

Supplementary materials (Eckerstorfer et al. 2024)

Table S1: List of publications identified for GM viruses used as molecular tools in biotechnology applications, indicating their status of development and the use of GM viruses. VIGS: virus induced gene silencing; VAGE: virus aided gene expression; Status: assigned status of development; BR (L): Basic research (vector developed in laboratory conducting the study); R&D (SC): Research and development (vector shared in scientific community); NM/M (C): near market/market (vector available commercially)

No.	Virus used as vector	Purpose of the application	Purpose of the Study	Reference (study)	Status (vector)	Reference (vector)
1	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	Silencing genes involved in drought tolerance	[1]	R&D (SC)	[2]
2	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	Study of silenced and overexpressed gene involved in drought tolerance	[3]	R&D (SC)	[2]
3	-	Biology study (BPIV-3)	Development of molecular characterization to assess the role of homologous recombination events in the evolution of Bovine parainfluenza-3 virus	[4]	-	-
4	Nucleopolyhedrovirus (BmNPV), BmNPV/DmTβH	VAGE	Baculovirus-mediated expression of protein in <i>Bombyx mori</i>	[5]	BR (L)	[6]
5	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS to suppress genes inducing programmed cell death to confer tolerance against abiotic stresses in plants.	[7]	R&D (SC)	[2,8,9]
6	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS of NbDODAL1 gene to modify the metabolism of aromatic compounds contributing to antimicrobial or antioxidative activity	[10]	R&D (SC)	[2]
7	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS to silence LOX2 expression to induce anti-herbivory responses against <i>S. littoralis</i> larvae	[11]	R&D (SC)	[2]

8	Nucleopolyhedrosis virus (BmNPV); pcDNA3.0, PGL3	VAGE	BmNPV-driven expression of miRNAs regulating gene expression in <i>Bombyx mori</i>	[12]	R&D (SC)	[13]
9	-	Virus-host specificity baculovirus	Study of virus-host specificity to aid the application of baculovirus in protein expression systems and the development of bio-control agents	[14]	-	-
10	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS of GhGPA expression in Arabidopsis increased susceptibility to Verticillium wilt	[15]	R&D (SC)	[2,16]
11	Tobacco rattle virus (TRV); pTRV1&pTRV2-LIC	VIGS	Development of TRV vectors for VIGS in <i>Centaurea spp.</i>	[17]	R&D (SC)	[18]
12	Baculovirus, pFastBac™ Dual Expression Vector	VAGE	Development of a baculovirus recombinant expression of transmembrane SVCV-G protein in insect cells, for use as whole-cell subunit vaccine through the oral and injection route in carp	[19]	NM/M (C)	Invitrogen / Thermo Fisher Scientific
13	Baculovirus, pFastBac™ Dual Expression Vector	VAGE	Baculovirus mediated expression of proteins for use in ELISA	[20]	NM/M (C)	Invitrogen / Thermo Fisher Scientific
14	Baculovirus; BmNPV K1	VAGE	Design of Baculovirus vectors for high efficiency protein expression	[21]	BR (L)	[22]
15	Cymbidium mosaic virus (CymMV); CymMV-Gateway	VIGS	CymMV-based VIGS system to be used with orchids	[23]	R&D (SC)	[24]
16	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS silencing of SINAC61 transcription factor to elicit response to Tomato yellow leaf curl virus infection.	[25]	R&D (SC)	[2]

17	Hemorrhagic septicemia virus (VHSV); pVHSV-A-RFP	VAGE	GM VHSV to express IFN-proteins in flounder cells	[26]	R&D (SC)	[27]
18	Barley stripe mosaic virus (BSMV); BSMV-sg vectors	VAGE	Development of BSMV-based sgRNA delivery vector (BSMV-sg) in wheat	[28]	BR (L)	[29]
19	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS to elucidate the role of the PYL4 gene in response to drought in tomato	[30]	R&D (SC)	[9,31]
20	Cucumber green mottle mosaic virus (CGMMV); pXT- CGMMV	VAGE	CGMMV-based virus vectors to test use of subgenomic promoters	[32]	R&D (SC)	[33]
21	Barley stripe mosaic virus (BSMV); pCa- γ bLIC	VIGS	VIGS to address cereal cyst nematode (CCN) infections in barley	[34]	R&D (SC)	[35]
22	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS-mediated knockdown of PAP3 led to the shriveling of pollen grains and male sterility in peppers	[36]	R&D (SC)	[2]
23	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS-mediated silencing of GhHD-1A and GhHD-1D in allotetraploid cotton significantly reduces the density of leaf hairs and affects the expression levels of other genes related to leaf trichome formation	[37]	R&D (SC)	[2]
24	Baculovirus, pFastBac™ Dual Expression Vector	VAGE	Baculovirus expression of Bovine parainfluenza virus type 3 (BPIV3) self-assembled GM-BPIV3 nanoparticles	[38]	NM/M (C)	Invitrogen / Thermo Fisher Scientific
25	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS to study the Ph-3-dependent resistance signaling pathway in tomato	[39]	R&D (SC)	[2,40]

