovirus described as infecting plants in *Cucurbitaceae* (Hollings et al. 1975). Several strains have been described. Two former strains are now described as *Kyuri green mottle mosaic virus* – see below.
- *Kyuri green mottle mosaic virus*, KGMMV. This virus was first mentioned as a "cucumber strain" of CGMMV in Japan. The "Yodo-strain", which formerly was described as CGMMV, is now classified as a strain of KGMMV (Francki et al. 1986).
- *Zucchini green mottle mosaic virus*, ZGMMV. This virus is recently described from Korea (Ryu et al. 2000).

Regarding CGMMV, several strains are described (Hollings et al. 1975, Antignus et al. 2001), but the picture can be a bit confusing as some isolates formerly classified as strains are now regarded as separate virus species.

The type strain is the most common strain in Europe. This strain does not give fruit symptoms. The type strain can give local lesions in *Chenopodium amaranticolor* under certain growing conditions, but does not infect *Datura stramonium* and *Petunia x hybrida*.

The "Cucumber aucuba mosaic strain" (synonyms are "cucumber virus 4" and "Cucumis virus 2A") has also been found in Europe. This strain can give fruit symptoms in cucumber and local lesions in *C. amaranticolor*, but not symptoms in *D. stramonium*.

The "Watermelon strain" has been described in Japan. This strain also gives local lesions in *C. amaranticolor*, but not in *D. stramonium*.

Japanese cucumber strain has been described from Japan. This strain gives severe fruit symptoms in cucumber and local lesions in *D. stramonium*, but no local lesions in *C. amaranticolor*. This strain is now classified as a separate species, KGMMV.

The formerly described Yodo strain gives severe fruit symptoms in cucumber and local lesions in *C. amaranticolor*, *D. stramonium* and *P. x hybrida*. This strain is now classified as KGMMV-Y (Francki et al. 1986).The "Indian strain" was isolated from bottlegourd (*Lagenaria siceraria*) in India (Hollings et al. 1975), in which it caused mosaic, growth reduction and yield loss. This isolate is reported to give local lesions in *C. amaranticolor*, symptomless infection in inoculated leaves of *D. stramonium* and no infection in tobacco or *P. x hybrida*.

Of the 22 definitive members in the genus Tobamovirus, four have been identified in Norway (Blystad and Munthe 1997):

- *Cucumber green mottle mosaic virus* (agurkgrønnmosaikkvirus) in cucumber
- *Ribgrass mosaic virus* (smalkjempemosaikkvirus) in *Plantago major*
- *Tobacco mosaic virus* (tobakkmosaikkvirus) in petunia
- *Tomato mosaic virus* (tomatmosaikkvirus) in tomato

4.1.1.5 Bayer computer code

CGMMV

4.1.2 Methods for detection and identification

4.1.2.1 Symptoms in cucumber

Typical symptoms of CGMMV such as mosaic, leaf bubbling, wilting and chlorosis are easily recognized, but symptoms on lower leaves and weak symptoms may look like physiological disorders.

Figure 1. Symptoms of CGMMV consisting of mosaic (upper left) (photo: Erling Fløistad), leaf bubbling (upper right) (photo: Dag-Ragnar Blystad), wilting (lower left) (photo: Dag-Ragnar Blystad) and chlorosis (lower right) (photo: Ørjan Omdal).

4.1.2.2 Test plants

The host plant cucumber (*Cucumis sativus*) can be used as a test plant. The time from inoculation to symptom development is 14 days.

CGMMV infects very few of the commonly used test plants in plant virology. The test plants *C. amaranticolor, D. stramonium, Nicotiana benthamiana* and *P. x hybrida* have been used to describe and differentiate isolates.

4.1.2.3 Electron microscopy

There are relatively high amounts of CGMMV particles in the plant sap of infected leaves. This gives the possibility to use negative staining as a rapid method to assess the occurrence of CGMMV particles. These particles are typical for tobamoviruses with the dimensions 300 x 18 nm.

