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The present situation of Barley Yellow Dwarf Virus and other recently discovered cereal viruses in Germany

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Viruses on *Poaceae* (*Gramineae*) in Germany



Table 1a) Viruses with elongated (threadlike) particle morphology identified in grasses

Common virus name	Abbreviation	Family (Genus)	Reference
<i>Agropyron mosaic virus</i>	AgMV	<i>Potyviridae</i> (<i>Rymovirus</i>)	Schuhmann (1967)
<i>Brome streak mosaic virus</i>	BrSMV	<i>Potyviridae</i> (<i>Tritimovirus</i>)	Schubert & Rabenstein (1995), Götz & Maiss (1995)
Cocksfoot streak mosaic virus	CfSMV	<i>Potyviridae</i> (<i>Tritimovirus</i>)	Rabenstein et al. (2014)
<i>Cocksfoot streak virus</i>	CSV	<i>Potyviridae</i> (<i>Potyvirus</i>)	Ohmann-Kreutzberg (1963), Götz & Maiss (2002)
Festuca necrotic mottle virus	FNMV	<i>Potyviridae</i> (<i>Poacevirus</i>)	Rabenstein et al. (2013a)
Festuca necrosis virus	FNV	<i>Closteroviridae</i> (<i>Closterovirus?</i>)	Schmidt et al. (1963)
<i>Lolium latent virus</i>	LLV	<i>Flexiviridae</i> (<i>Lolavirus</i>)	Huth et al. (1995)
Luzula leaf streak virus	LLSV	<i>Potyviridae</i> (<i>Potyvirus?</i>)	Lesemann et al. (1998)
<i>Oat necrotic mottle virus</i>	ONMV	<i>Potyviridae</i> (<i>Tritimovirus</i>)	Rabenstein et al. (2002)
<i>Ryegrass mosaic virus</i>	RGMV	<i>Potyviridae</i> (<i>Rymovirus</i>)	Rabenstein & Stanarius (1982)
Spartina mottle virus	SpMoV	<i>Potyviridae</i> unassigned	Götz et al. (2002)

Number of viruses with elongated particles

1980: 3
 2005: 9
 2015: 11

Viruses on *Poaceae* (*Gramineae*) in Germany

Table 1b) Viruses with spherical (isometric) particle morphology identified in grasses



* Strains of CMMV: Brome stem leaf mottle virus Cocksfoot necrosis and mosaic virus, Festuca mottle virus, Holcus transitory mottle virus und Phleum mottle virus.

2015: as many as 13

Viruses on winter wheat and winter barley



Table 2a) viruses described on wheat

Common virus name	Genus	References
Barley yellow dwarf virus (BYDV)		Klinkowski & Kreuzberg (1958)
- Barley yellow dwarf virus-PAV	<i>Luteovirus</i>	Haase (1988)
- Barley yellow dwarf virus-MAV	<i>Luteovirus</i>	Haase (1988)
- Barley yellow dwarf virus-RMV (formerly), now Maize yellow dwarf virus (MYDV-RMV)	<i>Polerovirus</i>	Helmke & Huth (1996)
Brome mosaic virus (BMV)	<i>Bromovirus</i>	Rabenstein & Proeseler (1982)
Cereal yellow dwarf virus (CYDV-RPV)	<i>Polerovirus</i>	Huth (1985)
Wheat dwarf virus (WDV)	<i>Mastrevirus</i>	Huth & Lesemann (1994)
Soil-borne cereal mosaic virus (SBCMV)	<i>Furovirus</i>	Proeseler et al. (1982)
Soil-borne wheat mosaic virus (SBWMV)	<i>Furovirus</i>	Koenig & Huth (2003), Ziegler et al. 2013
Wheat spindle streak mosaic virus (WSSMV)	<i>Bymovirus</i>	Proeseler et al. (1982)
Wheat streak mosaic virus (WSMV)	<i>Tritimovirus</i>	Schubert et al. (2015)

2b) viruses described on barley

Common virus name	Genus	References
Barley dwarf virus (BDV, barley strain of WDV)	<i>Mastrevirus</i>	Schubert et al. (2002)
Barley mild mosaic virus (new strains)	<i>Bymovirus</i>	Huth & Adams (1990)
Barley stripe mosaic virus	<i>Hordeivirus</i>	Ohmann-Kreuzberg (1963)
Barley yellow dwarf virus (BYDV)		Klinkowski & Kreuzberg (1958)
- Barley yellow dwarf virus-PAV	<i>Luteovirus</i>	Haase (1988)
- Barley yellow dwarf virus-MAV	<i>Luteovirus</i>	Haase (1988)
- Barley yellow dwarf virus-RMV (formerly), now Maize yellow dwarf virus (MYDV-RMV)	<i>Polerovirus</i>	Helmke & Huth (1996)
Barley yellow mosaic virus (new strains)	<i>Bymovirus</i>	Huth & Lesemann (1978)
Cereal yellow dwarf virus (CYDV-RPV)	<i>Polerovirus</i>	Huth (1985)
Oat sterile dwarf virus (OSDV)	<i>Fijivirus</i>	Mühle & Kempniak (1971),
Soil-borne barley mosaic virus	<i>Furovirus</i>	Rabenstein et al. (2011)

Yellow dwarf viruses of wheat and barley

The yellow dwarf viruses (YDVs) belonging to the *Luteoviridae* family are the most widespread group of cereal viruses worldwide.

