Dissemination of plant viruses

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Spread of plant viruses

viruses are obligate parasites

have to move from infected to uninfected plants for survival

otherwise, they may not be able to survive

Animal/human viruses

In many cases the host serve dual function:

as a host

as a vector (can move from place to place and spread viruses)

Plant viruses

Plants can not move (sessile) and can not spread viruses

Plant viruses: how do they spread ?

- different insect species
- seeds
- vegetative propagules (cuttings, bud wood, etc.)
- pollen
- contact
- grafting
- soil (nematodes & fungi)

How do plant viruses spread ?

Means of spread	Local	Distant
Contact	+	-
Seed transmission	+	+
Pollen transmission	+	+
Active vectors	+	+
Less active vectors	+	-
Vegetative propagation	+	+
Soil-borne (nematodes & fungi)	+	-
Humans*	+	+

No single virus can be spread by all of the different modes

some have one, others have two modes of transmission

Tobacco mosaic virus	: Contact & seed*
Tomato mosaic virus	: Contact & seed*
Pepino mosaic virus	: Contact & seed*
Cucumber mosaic virus	: Seed and aphid
Bean common mosaic virus	: Seed and aphid
Tomato spotted wilt virus	: Thrips
Tomato leafcurl virus	: Whiteflies
Potato virus Y	: Tubers and aphid
Tobacco streak virus	: Pollen, seed
Grapevine leafroll viruses	: Cuttings & mealybugs
Grapevine fanleaf virus	: Cuttings & nematode

*Surface contaminant

Seed transmission of plant viruses

- Not all viruses are transmitted via seed
- Seed transmission has been reported for approximately 20% of plant viruses.
- Specific interactions between virus and host factors are required for efficient transmission through seed.
- Rate of seed transmission vary depending on host plant, cultivar, stage of plant at which infection occurs, etc.

Seed transmission of plant viruses

Virus present on the seed coat as surface contaminant, not in the cotyledon/embryo.

e.g. Tobacco mosaic virus
Tomato mosaic virus
Pepino mosaic virus

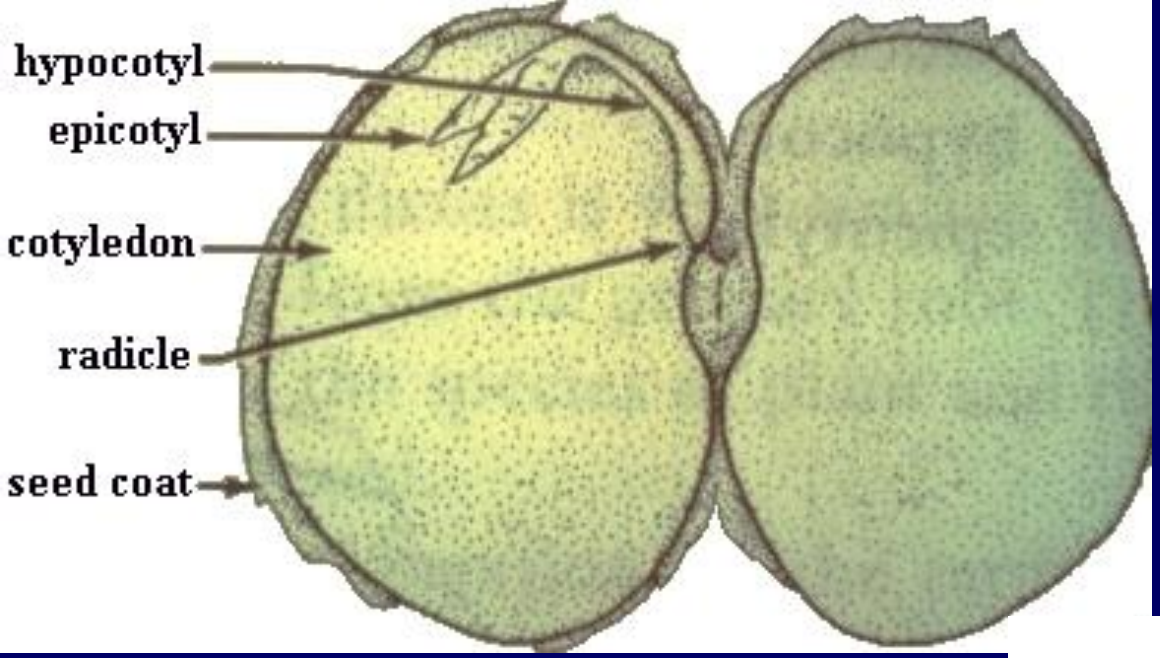
Virus present inside the seed tissue (in the cotyledon/embryo).