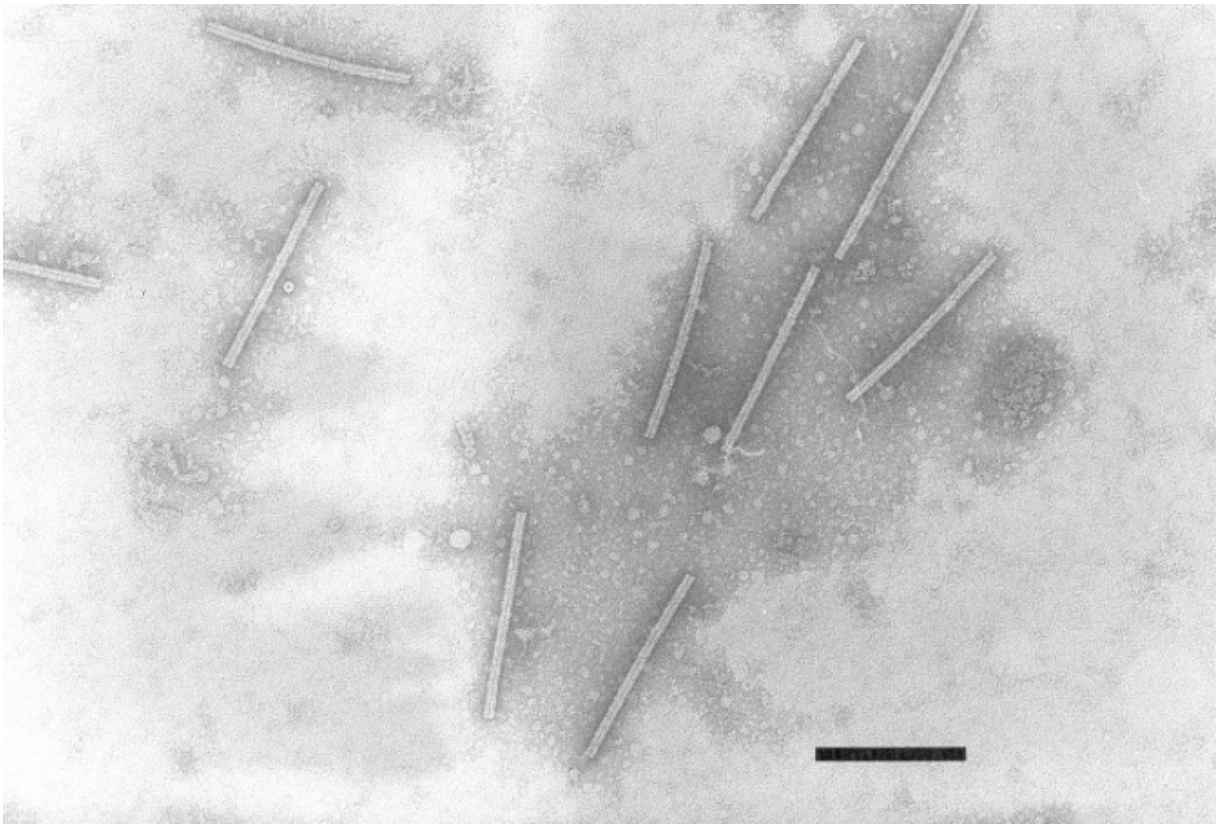

Figure 2. Tobamovirus particles are easily recognized in sap samples from infected plants. The black line represents 200 nm (photo: Dag-Ragnar Blystad).

4.1.2.4 Serology

Antisera and ELISA test kits are available from commercial suppliers.

4.1.2.5 Nucleic acid based methods

PCR is very sensitive and has been used to detect CGMMV in seeds and soil (Varveri et al. 2002).

4.1.3 Occurrence in Europe

CGMMV is reported to have occurred in our neighbouring Nordic countries Sweden, Denmark and Finland between 1960 and 1980 (Kristensen 1977, Rydén 1965a, Linnasalmi 1966). After that the occurrence of CGMMV has decreased.

A short inquiry among Nordic colleagues during spring 2007 regarding CGMMV cases gave the following information: in Finland there was an epidemic in 1968, since then the virus has been found in 1987, 1989 and 1990; in Sweden, there was one known case early in the 1990s, one case in 2002 and two cases in 2006; in Denmark seven cases have been detected during the last few years (Blystad 2007).

Regarding strains of CGMMV, the ordinary strain is the only one occurring in Norway and in the other Nordic countries. Rydén (1965a) reported a finding of the aucuba strain in Sweden in 1965.

The situation in other European countries is unclear, but some of the Norwegian extension officers have the impression that CGMMV is occurring in Dutch cucumber production with up to 30-50 % of the greenhouse cultures being infected during the year.

4.1.4 Presence or absence in PRA area

Before 1980, CGMMV was regarded as commonly occurring in greenhouse cucumber in Norway (Bjørnstad 1970, Bjørnstad 1979). Since then, there was one known case of CGMMV in 1983 and no more known cases of CGMMV until 2007. The latter outbreak was followed up by a survey, which is reported in the following sections. Because successful eradication has not been confirmed after the 2007 outbreaks, CGMMV should currently be regarded as of limited distribution and under voluntarily eradication in the PRA area.

Altogether 21 out of 62 cucumber producing growers, representing 48 % of the greenhouse cucumber production area, were surveyed during 2007. CGMMV infection was detected at four growers. Details of these cases are described in the next section.

The area of field grown cucumbers is about 80 hectares in Norway, mainly located in Østfold County (50 hectares) and Aust-Agder County (30 hectares). During August and September 2007 the cucumber fields of altogether 14 growers in Østfold and 10 growers in Aust-Agder, in total approximately 36 hectares, were surveyed for CGMMV. The fields were inspected for symptoms and 25 leaf samples from each farm were sent for testing (ELISA) at Bioforsk. The farms surveyed represent approximately 50 % of the area in Østfold and 30-35 % of the area in Aust-Agder. No suspicious symptoms were seen, and no samples were found to be infected by CGMMV.

4.1.5 Cases of CGMMV in Norway during 2007

4.1.5.1 Grower A

This was the first detection of CGMMV in Norway in 2007. This grower is located in the southwest of Norway, and has a year-round cultivation with additional light. All seedlings are grown in a separate greenhouse connected to the production greenhouses via a machine and packing hall. Each cucumber crop is grown for 10 weeks with a high amount of additional light.

The grower observed the first diseased plants in June 2006, but the symptoms (Fig. 3) were assumed to be caused by physiological factors (light, nutrients etc). It was not realised that it could be a virus disease until February 2007, when Bioforsk Plant Health and Plant Protection diagnosed a sample as CGMMV.

Figure 3. Chlorosis (left) and mosaic (right) in CGMMV infected plants at Grower A (left photo: Ørjan Omdal, right photo: Erling Fløistad).

The grower had observed up to 70 % infected plants in some holds and claimed to suffer up to 30-50 % crop loss. Yield data received in December 2007 showed the yield level before the eradication (weeks 1 to 9, 2007), the eradication period (weeks 10 to 14) and the yield level after new virus free plants were used in production (from week 15) (Fig 4). This data seem to confirm the grower's assumption of about 50 % yield loss due to CGMMV.

All plants were removed from the production area, and the greenhouses were all washed with high pressure water at 40-50°C and then treated with hydrogen peroxide. Before planting, the greenhouse area was sprayed with 5 % citric acid. New crops were started two to four weeks after cleaning and disinfection.

CGMMV has not shown up again, probably due to a strict hygienic regime. After 9 months there is still no new infection of CGMMV. The yield of cucumber fruits is now 40-50 % higher than before the infected plants were eradicated.