26	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	TRV-based VIGS for gene function research in <i>Forsythia</i>	[41]	R&D (SC)	[2]
27	Barley stripe mosaic virus (BSMV); pSL038-1	VIGS	VIGS based functional study of TaNAC032 in Fusarium head blight in wheat	[42]	R&D (SC)	[43]
28	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	VIGS to downregulate SLB3 expression to reveal the function of the SLB3 gene under drought stress in tomato	[44]	R&D (SC)	[2]
29	Baculovirus; Bac-to-Bac™ Vector	VAGE	Development of pseudotyped recombinant baculovirus (Bacmid-GUS/VP28) for infection and expression in penaeid shrimps	[45]	NM/M (C)	Invitrogen / Thermo Fisher Scientific
30	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	TRV-based VIGS of a Phytoene Desaturase ortholog (LhPDS) in Lilium	[46]	R&D (SC)	[2]
31	Barley yellow striate mosaic virus (BYSMV); pBY-GR vector	VAGE	BYSMV a plant cytorhabdovirus as versatile expression platforms in small brown planthoppers and cereal plants.	[47]	R&D (SC)	[48]
32	Tobacco rattle virus (TRV); pTRV1&pTRV2	VIGS	Development of a TRV-based VIGS system in Chinese narcissus	[49]	R&D (SC)	[2]
33	Baculovirus, pFastBac™ Dual Expression Vector	VAGE	Development of a baculovirus insect cell system for expression of capsid protein of Infectious hypodermal and hematopoietic necrosis virus (IHHNV)	[50]	NM/M (C)	Invitrogen / Thermo Fisher Scientific

Table S2: List of publications identified for GM viruses for the development of vaccines for animals, indicating their status of development and the use of GM viruses
Status: Status of development; BR: Basic research; R&D: Research and development; FT: Field trial

No.	Virus	Purpose of the application	Purpose of the Study	Reference (study)	Status	GMO
1	Canine distemper virus (CDV)	Dog vaccine	Evaluation of wild-type CDV and vaccine isolates to determine if the genetic differences among various strains result in significant antigenic differences	[51]	BR	No
2	Bovine herpesvirus 5	Cattle vaccine	A recombinant bovine herpesvirus 5 lacking thymidine kinase and glycoprotein E genes (BoHV-5gEΔTKΔ) was evaluated as a live experimental vaccine.	[52]	R&D	Yes
3	Feline Coronavirus (PBFIPV-DF-2, PBFIPV-DF-2-R3i)	Cat vaccine	Evaluation of a FCoV pair as possible vaccine candidates	[53]	R&D	Yes
4	Equine herpesvirus type-1 (EHV-1)	Horse vaccine	Assessment of intranasal and intramuscular vaccination of horses with a modified live equine herpesvirus type-1 (EHV-1) vaccine	[54]	R&D	No
5	Bovine rotavirus	Cattle vaccine	Test of adjuvanted vaccine containing recombinantly-expressed rotavirus virus-like particles	[55]	R&D	No
6	Betanodavirus	Fish vaccine	Review of antigenic preparations derived from the viral encephalopathy and retinopathy virus (betanodavirus) used in European sea bass	[56]	BR	No
7	Bovine herpesvirus type 5 (BoHV-5)	Cattle vaccine	Evaluation of inactivated, oil adjuvanted vaccine prepared with a GM BoHV-5 from which the genes coding for glycoprotein I (gI), glycoprotein E (gE) and membrane protein US9 were deleted (BoHV-5 gI/gE/US9–)	[57]	R&D	Yes
8	Pseudorabies virus (PRV)	Pig vector vaccine	GM PRV expressing siRNAs against the ORF7 of porcine reproductive and respiratory syndrome virus (HP-PRRSV)	[58]	BR	Yes
9	Baculovirus	Fish vector	Testing of GM baculoviruses expressing nine truncated membrane glycoproteins	[59]	R&D	Yes

		vaccine	of Cyprinid herpesvirus 2 (CyHV-2)			
10	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Evaluation of the cross-protection efficacy of two commercial PRRS modified-live virus (MLV) vaccines, derived from classical PRRSV (VR2332) and highly pathogenic (HP) PRRSV (TJM-F92), against a NADC30-like lineage in pigs	[60]	R&D	No
11	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Research into concerns about modified live vaccines (MLV)-derived PRRSV isolates	[61]	BR	No
12	Siniperca chuatsi rhabdovirus (SCRV)	Fish DNA vaccine	Determination of the antiviral immune response elicited by DNA vaccination in mandarin fish.	[62]	BR	No
13	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Safety and efficacy tests under experimental and field conditions for evaluation of K418DM1.1, a plaque-purified K418DM PRRSV vaccine	[63]	FT	Yes
14	Viral hemorrhagic septicemia virus (VHSV)	Fish vaccine (viral replicon particles)	Viral replicon particles / single-cycle viruses defective for function(s) needed for viral replication for safer vaccination of animals (olive flounders) against compared to attenuated live viruses	[64]	R&D	Yes
15	Betanodaviruses (Nodaviridae)	Fish vaccines	Assessment of viral encephalopathy and retinopathy (VER) disease agents: Striped Jack nervous necrosis virus (SJNNV), Tiger puffer nervous necrosis virus (TPNNV), Barfin flounder nervous necrosis virus (BFNNV), Red-spotted grouper nervous necrosis virus (RGNNV), turbot betanodavirus strain (TNV)	[65]	BR	No
16	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Assessment of a novel recombinant PRRSV, SD043, isolated from a pig farm experiencing disease in 2019	[66]	BR	No
17	Sindbis virus (SV)	Cattle SV-DNA prime-protein	Development of a SV replicase-based DNA vaccine against foot-and-mouth disease	[67]	BR	Yes