Barley yellow dwarf viruses(BYDVs) are a group of viruses included in YDVs.

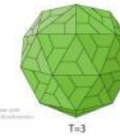
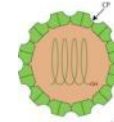
BYDVs were previously placed into several strains based on the differences in their biological characteristics.

Genome sequence analyses revealed that the BYDV strains are classified into either the *Luteovirus* or the *Polerovirus* genera of the *Luteoviridae* family.

Krueger et al.(2013) analyzed the genome sequence of one of the BYDV strains, BYDV-RMV, showed that BYDV-RMV is a polerovirus distantly related to other YDVs, and proposed to rename it *Maize yellow dwarf virus-RMV*.

Poaceae infecting viruses of the B/CYD-complex (Family *Luteoviridae*):

ss+ RNA



Genus *Luteovirus*

- Barley yellow dwarf virus-PAV* (BYDV-PAV) (Type)
- Barley yellow dwarf virus-PAS* (BYDV-PAS)
- Barley yellow dwarf virus-MAV* (BYDV-MAV)
- Barley yellow dwarf virus-ker-II* * (Subantarktisch)
- Barley yellow dwarf virus ker-III* * (Subantarktisch)
- Barley yellow dwarf virus-GAV* (BYDV-GAV) (China)**

Genus *Polerovirus*

- Cereal yellow dwarf virus-RPV* (CYDV-RPV)
- Cereal yellow dwarf virus-RPS* (CYDV-RPS) (Mexiko)
- Maize yellow dwarf virus-RMV* (MYDV-RMV)
- Sugarcane yellow leaf virus* (ScYLV)
- Wheat yellow dwarf virus* (WYDV-GPV) (China)



Rhopalosiphum padi
Vector of BYDV-PAV and
CYDV-RPV



Macrosiphum (Sitobion)
avenae, main vector of
BYDV-MAV

Analysis of yellowing viruses (Selection from submissions 2014)

Sender	Origin	Date	Variety	BYDV -PAV	CYDV -RPV	WDV
NU Agrar	Frankfurt/O	27.10.	WW Famulus	+	-	-
PSA Hessen	Bauernheim	05.11.	WB Sandra	+	-	-
PSA Hessen	Sample 9222	05.11.	WB	+	-	-
NU Agrar	16306 Passow	06.11.	WB	+	-	-
PSA Hessen	Wallerstädten	13.11.	WB	+	-	-
NU Agrar	Kuhstorf 23758	14.11.	WB Keeper	+	-	-
NU Agrar	Seelow	15.11.	Oat (cover crop)	+	-	-



Infection with BYDV-PAV at the site Bauersheim (Photo Michael Lenz, end of October 2014)

“Provocation field” Quedlinburg 2014/15

Winter rye variety 'Conduct'

ELISA results (09.04.2015)

BYDV (PAV-AS)	32/50 (64%)
WDV	0/50



“Provocation field” Quedlinburg 2014/15

Triticale variety 'Cultivao'

ELISA results

BYDV (PAV)	35/50 (70%)
WDV	0/50



“Provocation field” Quedlinburg 2014/15

Winter wheat variety 'Tiger'

ELISA results (09.04.2015)

BYDV (PAV)	44/50 (70%)
WDV	0/50



“Provocation field” Quedlinburg 2014/15

Winter oat variety 'Fleuron'

ELISA results (09.04.2015)

BYDV (PAV)	50/50
WDV	0/50



“Provocation field” Quedlinburg 2014/15

Winter barley variety 'Kathleen'

ELISA results (09.04.2015)