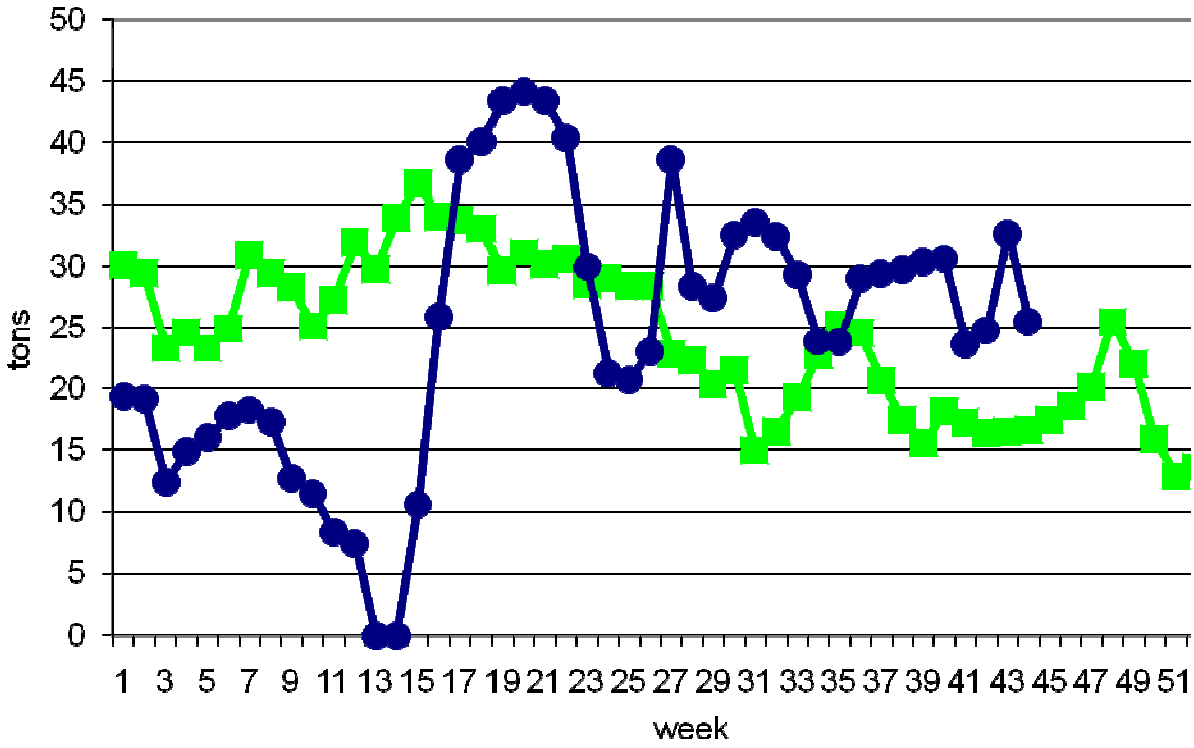

Figure 4. Cucumber produced in a CGMMV infested greenhouse (grower A) with intensively grown crops with additional light. The blue line with circles indicates production of marketable cucumber in 2007, while the green line with squares indicates the production in 2006 (data from grower).

4.1.5.2 Grower B

This grower is located in southeast Norway. The grower has summer cultivation without additional light, and grows its own seedlings.

A cucumber culture was planted by the grower in February. In early March an abnormal plant was seen. This plant was removed later in March, but after a while disease symptoms were observed on plants in the same row.

Bioforsk Plant Clinic received a sample in April and CGMMV was found to be the cause of these disease symptoms. The grower was visited at the end of April. There was then a heavy infection of CGMMV in the part of the greenhouse where the diseased plant was first found, but virus symptoms were also found in all other parts of the greenhouse.

All infected plant material was removed in the first week of May and washing and disinfection were started.

The strategy of this grower was to use soap ("Grønnsåpe") intensively. The grower used soap altogether three times during a three week period. All pipes and underground reservoirs were filled with a strong soap solution before being rinsed with water. The third treatment was a soap layer on the floor that was left to dry and a high temperature treatment (heating with no windows open) to minimize the survival of other potential pests and pathogens. Metal wires were treated with flames to burn all possible plant debris remaining.

The greenhouse was left empty for 6 weeks before a new culture was started.

A new cucumber culture was planted on July 15th. During this culture period, ending in the first week of November, no plants infected by CGMMV were found, indicating that the described control measures had been successful.

There are no conclusive yield data from this grower, so it is not possible to measure yield loss due to CGMMV.

Figure 5. Chlorosis (left) and wilting (right) in virus-infected plants at Grower B (photos: Dag-Ragnar Blystad).

4.1.5.3 Grower C

This grower, located in southwest of Norway, has a year round cultivation of cucumbers using additional lighting. The grower also produces tomatoes and other crops.

Cucumber seedlings were bought from Grower A. As diseased plants were observed and diagnosed at Grower A in February 2007, samples from Grower C were also investigated and CGMMV was found.

All cucumber plants were removed and the greenhouse areas were washed and disinfected, but due to the production of other crops, all the greenhouse areas could not be treated at the same time.

When new samples were analysed in September 2007, it turned out that CGMMV was infecting the newly planted cucumber crops.

The grower did not succeed to get rid of CGMMV during 2007, probably because of inadequate disinfection. Because the greenhouse contained several cultures, it was not possible to clean and disinfect all the greenhouse area at the same time. To avoid the disease problems caused by CGMMV, this grower will change from cucumber to tomato production for one year (2008).

4.1.5.4 Grower D

This grower is located in the southwest of Norway, and he produces cucumber both with and without artificial light. The seedlings are produced by the grower. There is no cucumber production during the winter.