		boost vaccine				
18	Infectious spleen and kidney necrosis virus (ISKNV)	Fish vaccine	Assessment of a formalin-killed cell-cultured ISKNV vaccine mandarin fish in China as basis for GM ISKNV vaccines	[68]	BR	No
19	Newcastle disease virus (NDV)	Poultry / Chicken vaccine	Assessment of different NDV vaccines for efficacy against different isolates based on different vaccination regimes	[69]	BR	Yes
20	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Assessment of co-infection of a PRRSV type 1 modified live vaccine-like strain and a type 2 porcine circovirus (PCV2)	[70]	BR	No
21	Avian infectious bronchitis virus (IB)	Poultry vaccine	Non-GM IB vaccine variant testing	[71]	FT	No
22	Lumpy Skin Disease virus (LSDV) and Bluetongue virus (BTV)	Cattle vaccine	Developed of an inactivated, oil adjuvanted bivalent vaccine against both Lumpy Skin and Bluetongue disease based on LSDV Neethling strain and BTV4	[72]	BR	No
23	Infectious bursal disease virus (IBDV)	Poultry vaccine	Development and testing of a reassortment virus strain rGtVarVP2 effective against the novel variant IBDV	[73]	FT	Yes
24	Newcastle disease virus (NDV)	Poultry vaccine	Development and testing of an in-ovo NDV vaccine strain TS09-C to induce protective cellular immunity in chicks in the presence of maternal antibodies	[74]	FT	No
25	Classical Swine Fever Virus (CSFV)	Pig vaccine	Characterisation of genetic modifications in attenuated vaccine strains of CSFV	[75]	BR	No
26	African swine fever virus (ASFV)	Pig vaccine	Molecular evolution of circulating ASFV isolates and the important role of this gene in the evasion of the host immune system	[76]	BR	No
27	Pseudorabies virus (PrV)	Pig vector vaccine	Review of GM PrV as a powerful vector system for expression of foreign genes to	[77]	BR	Yes

			vaccinate against several infectious diseases of swine			
28	Semliki Forest virus (SFV)	Poultry DNA vaccine	A suicidal DNA vaccine based on a Semliki Forest virus (SFV) replicon was evaluated for the development of a vaccine against duck hepatitis virus type 1 (DHV-1)	[78]	R&D	Yes
29	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Testing of a recombinant PRRS virus (PRRSV) vectored vaccine candidate rPRRSV-E2, which expresses CSF virus (CSFV) E2 protein,	[79]	FT	Yes
30	Infectious bursal disease virus (IBDV)	Poultry DNA vaccine	Development of a DNA prime–protein boost vaccine against IBDV	[80]	R&D	Yes
31	Foot-and-mouth disease virus (FMDV)	Cattle vaccine	Characterisation of the effects of genetic changes in attenuated FMDV isolates	[81]	BR	Yes
32	Newcastle diseases virus (NDV) and Marek's disease virus (MDV)	Poultry vector vaccine	New generation vector vaccines against infectious laryngotracheitis in poultry stocks	[82]	R&D	Yes
33	Canarypox virus (CV)	Dog vector vaccine	Development of a recombinant canarypox virus “ALVAC-CDV-M-F-H/C5–” against Canine distemper virus (CDV) that contained CDV virus-like particles (VLPs) by using the CRISPR/Cas9 gene editing	[83]	R&D	Yes
34	Infectious hematopoietic necrosis virus (IHNV) and infectious pancreatic necrosis virus (IPNV)	Fish vaccine	Development of rIHNV-IPNV VP2 and rIHNV-IPNV VP2COE candidate vaccine against IHNV and IPNV in rainbow trout	[84]	R&D	Yes
35	Oxyeleotris marmoratus iridovirus (OMIV) and Oxyeleotris marmoratus	Fish vaccine	Development of a bivalent inactivated vaccine against OMIV and OMRV and evaluation of its protective effect in marbled sleepy goby <i>Oxyeleotris marmoratus</i>	[85]	R&D	No

	rhabdovirus (OMRV)					
36	Tembusu virus (TMUV)	Poultry vaccine	Development of a polytope DNA vaccine (pVAX1-rTEM) consisting of B-cell and T cell epitopes from the TMUV envelope (E) protein	[86]	R&D	Yes
37	Porcine circovirus 2 (PCV2)	-	Characterisation of genotypes and the evolution of Porcine circoviruses	[87]	BR	No
38	Koi herpesvirus (KHV) or Cyprinid Herpesvirus 3 (CyHV-3)	Fish vaccine	Development of a coupled plasmid expression vector for ORF149 and single walled carbon nanotubes (SWCNTs) for an anti-KHV vaccine	[88]	R&D	Yes
39	Porcine epidemic diarrhea virus (PEDV)	Pig vaccine	Assessment of the safety and efficacy of an attenuated live vaccine based on highly virulent genotype 2b porcine epidemic diarrhea virus in nursing piglets	[89]	R&D	No
40	Newcastle disease virus (NDV)	Poultry vaccine	Development of G7M mutated NDV as a promising genotype VII candidate vaccine	[90]	R&D	Yes
41	Nervous necrosis virus (NNV)	Fish vaccine	Investigation of humoral and cellular immunity responses of bath and oral vaccinations with BEI-inactivated NNV	[91]	BR	No
42	H5 highly pathogenic avian influenza virus (HPAIV)	-	Evaluation of different vaccine technologies for efficacy: 1) inactivated reverse genetic laboratory-generated virus encoding a clade 2.3.4.4 H5 hemagglutinin (HA) gene (rgH5), 2) recombinant turkey herpesvirus encoding a clade 2.2. H5 HA (rHVT-AI), and 3) recombinant replication-deficient alphavirus RNA particle vaccine encoding a clade 2.3.4.4 H5 HA (RP-H5)	[92]	BR	Yes
43	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Experimental testing of an experimental inactivated PRRSV vaccine	[93]	R&D	No
44	Viral hemorrhagic septicemia virus (VHSV)	Fish vaccine	Assessment of effectivity of differently treated VHSV vaccines in olive flounder	[94]	BR	No