BYDV (PAV-AS)	45/50 (90%)
WDV	0/50



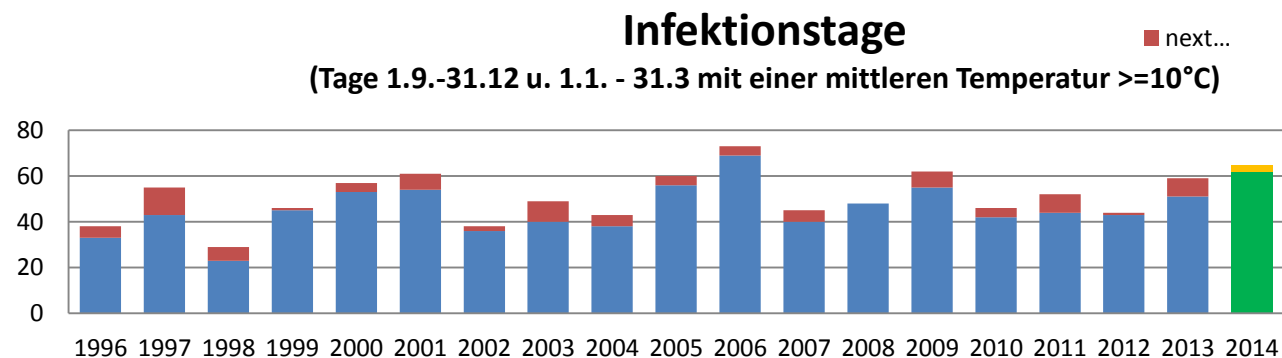
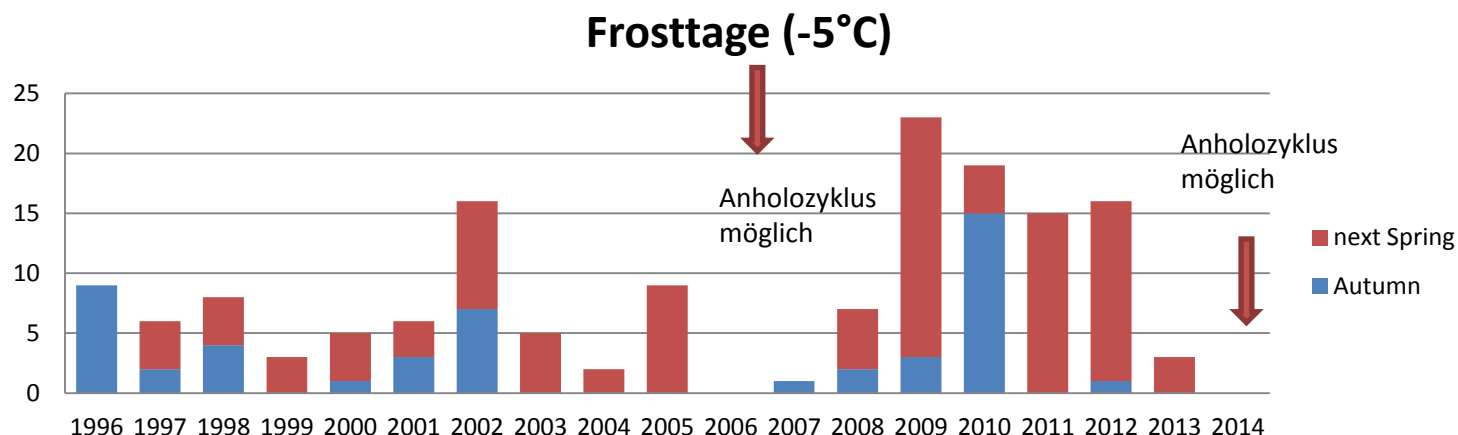
Strong impairment of breeding work by BYDV in 2015 (field trials for BaYMV and BaMMV resistance evaluation)