e.g. Bean common mosaic virus
Cucumber mosaic virus
Zucchini yellow mosaic virus

Seed transmission of plant viruses

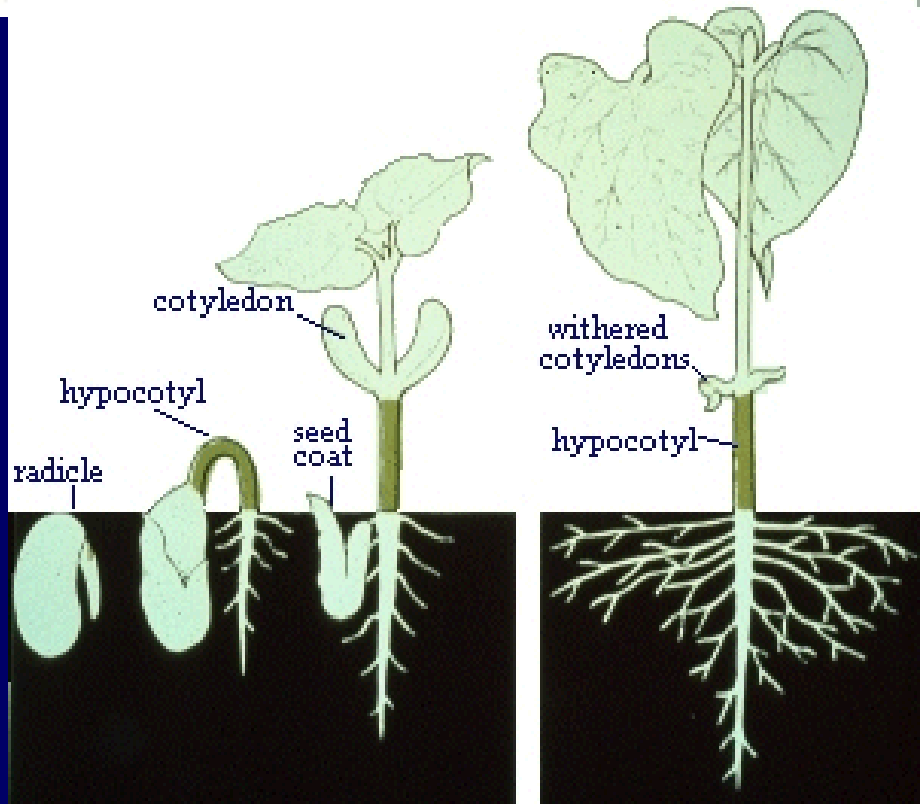
Presence of a virus in the cotyledon or embryo or on seed coat is not sufficient to classify the virus as seed-transmitted.

The virus must remain ‘viable’ during the maturation and storage of the seed, and be able to infect the seedling after seed germination.



Assessing seed transmission of plant viruses

Virus detection in the seed
vs.
grow-out tests



http://www.pssc.ttu.edu/pss1321/web%20Topics/cpa2.htm

Pollen- and seed-transmission of Tobacco streak virus in okra

- Pollen from an infected plant used for hybridization can carry virus and infect embryo of a recipient plant during fertilization.
- Seed from recipient plants can carry virus leading to virus transmission.