45	Viral hemorrhagic septicemia virus (VHSV)	Fish vaccine	Development of a GM VHSV vaccine against virulent VHSV in olive flounder	[95]	R&D	Yes
46	Viral hemorrhagic septicemia virus (VHSV)	Fish vaccine	Development of a further developed GM VHSV vaccine in olive flounder	[96]	R&D	Yes
47	Viral hemorrhagic septicemia virus (VHSV)	Fish vaccine (viral replicon particles)	Development of a viral replicon particles rVHSV- Δ TM variant which inhibits the replication of wild-type VHSV when co-infected	[97]	R&D	Yes
48	Viral hemorrhagic septicemia virus (VHSV)	-	Review of VHSV mutants-based vaccines, particularly on the enhancement of immunogenicity, vaccine administration routes, safety to environments to support practical use in aquaculture farms	[98]	BR	-
49	Viral hemorrhagic septicemia virus (VHSV)	Fish vaccine (viral replicon particles)	Development rVHSV- Δ G a single cycle virus whose progenies are not infectious as a prophylactic vaccine	[99]	R&D	Yes
50	Orange-spotted grouper nervous necrosis virus (OGNNV) - Betanodavirus	Fish vaccine / Virus like particles	Demonstration that vaccination with OGNNV VLP induces humoral immune responses in orange-spotted grouper, <i>Epinephelus coioides</i>	[100]	R&D	No
51	Reticuloendotheliosis virus (REV)	Poultry vaccine	Demonstration of potential value of DNA vaccination in the prevention of REV infection and of codon optimization and GM DNA vaccines	[101]	BR	Yes
52	Tembusu virus (TMUV) - Baculovirus pFastBacDual vector	Poultry vaccine / virus-like particles (VLPs)	Demonstration that chimeric VLPs E protein of the TMUV and HA2 protein of the H3N2 avian influenza virus is a candidate vaccine to control TMUV infections in young duck	[102]	R&D	Yes
53	Fowl adenovirus (FAdV)	-	Comprehensive review of FAdV-4, including its epidemiology, pathogenesis, diagnostic detection, and vaccine strategies	[103]	BR	-
54	Baculovirus	Pig vaccine / virus-like	Baculovirus (rAc-Cap-SS) porcine circovirus-like particles as a novel subunit candidate vaccine for preventing PMWS	[104]	R&D	Yes

		particles (VLPs)				
55	Baculovirus	Cattle subunit vaccine	Silkworm baculovirus produced protein vaccine against foot-and-mouth disease virus (FMDV) Asia I/HNK/CHA/05	[105]	R&D	Yes
56	Pseudorabies virus (PRV)	Pig vaccine	Assessment of deletion-variant, attenuated PRV strain	[106]	R&D	No
57	Infectious bronchitis virus (IBV)	Poultry vaccine	Development of a highly attenuated nephropathogenic K2 IBV vaccine, with increased levels of protection against IBV	[107]	R&D	No
58	Porcine epidemic diarrhea virus (PEDV)	Pig vaccine	Characterisation of attenuated PEDV variants	[108]	BR	No
59	Highly pathogenic porcine reproductive and respiratory syndrome virus (HP-PRRSV)	Pig vaccine	Characterisation of live modified HP-PRRSV vaccine strains to regain infectivity	[109]	BR	No
60	African swine fever virus (ASFV)	Pig vaccine	Characterisation of the infectivity of ASFV Δ MGF100-1R deletion strain	[110]	BR	Yes
61	Adenovirus	Pig vector vaccine	Assessment of protective potential of 2 adenovirus-vectored cocktails containing ASFV antigens	[111]	R&D	Yes
62	Adenovirus	Pig vector vaccine	Demonstration that rAd-F1-Hsp70 has potent mucosal adjuvanticity in pigs, and is a candidate ASFV mucosal vaccine	[112]	R&D	Yes
63	Pseudorabies virus (PRV)	Pig vaccine	Development of a PRV candidate strain in which the protein kinase UL13 gene was deleted was constructed with the CRISPR/Cas9 system based on the recombinant pseudorabies virus (PRV) ZJ01- Δ gI/gE/TK	[113]	R&D	Yes
64	Pseudorabies virus (PRV)	Pig vaccine	Demonstrate of oral immunization against PRV infection in wild boar with Bartha vaccine	[114]	BR	No