'Paroli' , first German winter barley with resistance (tolerance) to BYDV



Possible reasons for the outbreak of BYDV in Germany

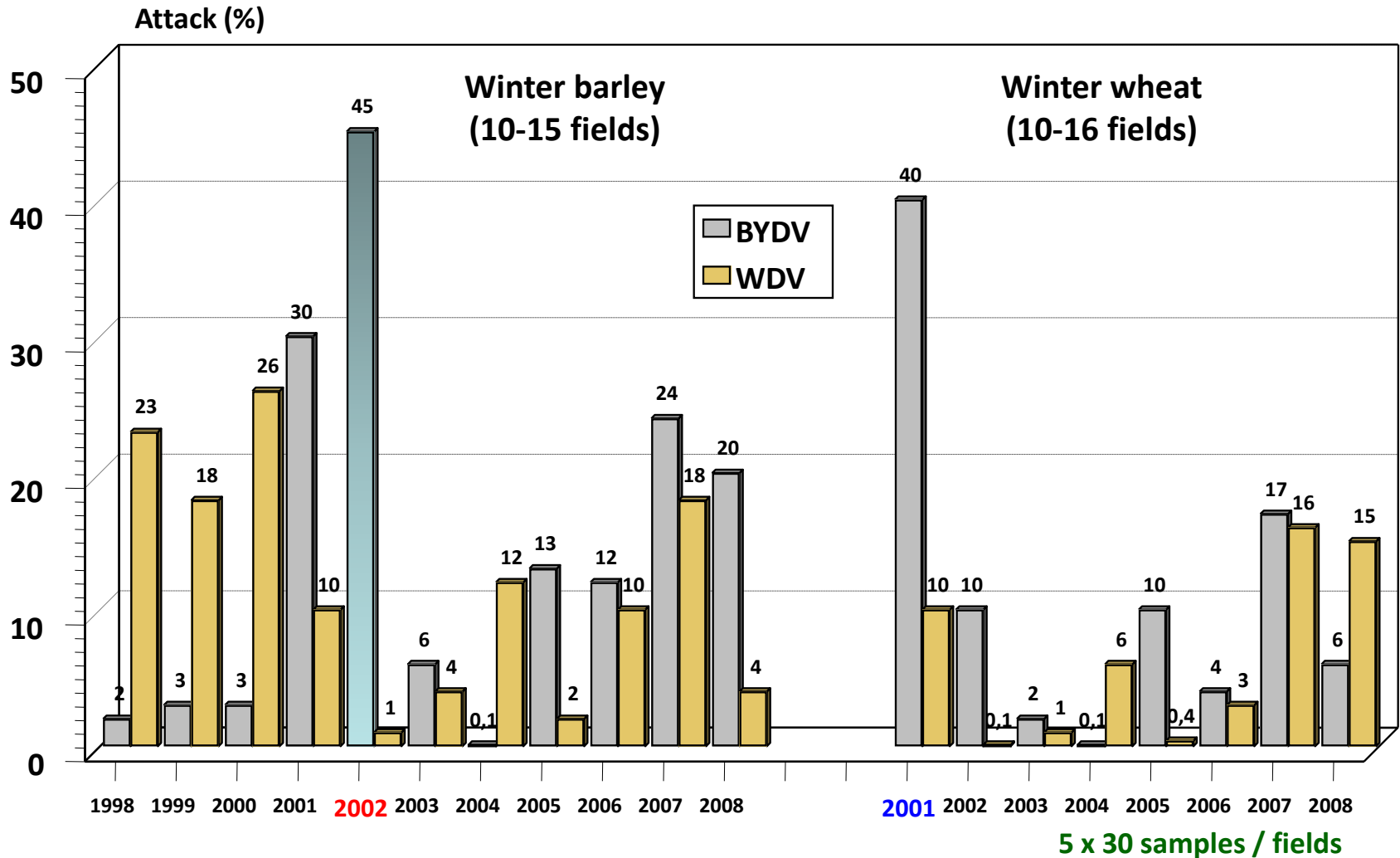


- Mild weather conditions, no frost days in winter 2014/15, **anholocycle** possible
- To early planting dates (sowing of WB not before end of September)
- No seed treatment with insecticides (seeds dressing) allowed in the EU



- Spreading out of grass weeds (*Bromus spec.*, *Alopecurus spec.*, resistance to herbicides)
- Insecticide resistance of aphids (?)

Virus attack of winter barley and winter wheat fields in spring in Saxony-Anhalt (Central Germany)



The yellow dwarf viruses (YDVs) in Germany 2015

Testing of 100 samples from barley, wheat, triticale, spelt, oats, and grasses collected 2015

Test kits from BioReba

PAV-type	MAV-type	RPV-type	WDV
88	7 (mixed inf.)	2 (Lolium spec.)	3 (2 WB + 1 WW)

Samples prepared for sequencing

Primers for detection:

BYDV-PAV, -PAS, -MAV,
CYDV-RPV
MYDV
WYDV

Insect-borne viruses of Wheat dwarf- /Barley dwarf- virus complex



Barley yellow dwarf virus-PAV, Cereal yellow dwarf virus-RPV and Wheat dwarf virus on winter wheat
 – similar symptom, **3 different viruses, detection by DAS-ELISA**



Virus (isolate)	BYDV-PAV	CYDV-RPV	WDV
BYDV-PAV ASL1	1,77	0,01	0,05
CYDV-RPV Dittersbach	0,01	1,34	0,01
WDV Westdorf	0,03	0,01	0,75
Healthy wheat	0,02	0,02	0,04

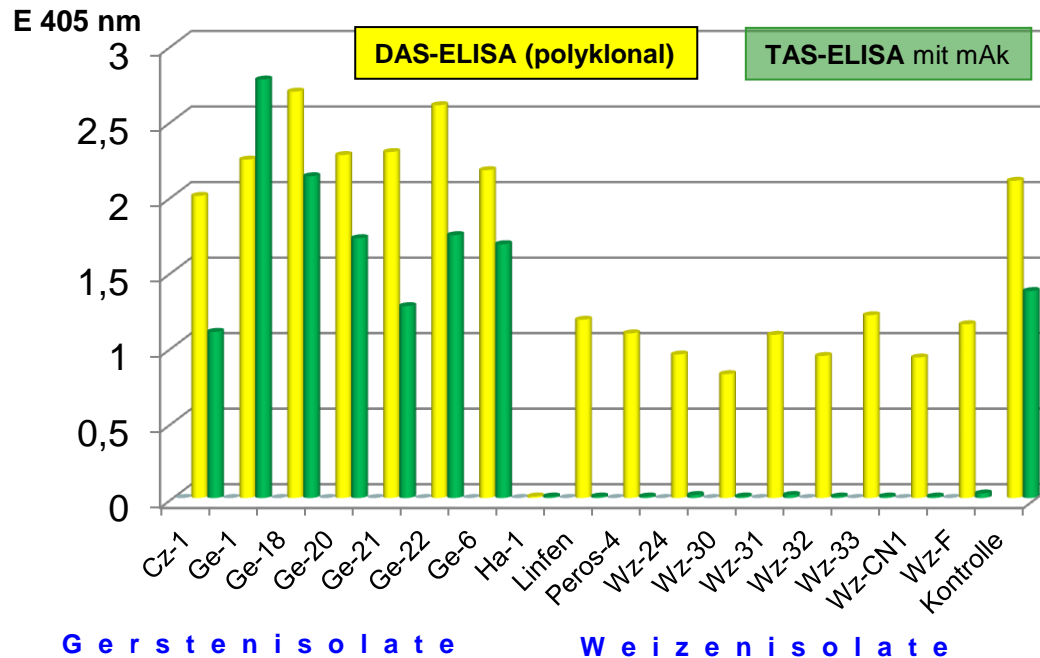
Serological investigation of samples for What dwarf virus (WDV) and Barley dwarf virus (BDV) in 2012