Diseased plants were observed in July 2007. A sample sent to Bioforsk was diagnosed as CGMMV. It was decided to continue production until the end of October. The grower did not have any crop loss in late summer, but there was increasing damage in September and October.

This implies that late infections do not cause dramatic yield loss. However, the occurrence of CGMMV requires the grower to carry out every possible measure to control the virus and get rid of possible infection sources before the start of a new season.

All plants were removed from the greenhouses in October - November 2007 and intensive cleaning and disinfection programs have been followed. It is not possible to know if there has been a successful control of CGMMV at this grower before cucumber production starts again in early 2008.

4.1.6 Regulatory status

Norway: No regulation

EPPO: No regulation

EU: No regulation

4.1.7 Biological characteristics of the pest

4.1.7.1 Interaction host/pest

CGMMV has a narrow host range, as most isolates are confined to a host range mainly within *Cucurbitaceae* (Hollings et al. 1975).

Cucumber is the only known host plant for CGMMV among cultivated species in Norway. Other susceptible hosts such as melon and watermelon are not grown commercially in the PRA area.

In a field with CGMMV infected watermelon in Greece, weeds were also investigated as potential hosts (Bourbourakas et al. 2004). The following weeds were found to be infected by CGMMV:

Amaranthus blitoides

A. retroflexus

Chenopodium album

Heliotropium europeum

Portulacea oleracea

Solanum nigrum

C. album and *S. nigrum* are also common weeds in Norway. Whether CGMMV infects these species in Norway is not known.

4.1.7.2 Disease cycle

CGMMV has, like other viruses in the genus *Tobamovirus,* very stable particles. These viruses are spread by mechanical transmission without any vector. Seeds of susceptible species can have infective virus particles in the seed coat that can infect the seed plant when germinating (Hollings et al. 1975, Fletcher et al. 1969).

4.1.7.3 Dissemination

CGMMV is disseminated by infected seeds, infected plants or infected plant sap on tools, clothes or transport containers (Hollings et al. 1975, Lovisolo 1980). CGMMV can also be disseminated through water (Rydén 1965b, Paludan 1985).

4.1.7.4 Survival

CGMMV survives in the seed coat of infected seeds (Fletcher et al. 1969), infected plant debris, in soil and water and as infectious particles on tools and clothes (Hollings et al. 1975, Lovisolo 1980).

4.1.7.5 Control

CGMMV can only be controlled by indirect control measures.

Fletcher et al. (1969) investigated the use of dry heat to disinfect cucumber seeds to get rid of CGMMV. They found it highly effective to heat seed lots to 70°C for 2-4 days. In this way it was possible to start a cucumber culture with virus free seedlings. This procedure was later adopted by commercial seed companies and has probably been the most effective measure to prevent the spread of CGMMV.

In greenhouses with no earlier case of CGMMV, the culture must start with healthy seed or healthy seedlings. In addition, hygienic measures have to be taken to avoid virus entering the greenhouse by other means. It is important to limit the amount of visitors, and avoid tools or trays or people coming from potentially infected greenhouses.

For greenhouses where CGMMV has been detected, it is important to avoid spread of the virus to the entire crop. The grower should handle healthy plants first and carry out plant culture and harvesting on infected spots last. Use of skimmed milk (dipping hands, spraying on leaves) has been a measure to slow down the spread of tobamoviruses.

In the case of a crop infection, there has to be strict destruction of infected plant material, washing and disinfection of greenhouses, equipment, tools and clothes. To safeguard the new crop there should be a stop in cucumber production before starting a new cucumber crop.

4.1.8 Potential for establishment and spread in PRA area

Both recent and previous presence of CGMMV in the PRA area indicates that the pest is able to establish itself in the PRA area. While the host plant cucumber is grown under both protected and field conditions, successful establishment of CGMMV has only been recorded in protected environments (i.e. greenhouses) of the PRA area. The production of greenhouse cucumber in Norway is mainly concentrated in two regions: 1) in the southwest close to Stavanger in Rogaland County, and 2) in the counties Buskerud (Lier), Østfold and Vestfold near Oslo. The concentration of production increases the risk of rapid spread of CGMMV.

Since there have been cases in both regions during 2007, there is a high potential for establishment and spread of CGMMV in the PRA area.

4.1.9 Potential for economic consequences in PRA area

4.1.9.1 Norwegian cucumber production

Greenhouse

The Norwegian greenhouse production of cucumbers represents an important industry. The annual production amounts to 12 400 tons with a firsthand value of more than 200 mill NOK in 2007 (source: the Norwegian Horticultural Growers Association). There has been an increase in production during the last ten years (Fig. 6). Most of the production takes place in the counties of Rogaland, Buskerud, Østfold and Vestfold (Fig. 7), but there is also some production in other counties like Møre and Romsdal and Nord-Trøndelag (Fig. 7).