65	Baculovirus	Sea Lion virus-like particles (VLPs)	Development of VLP with epitopes of Steller sea lion viruses V810 and V1415	[115]	BR	Yes
66	Kenyan sheep pox virus (KSPV)	Sheep vaccine	Assessment of effectivity of Kenyan sheep pox virus strain vaccine (KS1 O-180) against natural lumpy skin disease (LSD) infection under field conditions	[116]	BR	No
67	Lentivirus-based gene delivery system	Pig subunit marker vaccine	Development of Subunit vaccine to decrease vertical transmission of classical swine fever virus	[117]	R&D	Yes
68	Bovine viral diarrhea virus (BVDV)	Cattle vaccine	Assessment of effects of multivalent modified-live virus vaccine containing noncytopathic BVDV administered off-label to pregnant cattle	[118]	BR	No
69	Turkey herpesvirus (HVT)	Poultry vector ND vaccine	Assessment of immunity provided by a recombinant ND vaccine using HVT virus as vector (rHVT-ND)	[119]	R&D	Yes
70	African swine fever virus (ASFV)	-	Study to identify of ASFV antigens that induce a protective immune response	[120]	BR	Yes
71	Classical Swine Fever virus (CSFV)	Pig vaccine	Assessment of E2-CD154 subunit candidate vaccine in pregnant pigs	[121]	R&D	No
72	Bovine viral diarrhea virus (BVDV)	Cattle vaccine	Comparison of immune responses of calves exposed to a single dose of Bovela® bovine viral diarrhea virus (BVDV) live double deleted vaccine or a field strain virus (FSV) of BVDV type 2 (strain 890)	[122]	BR	Yes
73	Infectious Bursal Disease Virus (IBDV)	Poultry subunit DNA vaccine	Examination of the protective efficacy of a subunit DNA vaccine against IBDV infection in chickens	[123]	R&D	Yes
74	Foot and mouth disease virus (FMDV)	Cattle vaccine	Report of the construction and characterization of an infectious cDNA clone of the Indian vaccine strain of FMDV serotype O, IND-R2/75.	[124]	BR	Yes
75	Infectious Bursal Disease	Poultry subunit	Assessment of a live IBDV vaccine strain, IBDV MB-1	[125]	BR	No

	Virus (IBDV)	DNA vaccine				
76	Marek's disease virus (MDV)	Poultry vaccines	Review discussing the current status of MD vaccines and their use as vector vaccines to control important viral poultry diseases	[126]	BR	-
77	Bovine viral diarrhea virus (BVDV)	Cattle vaccine	Construction of a new chimeric pestivirus "CP7_E1E2alf_TLA", based on the infectious cDNA of BVDV strain CP7	[127]	R&D	Yes
78	African swine fever virus (ASFV)	-	Review focusing on the challenges surrounding ASF vaccine design and development and existing knowledge gaps	[128]	BR	-
79	Turkey Herpesvirus (HVT)	Poultry vaccine	Assessment of a recombinant HVT-IBD vector vaccine and an intermediate plus live IBDV vaccine	[129]	R&D	Yes
80	Newcastle disease virus (NDV)	Poultry vaccine	Development of a thermostable, attenuated vaccine candidate strain NDV/rHR09	[130]	R&D	Yes
81	African swine fever virus (ASFV)	-	Review of information on the pathogenesis of ASF virus strains, the immune response to infection and prospects for developing vaccines	[131]	BR	-
82	Highly pathogenic avian influenza virus (HPAIV)	Poultry vaccine	Assessment of an inactivated influenza vaccine prepared from a non-pathogenic H5N1 AIV, A/duck/Hokkaido/Vac-3/2007 (H5N1)	[132]	R&D	Yes
83	Foot-and-mouth disease virus (FMDV)	Cattle vaccine	Evaluation of newly developed FMDV vaccine strains against the emerging serotype FMDV Asia1	[133]	R&D	Yes
84	Indian Peste des Petits Ruminants virus (PPRV)	Cattle vaccine	Assessment of virological and antigenic characteristics of two Indian Peste des Petits Ruminants (PPR) vaccine viruses namely "PPRV-Sungri/96" and "PPRV-AR/87"	[134]	BR	No
85	Marek's disease virus (MDV)	Poultry vaccine	Assessment of a deletion variant of the GM MDV variant GX0101, a field strain of MDV with a naturally occurring insertion of the reticuloendotheliosis virus long terminal repeat (LTR) fragment	[135]	R&D	Yes