Epidemiological studies on the incidence of WDV and BDV have shown that an infestation with both viruses occurred in 2012.

The WDV was present in WW and winter triticale, spelt, and *Poa spec.* Only one spring barley sample also contained WDV.

BDV occurred in WB und SB and occasionally in *silky bent grass (Apera spica venti)*.



Whether WDV and BDV differ in their host range and wintering hosts, is not yet known.

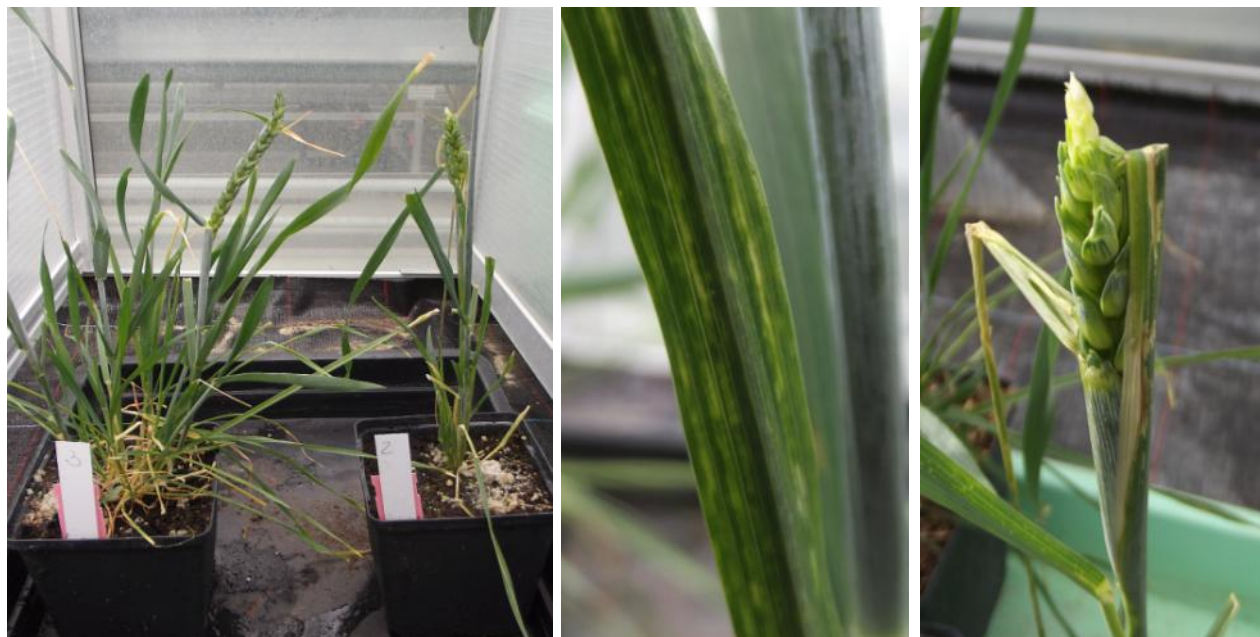
The Brome mosaic virus (BMV)
- An old friend with a new companion ?

BMV first described in Germany in grasses (Ohmann-Kreutzberg, 1963). In the past only one report for BMV in WW (Rabenstein & Proeseler, 1982)



2013 BMV was detected in wheat breeding plots of firms from Germany and Austria.

BMV also occurred massively in DH lines of a wheat breeder in the greenhouse, so all the material had to be destroyed.



Growth depression (left), mosaic symptoms (center) and stuck of ears (right) on plants of DH wheat lines in the greenhouse caused by infection with the BMV.