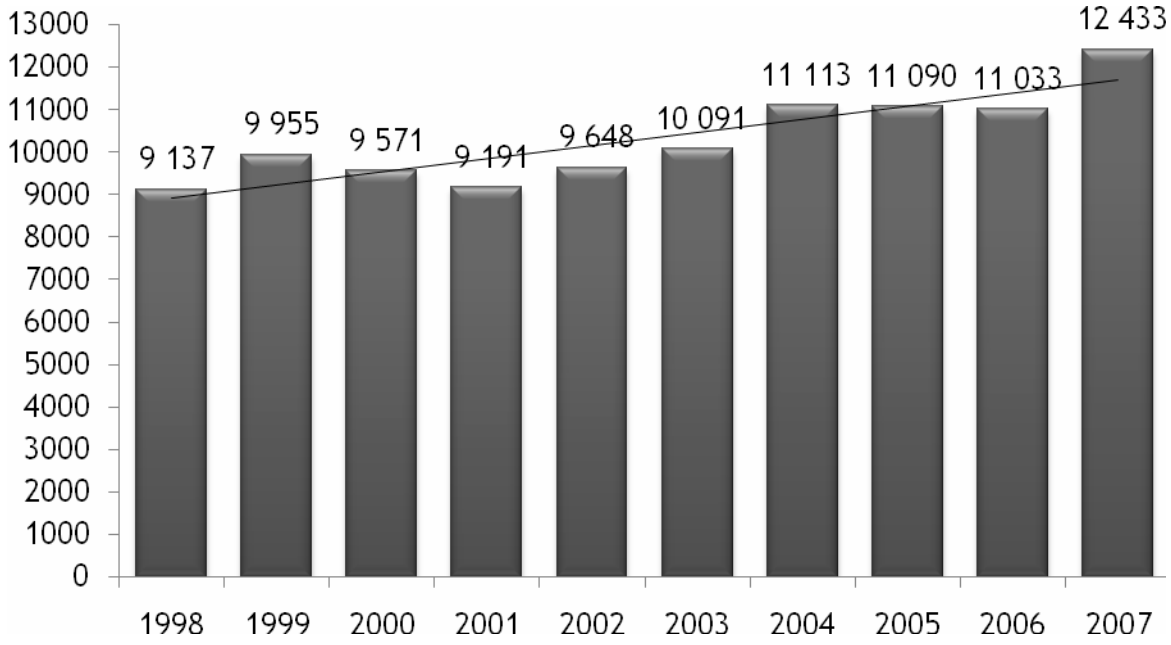

Figure 6. Total production (in tons) of Norwegian greenhouse cucumber from 1998 to 2007 (source: the Norwegian Horticultural Growers Association).

Traditionally, Norwegian cucumbers have been grown as summer cultures with production from February to October and a break during the winter months. More than half of the current production is still grown in this traditional way with 12 weeks between each replanting. During the latest years there has been a shift towards a more intensive production using additional artificial light. Some growers use small amounts of light to increase the yield and extend the cropping period of a traditional culture. Most, however, install larger amounts of artificial light (~200 W/m^2) in a year round production with 10 weeks between each replanting. Near half of Norwegian cucumbers are now produced by the use of additional lighting. The prognosis for 2008 is a production area of 97 890 m^2 with and 126 254 m^2 without additional artificial light (source: the Norwegian Horticultural Growers Association).

Open fields

The area of field grown cucumbers in Norway is about 80 hectares, mainly located in Østfold County (50 hectares) and Aust-Agder County (30 hectares).

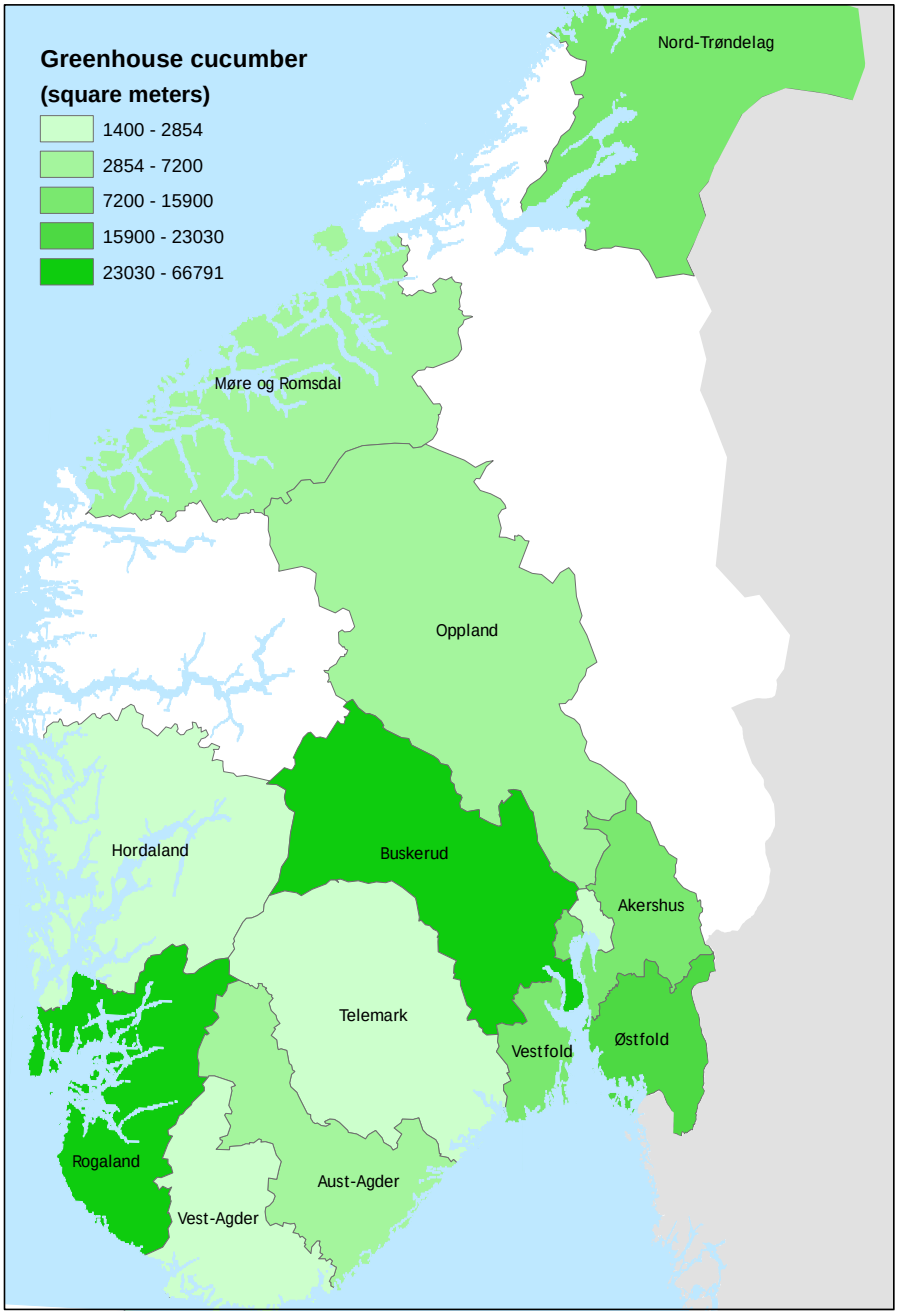

Figure 7. Geographical distribution of the area of greenhouse cucumber production in Norwegian counties (source: the Norwegian Horticultural Growers Association).