86	Marek's disease virus (MDV)	Poultry vaccine	Development and assessment of a double deletion mutant MDV lacking virus-encoded meq and lorf9 as candidate vaccine	[136]	R&D	Yes
87	Newcastle disease virus (NDV), Tembusu virus (DTMUV)	Poultry vaccine	Assessment of a candidate vaccine aGM/prM + E against NDV and DTMUV transmissions in waterfowl raising areas in China	[137]	R&D	Yes
88	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Assessment of the efficacy of a novel BEI-inactivated PRRSV candidate vaccine in pigs	[138]	R&D	No
89	Classical swine fever virus (CSFV)	Pig vaccine	Examination of the induction of a strong T cellular response to confer a solid protection upon DNA-E2 vaccination against CSFV.	[139]	R&D	Yes
90	Classical swine fever virus (CSFV)	Pig vaccine	Assessment of a tandem-repeat multiple-epitope recombinant vaccine can protect pigs from CSFV challenge	[140]	R&D	Yes
91	African swine fever virus (ASFV)	-	Review of the research progress on ASFV in recent years	[141]	BR	-
92	Rabies virus (RV)	(Wild) dog vaccine	Applications of RV vector LBNSE expressing foreign antigens have shown considerable promise as vaccines against viral and bacteria diseases, e.g. canine distemper virus (CDV)	[142]	R&D	Yes
93	African swine fever virus (ASFV)	-	Overview of the current knowledge in innate and adaptive immune responses elicited by ASFV infection and different kinds of vaccine candidates	[143]	BR	-
94	Duck Orthoreovirus	-	Examination of effects of duck reovirus (DRV/GX-Y7) on waterfowl	[144]	BR	No
95	Porcine epidemic diarrhea virus (PEDV)	Pig vaccine	Investigation of the characteristics of a field strain of PEDV (PEDV strain SH) to develop candidate vaccines	[145]	BR	No
96	Newcastle disease virus	Poultry DNA	Assessment of immunization of chickens with Salmonella with pYL58 a NDV	[146]	BR	Yes

	(NDV)	vaccine	based DNA vaccine construct			
97	Infectious laryngotracheitis virus (ILTV)	Poultry vector vaccine	Study of potential utility of ILTV-ΔgC-F as a bivalent candidate vaccine against both infectious laryngotracheitis and Newcastle disease	[147]	BR	Yes
98	Porcine circovirus type 2 (PCV2)	Pig vaccine	Evaluation of the efficacy of a new vaccine combining inactivated PCV2 and Mycoplasma hyorhinis	[148]	R&D	No
99	Infectious salmon anemia virus (ISAV)	Fish vaccine	A SAV-based replicon encoding the ISAV hemagglutinin-esterase, pSAV/HE, is an efficacious vaccine against infectious salmon anemia (ISA)	[149]	R&D	Yes
100	Pseudorabies virus (PRV)	Pig vaccine	Construction of a herpesvirus based bivalent vaccine with high-level expression of the ORF2 gene encoding the major antigen protein Cap of porcine circovirus type 2 (PCV2) in PRV	[150]	R&D	Yes
101	Avian infectious bronchitis virus (AIBV)	-	Characterization of a novel recombinant AIBV derived from GI-1, GI-13, GI-28, and GI-19 strains	[151]	BR	No
102	Foot-and-mouth disease virus (FMDV)	Cattle DNA vaccine	Assessment of FMD DNA vaccine with IL-18 formulated with PLGA nanoparticles	[152]	R&D	Yes
103	Pseudorabies virus (PRV)	Pig vector vaccine	Evaluation of PRV-based vaccine against Porcine circovirus type 3 (PCV3)	[153]	R&D	Yes
104	Largemouth bass virus (LMBV)	Fish DNA vaccine	A DNA vaccine expressing LMBV Major capsid protein might represent a potential LMBV vaccine candidate	[154]	R&D	Yes
105	Foot-and-mouth disease virus (FMDV)	Cattle vaccine	Construction of a modified FMD vaccine strain, C3 Resende-R	[155]	R&D	Yes
106	Singapore grouper iridovirus (SGIV)	Fish vaccine	The DNA vaccine construct pcDNA3.1-19R could induce protective immunity in grouper, and is a potential vaccine candidate for controlling SGIV disease	[156]	R&D	Yes
107	Rabbit hemorrhagic	Rabbit DNA	Construction of a novel DNA vaccine (pcDNA-VP60) expressing the RHDV capsid	[157]	R&D	Yes

	disease virus (RHDV)	vaccine	protein (VP60)			
108	Bovine viral diarrhea virus (BVDV) type 2	Cattle vaccine	Development of BVDV-2ΔNpro mutant which represents a promising candidate for an efficacious future live vaccine	[158]	R&D	Yes
109	Tilapia lake virus (TiLV)	Fish DNA vaccine	Efficacy by TiLV VP20 with different prime-boost vaccination regimens was evaluated in tilapia (DNA prime-protein boost immunization strategy was better than a solo vaccination)	[159]	R&D	Yes
110	Porcine circovirus type-2 (PCV2)	Pig vaccine	Evaluation of an inactivated PCV2-vaccine covalently conjugated with chitosan oligosaccharide	[160]	R&D	No
111	Newcastle disease virus (NDV)	Poultry vaccine	Development of GM NDV variants (rClon30-chGM-CSF and rClon30-flic) conferring enhanced protection in chicks	[161]	R&D	Yes
112	Turbot reddish body iridovirus (TRBIV)	Fish nanoparticle-based DNA vaccine	Chitosan nanoparticles were promising carriers for plasmid DNA vaccine pDNA-CS-NPs through oral vaccination	[162]	R&D	Yes
113	Porcine reproductive and respiratory syndrome virus (PRRSV)	Pig vaccine	Study providing guidance for the choice and use of PRRSV modified live virus vaccines to control NADC30-like virus infection in the field	[163]	BR	No
114	Infectious bronchitis virus (IBV)	Poultry vaccine	IBV strain H120 was successfully rescued as infectious clone by reverse genetics and a mutated variant constructed for vaccine use	[164]	R&D	Yes
115	Grass carp reovirus	Fish DNA vaccine	Evaluation of single walled carbon nanotubes (SWCNTs) as carriers for DNA vaccines for intramuscular injection	[165]	R&D	Yes
116	Foot-and-mouth disease virus (FMDV)	Cattle vaccine	Construction of a FLAGG tagged virus as candidate FMD vaccine which can be differentiated in vaccinated animals	[166]	BR	Yes