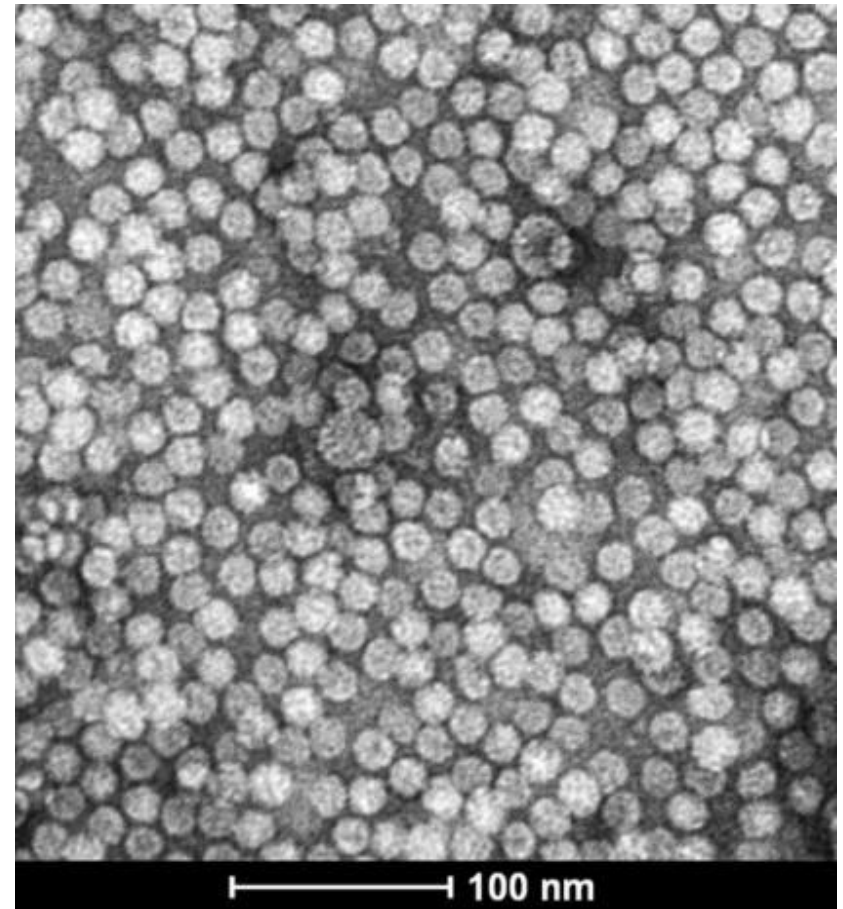
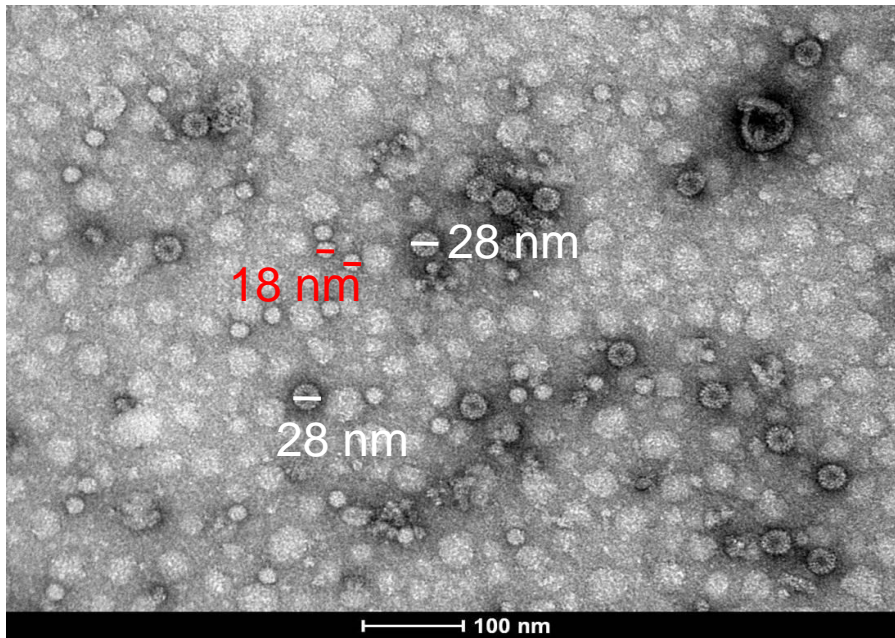
German Seed Alliance (GSA)

The branch with the trial plots located in Roschinski, some 100 kilometers north of the city of Lipetsk.



Symptoms on WB and WW in the field (Photo Danilkin Nikolay, Russia)

Electron microscopy:
Particles of BMV (28 nm diameter) (white) and
numerous spherical particles of 18 nm in diameter (red)



A particular problem represents a hitherto unknown satellite virus that occurred in breeding material from Russia in 2012 infected by BMV (helper virus).