4.1.9.2 Potential for economic consequences

If CGMMV becomes established permanently in the Norwegian cucumber production, there is a potential for economic losses both directly by crop losses and replanting, but also indirectly by forcing a less intensive production with less collaboration between growers and increased use of labour and consumables for washing and disinfection. Attacks of CGMMV seem to give even bigger reductions in cultures grown more intensively using additional artificial light compared to traditional cultures. Intensive production requires high capital investments and even small reductions in the crop yield (~10-15%) could have considerable

economic impact. Besides this, establishment of CGMMV could give a less stable supply of Norwegian cucumbers, which would influence the market situation.

4.1.10 Conclusion of pest categorization

CGMMV is a highly contagious virus, which is able to spread rapidly in cucumber crops if first introduced. It clearly has the potential to become established in protected environments in the PRA area. Moreover, CGMMV will have a substantial impact for those growers affected, even before becoming widespread and permanently established. This is partly due to changes in cucumber production. An increasing proportion of production occurs using intensified artificial lighting, which also seems to increase the potential of CGMMV as a plant pest.

Field grown cucumbers are less handled, plant density is lower, the temperature is lower (slower plant growth and virus multiplication), the crop is only grown for about 4 months a year, and the fields are used in a crop rotation. All this makes the probability for establishment and damage low in comparison to greenhouse grown cucumbers.

4.2. Assessment of the probability of introduction and spread

4.2.1 Probability of entry of the pest

4.2.1.1 Identification of pathways

The following are possible pathways of entry for CGMMV:

Seeds

The seeds can have infective virus particles in the seed coat. In the germination phase this may lead to infection of the seedling. This is a well known pathway (Fletcher et al. 1969, Hollings 1975). To avoid this way of dissemination, the seed companies use heat treatment of the seeds. Failure to do so, or failure in the heat treatment, may therefore lead to transmission of CGMMV virus particles from seeds to seedlings. Theoretically, it is also a possibility that more heat tolerant strains of the virus could evolve.

Seed transmission in *Lagenaria* has been found in Greece (Bourbourakas et al. 2004). Infected seeds of *Lagenaria* or more exotic plants within the family *Cucurbitaceae* is a possible pathway for CGMMV in to Norway.

Infected cucumber, melon or watermelon

Fruits of cucumber are imported into the PRA region during parts of the year, and melons and watermelons are imported the whole year. Such fruits, if infected, could introduce CGMMV to Norway.

Regarding another virus, *Pepino mosaic virus,* there have been indications that the virus has entered the tomato crop via people handling infected tomato fruits as a part of their meal and afterwards going to work in the tomato crop.

Reuse of transport trays.

Transport trays used in cucumber production are normally reused. If these trays have been used for infected fruits of cucumber, melon or watermelons and are used again without being properly washed and disinfected, they might introduce infective virus particles to new cucumber crops.

People

The grower, consultants or people servicing the technical equipment may bring CGMMV from an infected crop to a healthy one if they do not take enough care.

Seedlings

If seedlings are produced in a nursery where CGMMV is present, these seedlings may get infected and bring infections to new locations and growers.

Water and soil

Bjørnstad (1979) mentioned a case where CGMMV was probably introduced into a new crop by water. In this case the old cucumber plants were composted near to the irrigation water basin. This is also mentioned by Rydén (1965b). Spread of CGMMV through surface water and water for irrigation has also been observed in the Netherlands by Dorst (1988) and in India by Vani & Varma (1993).

Paludan (1985) and Buttner et al. (1995) have shown that CGMMV can spread in recirculating nutrient solutions.

4.2.1.2 Probability of the pest being associated with the pathway at origin

The most probable pathway for long distance spread (entry) into the PRA is seeds (Fletcher et al. 1969). Infected seedlings, people, water and soil are more probable pathways for short distance spread.

4.2.1.3 Probability of survival during transport or storage

The CGMMV particles are stable and could survive during transport and storage of seeds, fruits, plant debris and soil.

4.2.1.4 Probability of pest surviving existing pest management procedures

As CGMMV particles are very stable, it is difficult to get rid of the virus without an efficient washing and disinfection procedure. The experiences from the four cases of CGMMV in Norway during 2007 stress this. At least in one of the cases the disinfection procedure was not successful.

4.2.2 Probability of establishment

4.2.2.1 Availability of suitable hosts, alternate hosts and vectors in the PRA area

The only known host for CGMMV in the PRA area is cucumber. The weeds *Chenopodium album* and *Solanum nigrum* are present in Norway, but we have no indication of CGMMV infection in these weeds.

4.2.2.2 Suitability of environment

Cucumber greenhouse crops are easily infected by CGMMV if an inoculum source is present. The virus spreads rapidly through the crop if first introduced. High plant density and frequent crop handling facilitate the spread of mechanically transmitted viruses like tobamoviruses (Tomlinson 1987). Cucumber cultures grown intensively with additional artificial light (see the description of the case in Grower A in Section 4.1.5.1) seem to be more vulnerable in comparison to cultures grown more traditionally without additional light. Intensive cultivation

with additional artificial lighting, therefore, seems to increase the suitability of the environment for CGMMV. It is unlikely that a change in light quality when using additional artificial light makes the culture more susceptible to CGMMV. It is probably the intensity of the production that makes a difference.