Table S3: List of publications identified for GM viruses as agents against plant pathogens, indicating their status of development and the use of GM viruses
Status: Status of development; BR: Basic research; R&D: Research and development

No.	Virus	Purpose of the application	Purpose of the Study	Reference (study)	Status	GMO
1	Citrus tristeza virus (CTV)	GM citrus plant development	GM citrus with CTV resistance	[167]	R&D	No
2	Citrus tristeza virus (CTV)	GM CTV as vector	Development of GM CTV-based expression vectors for plants	[168]	R&D	Yes
3	-	-	Vector-borne <i>Liberibacter</i> disease in plants	[169]	- (Review)	No
4	Citrus tristeza virus (CTV)	-	Effects of CTV strains on plants	[170]	BR	No
5	Citrus tristeza virus (CTV)	GM CTV as vector	GM CTV infected plants as trap crops for <i>Liberibacter</i> insect vector <i>Diaphorina citri</i>	[171]	R&D	Yes
6	Citrus yellow vein clearing virus (CYVCV)	-	Detection and management of CYVCV in citrus plants	[172]	- (Review)	No
7	Citrus tristeza virus (CTV)	-	Assessment of CYVCV interactions with infected citrus plants	[173]	BR	No
8	Citrus yellow vein clearing virus (CYVCV)	-	Serological detection of CYVCV in citrus plants	[174]	BR	No
9	Citrus psorosis virus (CPsV)	-	Immunodiagnosics of CPsV isolates	[175]	BR	No

Table S4: List of publications identified for GM viruses for the use as biocontrol agents, indicating their status of development and the use of GM viruses
Status: Status of development; BR: Basic research; R&D: Research and development; FT: Field trial

No.	Virus	Purpose of the application	Purpose of the Study	Reference (study)	Status	GMO
1	Spodoptera litura nucleopolyhedrovirus (SpltNPV)	Biocontrol of agricultural pests	Biocontrol of <i>Spodoptera litura</i> as a primary insect pest of cotton in Pakistan due to reductions in pesticide use in GM cotton, resistant to <i>Helicoverpa armigera</i>	[176]	R&D	No
2	Spodoptera frugiperda multiple nucleopolyhedrovirus (SfMNPV)	Biocontrol of agricultural pests	Basic research of infectivity of SfMNPV occlusion bodies for <i>Spodoptera frugiperda</i>	[177]	BR	Yes
3	Chrysodeixis chalcites nucleopolyhedrovirus (ChchNPV)	Biocontrol of agricultural pests	Assessment of ChchSNPV-TF1 as a biological insecticide for control of <i>C. chalcites</i> in banana crops	[178]	R&D	No
4	A. ipsilon multiple nucleopolyhedrovirus (AgipMNPV)	Biocontrol of agricultural pests	Assessment of susceptibility of a grass-feeding caterpillar to a baculovirus	[179]	BR	No
5	Cryphonectria hypovirus (CHV1)	Hypovirulence as remedy to fungal blight disease	Detection of CHV1 virus in corticolous mites that are vectors of hypovirulence in blighted chestnut <i>Castanea sativa</i>	[180]	BR	No
6	Spodoptera exigua multiple nucleopolyhedrovirus (SeMNPV)	Biocontrol of agricultural pests	Assessment of key pathogenicity and virulence traits of SeMNPV isolates according to their principal transmission strategy	[181]	BR	No
7	Phthorimaea operculella granulovirus (PhopGV)	Biocontrol of agricultural pests	Development of a bioinsecticide based on PhopGV isolates against the pest Guatemala potato tuber moth	[182]	R&D	No

8	Condylorrhiza vestigialis nucleopolyhedrovirus (CoveNPV)	Biocontrol of forest pests	Research aimed at the use of CoveNPV in integrated pest management programs in Poplar crop	[183]	BR	No
9	Culex flavivirus (CxFV)	Identification of mosquito-associated virus	Characterisation of CxFV, a novel insect-specific flavivirus	[184]	BR	No
10	Nucleopolyhedroviruses	Biocontrol of agricultural pests	Study of virus-host specificity to aid the application of baculovirus in protein expression systems and the development of biocontrol agents	[14]	BR	No
11	Junonia coenia densovirus (JcDV)	Biocontrol of agricultural pests	Research on the potential of JcDV as a biological control agent against pests such as <i>S. frugiperda</i>	[185]	BR	No
12	Anticarsia gemmatalis multiple nucleopolyhedrovirus (AgMNPV) i	Biocontrol of agricultural pests	Assessment of AgMNPV as a viral insecticide	[186]	BR	No
13	Listeriaphage P100	Biocontrol of food pathogens	Assessment of resistance development in <i>Listeria monocytogenes</i> against phage-based control agents	[187]	BR	No
14	Spodoptera frugiperda multiple nucleocapsid nucleopolyhedrovirus (SfMNPV)	Biocontrol of agricultural pest	Assessment of SfMNPV isolates as the basis for a biopesticide for the control of <i>S. frugiperda</i> in Mexico	[188]	FT	No
15	Baculoviruses	Biocontrol of agricultural pest	Study on regulation of the neuronal activity of host caterpillars by baculoviruses	[189]	BR	Yes
16	L. obfuscat multiple nucleopolyhedrovirus	Biocontrol of tree / forest pests	Assessment of application of LyobMNPV against the host populations of Indian gypsy moth on apple and willow	[190]	FT	No