Wheat streak mosaic virus (WSMV)

For the first time discovered in Germany in 2013

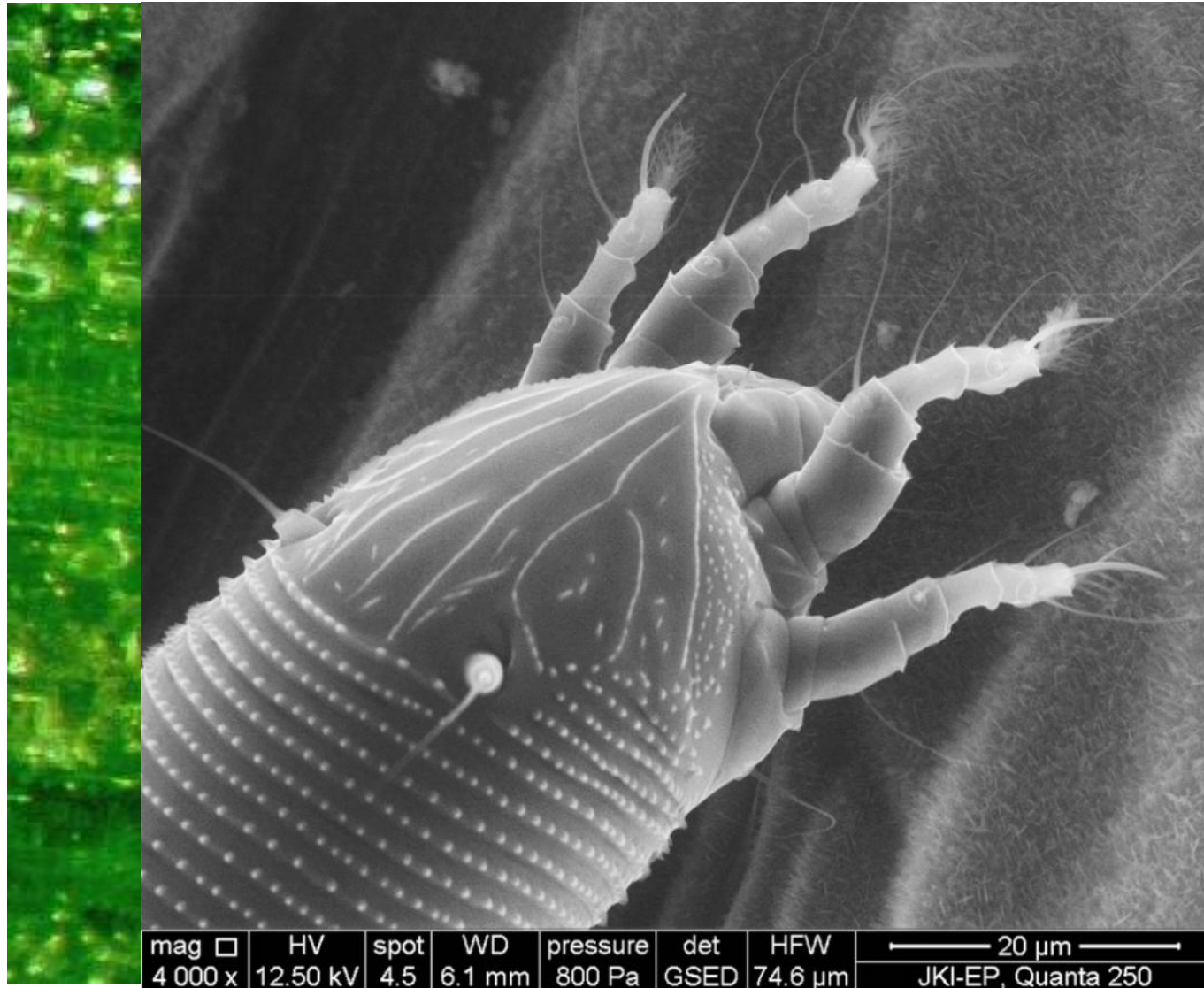
Virus symptoms on voluntary wheat in Saxony-Anhalt (2013)