Field grown cucumbers are less intensively handled. The crop is not grown in the same field year after year, and the crop is not in the field for more than 4 months a year. All this makes field grown cucumbers less vulnerable for mechanically transmitted viruses, such as CGMMV, than greenhouse-grown crops.

Figure 8. Cucumber production with (left) and without (right) additional artificial light (photos: Dag-Ragnar Blystad).

4.2.2.3 Cultural practices and control measures

Growers use the following control measures to avoid introducing CGMMV to a healthy crop:

- Use CGMMV free seeds
- Buy seedlings from a nursery that guarantees seedlings free from CGMMV
- Do not grow any other species of *Cucurbitaceae* at the same location
- Do not allow visitors that have been visiting infected crops

The following control measures are used in greenhouses where CGMMV has occurred:

- Destruction of all infected plant material
- Disinfection of greenhouses, equipment, tools and clothes
- Delay before starting new crop
- Growing a non-host (tomato) for a period

Additional control measures to delay occurrence and spread

- Use of milk (dipping hands, spraying on leaves)
- Handle diseased plants last

4.2.2.4 Other characteristics of the pest affecting the probability of establishment

None

4.2.3 Probability of spread after establishment

There is a lot of cooperation between different growers regarding production of seedlings, equipment, packing and transport of cucumber fruits. This gives a high probability for further spread from location to location.

4.2.3.1 Conclusion regarding endangered areas

There is no resistance to CGMMV available in commercial cultivars.

All greenhouse cucumber crops in Norway can potentially be infected by CGMMV. If introduced, CGMMV is very contagious and can easily survive in infected greenhouses from one season to another. In intensive year-round crops there are just a few days between the old crop being removed and the new crop being planted. Consequently, it is easy for infective virus particles to survive and infect a new crop.

4.3. Assessment of potential economic consequences

4.3.1 Pest effects

4.3.1.1 Direct pest effects

Symptoms

Infected plants develop mosaic and yellowing. The roots look healthy. Strains that give symptoms on the fruit are known, but the strains that occurred in Norway in 2007 did not give any fruit symptoms.

Reduced growth

Fletcher et al. (1969) found a 50 % reduction in the root system of infected plants. This may be the reason for the wilting observed on sunny days.

Crop loss

Fletcher et al. (1969) indicated the crop loss to be 15 % in traditional cultivation.

Nilsson (1977) found a similar crop loss if the crop was infected early in the season. In the early infected crops there was a higher loss of first grade fruits – up to 33 %.

From growers' experiences we know that crop losses are higher in modern, intensively grown crops with the use of artificial light.

4.3.1.2 Indirect pest effects

Reduced cooperation between growers

If CGMMV becomes established on a permanent basis in the important regions for greenhouse cucumber, it will lead to difficulties in the cooperation between growers. There

will be more uncertainty regarding cooperation in raising seedlings and handling, packing, and transport of cucumber fruits.

Reduced use of reusable trays

It is beneficial for the environment if transport trays can be reused. These trays all have to be cleaned after use. It is important that the washing and disinfection are efficient enough to get rid of residues of CGMMV infected plant sap. To avoid all possible means of CGMMV infection, some growers may be reluctant to use these kinds of trays.

More time and consumables used on cleaning and disinfection

If CGMMV becomes established and occurs regularly in the PRA-region, more time and consumables will be required to stop the survival and spread of the infection.

Unpredictable market situation

The market situation will be influenced by the yield loss when big producers or several growers are affected by CGMMV. Some growers may have to change to other crops or eventually finish production.

4.3.2 Analysis of economic consequences

It is difficult to make a good prediction of economic consequences, since there is limited scientific information available about crop losses. In traditional summer production of greenhouse cucumber, the direct effect of CGMMV on crop harvest is reported to be 10-15 % reduction if the infection comes early in cultivation (Fletcher et al. 1969, Nilsson 1977).

The data from Grower A showed yield losses up to 50 % due to CGMMV infection in an intensive production. The cases in Norway in 2007 also indicated a possibility for spread of the pest connected to cooperation in raising seedlings and in the sorting and packing of cucumber fruits.

Scenario 1: CGMMV widespread in the PRA area

This is a “worst-case” scenario where CGMMV has become widespread in the PRA area.

Repeated entries of CGMMV by imported seeds have led to new introductions of CGMMV in the PRA area. The intensive growing of cucumbers in the PRA area has facilitated a higher frequency of CGMMV infestation. Control strategy varies between growers and thus also the efforts invested in eradication and hygiene measures. Greenhouses are repeatedly re-infected after eradication by the relevant pathways identified in 4.2.1.1. The pest CGMMV has become a common problem in the Norwegian greenhouse cucumber production. This will lead to new adaptations among growers. Year-round growing of cucumber in Norway will end, and the growers involved in this production will either stop growing cucumber or go back to less intensive and less profitable part-year growing of cucumbers without use of additional lighting. Cooperation among growers will be limited due to CGMMV related problems.

Scenario 2: Regulations has been imposed

The Authority has imposed regulations on CGMMV. The following risk management measures have been put into force:

- Imports of cucumber seeds are sampled on a routine basis and tested for the presence of CGMMV.

- Outbreaks are managed according to a specific contingency plan for CGMMV, where outbreaks are eradicated and the grower compensated.

The growing of cucumbers in Norway will continue to develop in the direction of a modern year-round production. Growers can invest in their businesses and at least be secure that they will not run into bankruptcy due to CGMMV related problems. This will be a competitive advantage for domestically produced cucumber compared to imported cucumbers, because CGMMV is not regulated in the exporting countries.