	(LyobMNPV)					
17	Baculovirus	Biocontrol of agricultural pests	Assessment of earthworm activity on the distribution and dynamics of baculovirus occlusion body populations in soil	[191]	BR	No
18	<i>H. armigera</i> single nucleopolyhedrovirus (HaSNPV)	Biocontrol of agricultural pests	Research into virus-mediated manipulation of host physiology	[192]	BR	Yes
19	Salivary gland hytrosaviruses (SGHVs)	Biocontrol of agricultural pests	Assessment of different SGHVs as potential biocontrol agent for tsetse vector control or as agents that may jeopardize tsetse mass rearing	[193]	BR	No
20	<i>Glossina pallidipes</i> salivary gland hytrosaviruses virus (GpSGHV)	Protection of mass rearing facilities	Development of potential targets for novel and sustainable molecular-based antiviral strategies to control viral infections in tsetse colonies	[194]	R&D	No
21	Baculovirus	Biocontrol of agricultural pests	Detection of covert baculovirus infections in the eastern spruce budworm, <i>Choristoneura fumiferana</i>	[195]	BR	No
22	<i>Spodoptera exigua</i> multiple nucleopolyhedrovirus (SeMNPV)	Biocontrol of agricultural pests	Assessment of activity of SeMNPV for biocontrol in Amaranth (<i>Amaranthus hypocondriacus</i> L.) cultures	[196]	R&D	No
23	Muscavirus (MdSGHV)	Biocontrol / Sterilizing agent	Assessment of MdSGHV as a sterilizing agent to control house fly populations	[197]	BR	No
24	<i>C. capitata</i> noravirus (CcaNV).	Protection of mass rearing facilities	Covert infections by CcaNV may impair the fitness of sterile Mediterranean fruit flies produced by SIT program	[198]	R&D	No
25	Chilo iridescent virus (CIV)	Biocontrol of agricultural pests	Insertion of a toxin gene into CIV provides opportunities to control a wide range of pest insects, such as weevils, using an iridovirus	[199]	R&D	Yes

26	Iflavirus (EVV-1)	Biocontrol of agricultural pests	Development of virus-based strategies against phytoplasma disease transmitted by the leafhopper vector <i>Euscelidius variegatus</i>	[200]	BR	No
27	Salmonid birnavirus (IPNV)	Biocontrol / Hypoinfectivity	Use of non-pathogenic IPNV to elicit resistance to VHSV superinfection in aquacultured fish species	[201]	BR	No
28	Lymantria dispar multiple nucleopolyhedrovirus-BNP (LdMNPV-BNP)	Biocontrol of forest pest	Assessment of LdMNPV-BNP as an active component of biopesticides that can be used during forest integrated pest management	[202]	BR	No
29	-	Biocontrol / immunocontraception	Assessment of biological control strategies in vertebrate pest management in Australia in case studies of rabbits, cane toads and carp	[203]	Overview biocontrol vertebrate pests Australia	-
30	Spodoptera exigua multiple nucleopolyhedrovirus (SeMNPV)	Biocontrol of agricultural pests	Development of gene knockout variants as SeMNPV candidate agents with significantly increased OB pathogenicity	[204]	BR	Yes
31	Spodoptera litura nucleopolyhedrovirus (SpltNPV)	Biocontrol of agricultural pests	Isolation of faster killing isolates as good candidates for biological control of <i>S. litura</i> in Pakistan	[205]	BR	No
32	Spodoptera frugiperda multiple nucleopolyhedrovirus (SfMNPV-NIC)	Biocontrol of agricultural pests	Assessment of gene knockout variants of SfMNPV-NIC with modified oral transmission efficacy	[206]	BR	Yes
33	Nucleopolyhedrovirus NPV (AgMNPV-79 or SfMNPV-6nd)	Biocontrol of agricultural pests	Assessment of the advantages and disadvantages of the simultaneous applications of NPV and <i>M. rileyi</i> for the management of either <i>A. gemmatilis</i> or <i>S. frugiperda</i>	[207]	BR	No

34	Lymantria mathura nucleopolyhedrovirus (LymaNPV)	Biocontrol of forest pests	Study on the basis of the interaction between <i>L. mathura</i> and LymaNPV	[208]	BR	No
35	Entomopoxviruses (EPVs)	Biocontrol of agricultural pests	Analysis of potential candidate isolates to control tortricid pests	[209]	BR	No
36	Helicoverpa armigera single nucleopolyhedrovirus (HearNPV)	Biocontrol of agricultural pests	Study of HearNPV interactions with host immunity to aid agricultural pest control	[210]	BR	No
37	Bacteriophage LPST144	Biocontrol of food pathogens	Assessment of bacteriophage LPST144 and its endolysin as potential antibacterial agents for Salmonella control in food industry	[211]	BR	No
38	Autographa californica multiple nucleopolyhedrovirus (AcMNPV)	Biocontrol of agricultural pests	A serial passage experiment shows long-term maintenance of a recombinant in serial passage and suggests an ecosystem safety risk	[212]	BR	Yes

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