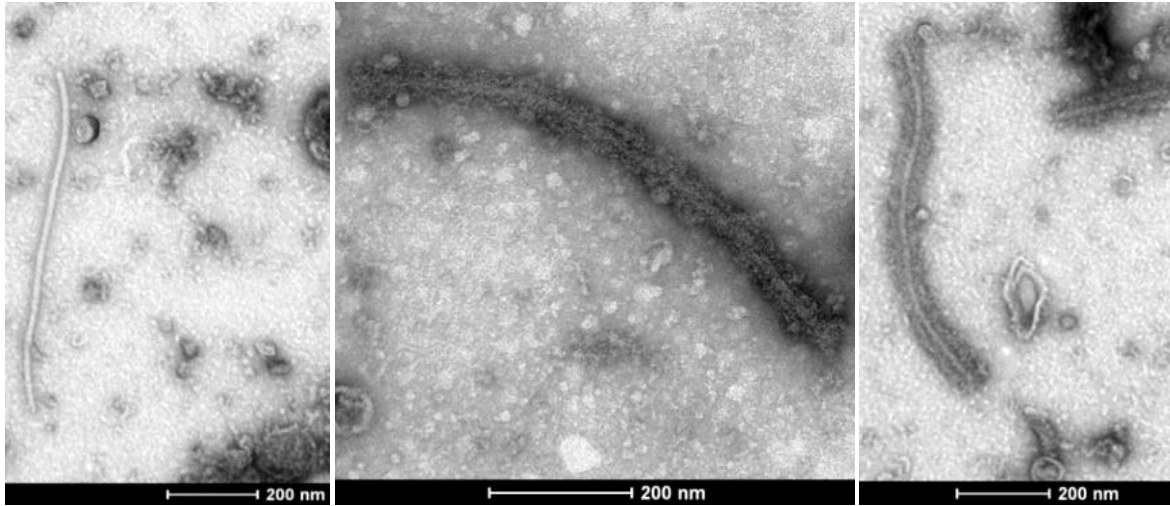
05/06/2015

Workshop Alnarp June 2015

Eriophyoid mite (*Aceria tosichella*) on WW – Vektor of WSMV

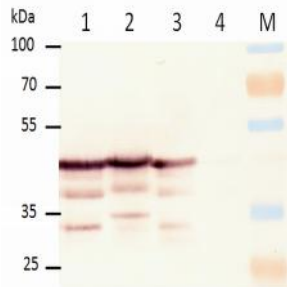


Immunolectron microscopy (decoration by WSMV antiserum)

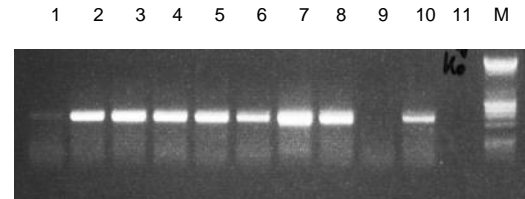


Virus detection confirmed by WB, PCR and ELISA

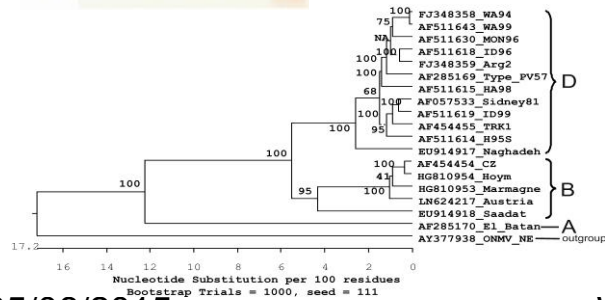
Primer WSM-8179: GCAATACTGCGTGTACGAATCGA
 Primer WSM-8910: GCATAATGGCTCGAAGTGATG



Western blot-Analyse von WSMV Isolaten mit Antiserum WSMV-58 (IgG).
 Linien: 1 WSMV-D (Wintergerste)
 2 WSMV-Type ACTC-PV-57,
 3 WSMV-D (Winterweizen)
 4 Winterweizen gesund, M Proteinmarker-Standards



1. Ausfallgetreide v. 16.09. 13 Feldrand Hoym D
2. WG Einsendung N.U. Agrar Schackenthal v. 02.05.13
3. WSMV Ungarn Isolat 1 (WW Genius, vertrocknet, 2013)
4. WSMV Ungarn Isolat 2 (WW, Nähe Bad Bük, 2013)
5. WSMV Isolat Gerste, Feldrand Hoym, D
6. WSMV Isolat Weizen, Feldrand Hoym, D
7. WSMV Typ ATCC-PV-57 (auf WW Alcedo)
8. WSMV Österreich, Pr. 3a (auf WW Alcedo)
9. BrSMV Isolat Wien auf WG Erfa
10. Positivkontrolle (WSMV-Ampulle, Agdia)
11. Wasserkontrolle



Complete genome sequencing: virus belongs to the Group of European isolates (clade B)

WSMV on WW (June 2014) - Virus infections start at the edge of the field



Virus infection begins only in the spring and is not relevant to the yield?

Distribution of WSMV in Europa



Summary and conclusions for cereal production in Germany

Threat of these important crop especially in 2015 by **BYDV** (PAV mainly?) (others?) and by Cereal dwarf viruses (**BDV, WDV**), (and speed of new soil-borne virus strains)

BYDV tolerance in var. Paroli by combination of resistance genes Ryd2 and Ryd3

2013 BMV and new satellite virus: economical importance?

2013 WSMV on edge of the field, in **2014 WSMV** in crop (introduction and spread over the seed?) about 0.1% seed transmission (import control?).

Importance of other grass viruses as reservoirs?

The emergence of new viruses in cereals can be expected as the result of climate change and rising global exchange of seeds (and plants).

With the development of new markets (e.g. in Eastern Europe), new problems can occur because there are other viruses and vectors and no resistances are available.

Thank you for your attention



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