Scenario 3: Business as usual

Current cucumber producers in the PRA area have until now not regarded CGMMV as a risk factor in their production, because the pest has been absent for more than two decades. The recent experiences with CGMMV have increased the risk for cucumber production in the PRA area. One must expect that the growers will respond and adapt to reduce the risk of CGMMV. This will incur, and has most likely already incurred, costs additional to the losses suffered by those growers that experienced outbreaks. The effects that can be expected will be similar to those described under Scenario 1, though less massive.

4.3.3 Conclusion of the assessment of economic consequences

If CGMMV establishes itself permanently in Norway, several growers will experience heavy losses, due to less intensive production, more use of labour and consumables for washing and disinfection, a more unpredictable market situation, and more difficulty in cooperation with other growers due to the need for hygiene barriers. All this will give negative economic consequences.

4.3.3.1 Endangered area

All cucumber greenhouse production areas in Norway are endangered area.

4.4. Degree of uncertainty

There is a moderate level of uncertainty regarding the pathway for entry of CGMMV into the PRA area, because CGMMV has never been found in any of the possible pathways identified in 4.2.1.1. The pathway of seed transmission is considered most likely. There is a low degree of uncertainty regarding the pathogen, its survival and its possibility for transmission, establishment and spread in Norwegian greenhouse cucumber production. There is a high degree of uncertainty about whether CGMMV is able to become established and spread in field cucumber cultivation in the PRA area, but both establishment and spread potential are assumed to be much lower due to lower temperatures (slower plant growth and virus multiplication) and limitations for spread due to lower plant densities and lower frequency of crop handling. The degree of uncertainty is moderate regarding the impact and economic losses, since these are based on observations made in practical production, where other factors may also have had an impact on growth and yield.

Panel 9 still has questions regarding how the virus is introduced to the cucumber crops, and more studies are needed regarding pathways into the PRA area. In particular, the possibility of seed transmission should be further investigated. The possibility of CGMMV following other relevant pathways such as imported cucumber fruits, melons, watermelons, and seeds of other *Cucurbitaceae* crops or flowers should also be studied.

More knowledge of possible pathways and the effectiveness of control measures will give the growers a possibility to handle CGMMV effectively.

5. CONCLUSION

The Norwegian Scientific Committee for Food Safety (VKM) Panel 9 submits the following conclusions in response to questions from the Norwegian Authority for Food Safety:

Both recent and previous presences of CGMMV in the PRA area indicate that the pest is able to establish itself in the PRA area. Successful establishment of CGMMV has only been recorded in greenhouses in the PRA area. The probability for establishment and damage in field production is regarded as low.

CGMMV has probably not been present in Norwegian cucumber production since 1983, and the four cases found in greenhouse production in 2007 should be regarded as new introductions of the virus into the PRA area. Because successful eradication has not been confirmed after the 2007 outbreaks, CGMMV should currently be regarded as of limited distribution and under voluntarily eradication.

The CGMMV particles are stable and could survive during transport and storage of seeds, fruits, plant debris and soil. The most probable pathway for long distance spread (entry) into the PRA area is seed transmission. Infected seedlings, people, water and soil are more probable pathways for short distance spread.

There is a lot of cooperation between different growers regarding production of seedlings, equipment, packing and transport of cucumber fruits. This gives a high probability for further spread from location to location.

In Finland there was an epidemic in 1968, since then the virus has been found in 1987, 1989 and 1990. In Sweden there was one known case early in the 1990s, one case in 2002 and two cases in 2006. In Denmark seven cases have been detected during the last few years.

Up to 30-50 % of the greenhouse cultures in Dutch cucumber production is reported to be infected per year.

CGMMV is a threat to the modern, highly intensive greenhouse production of cucumber in Norway. The risk for severe yield losses is higher in Norway than in countries with a more extensive production of greenhouse cucumber.

From yield studies in summer production CGMMV is known to reduce yield by at least 15 % if the infection occurs at an early stage in cultivation. Late infections cause no significant yield loss. A high loss of fruit quality has also been found.

The experience from the four cases of CGMMV in Norway during 2007 is that the yield losses seem to be above 15 % in intensive greenhouse production with additional artificial light. Yield data from one grower indicate losses of up to 40 to 50 % of marketable produce. At another grower, where the infection occurred in the springtime, the infected plants developed to be weak and wilted on sunny days. These weak plants were not able to produce an acceptable yield. In the Swedish study, a reduced root system was found to be an effect of CGMMV infection.

Due to the potential for high yield loss in modern cucumber production, rapid spread when first introduced and the difficulties and costs connected to controlling the virus, CGMMV is a threat to the modern, highly intensive greenhouse production of cucumber in Norway. The potential damage consists of yield loss, direct costs in controlling the virus (labour, chemicals,

and periods with no production) and the indirect costs due to difficulties in cooperation with other growers and uncertainty regarding the market situation.

To avoid all possible pathways of CGMMV infection, some growers may be reluctant to reuse trays for cucumber transport. Increased waste from the cucumber production can thus become a negative environmental consequence of a possible further establishment and spread of CGMMV in the PRA area.

As CGMMV particles are very stable, it is difficult to get rid of the virus without an efficient washing and disinfection procedure.

Dry heat treatment of seed lots (to 70°C for 2-4 days) has been found highly effective, and has probably been the most effective measure to prevent the spread of CGMMV.

New cultures must start with healthy seed or healthy seedlings. It is important to limit the amount of visitors, and avoid tools or trays or people coming from potentially infected greenhouses.

It is important to handle healthy plants before infected ones to avoid spread of the virus to the entire crop. Use of skimmed milk (dipping hands, spraying on leaves) has been found to slow down the spread of tobamoviruses.

In the case of a crop infection, there has to be strict destruction of infected plant material, washing and disinfection of greenhouses, equipment, tools and clothes. To safeguard the new crop there should be a stop in cucumber production before starting a new cucumber crop.

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