Experiment	Seed from	# seed tested	% transmission
I	Local variety - 1	300	0
II	Local variety - 2	250	2.8
III	Commercial hybrid variety - 1	200	29.0
IV	Commercial hybrid variety - 2	100	19.0
V	Commercial hybrid variety - 3	300	15.7
Mean		**1150**	**11.4**

Tobacco streak virus in okra in India

Primary spread

Via seed

Via pollen carried by thrips

Secondary spread

Bhendi yellow vein mosaic virus

- a virus disease in okra in Indian sub-continent
- Begomovirus transmitted by whiteflies

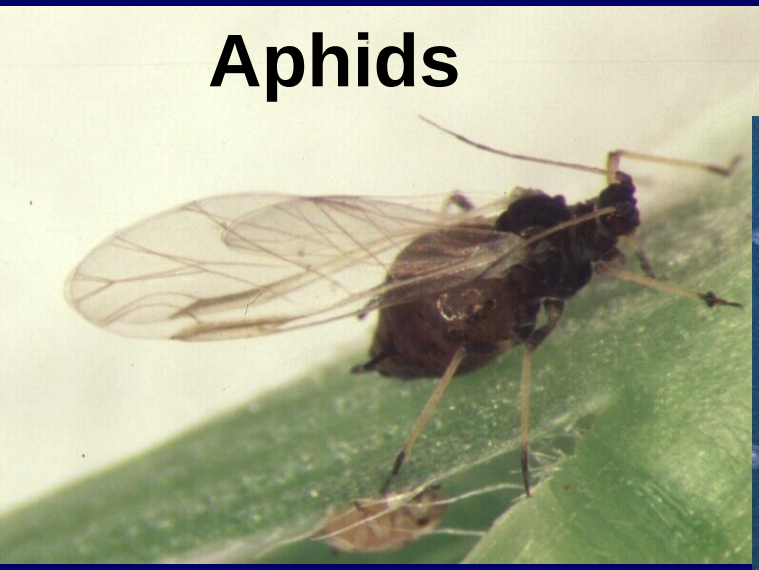
It is not seed transmitted

Seed-transmission of Bean common mosaic virus in beans

Primary spread by seed
Secondary spread by aphids

Insect (arthropod) vectors

Aphids



Thrips

Whiteflies

Leaf and plant hoppers

Mites

Mealybugs

Insect vectors of plant viruses

- Insect vectors of plant viruses are found in 7 out of the 32 orders of the class Insecta.
- The majority of vectors in the two orders of insects with pierce-sucking mouthparts: Hemiptera (300) and Thysanoptera (6).
- Fewer vector species in 5 orders of insects with chewing mouthparts: Orthoptera (10), Dermaptera (1), Coleoptera (30), Lepidoptera (4) and Diptera (2).
- The Hemiptera with pierce-sucking mouthparts are more successful as vectors.

Raccah, B; and, Fereres, A . 2009. Plant Virus Transmission by Insects. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester.

Aphids are the largest group of insects transmitting plant viruses

~ 55% of known insect vectors are aphids and most of these are in the family Aphididae.

Of the 288 aphid species that had been tested as potential vectors by 1983, 277 had been shown to be able to transmit at least one plant virus

Murant AF, Raccah B, Pirone TP. 1988. Transmission by vectors. In *The Filamentous Plant Viruses*, ed. RG Milne, pp. 237–73. New York: Plenum

Vectors and plant viruses that they transmit

Vector taxa	Vector group	Virus groups: Icosahedral particles RNA genome	Rod-shaped particles RNA genome	DNA genome	Enveloped particles RNA genome	Total	%
Hemiptera	Aphids	26	153[a]	13	5	197	28
	Whiteflies	–	13	115[b]	–	128	18
	Leafhoppers	8	–	15	3	26	4
	Planthoppers	10	4[c]	–	4	18	3
	Other hemiptera	–	8	5	–	13	2
Thysanoptera	Thrips	2	–	–	14	16	2
Coleoptera	Beetles	50	1	–	–	51	7
Acari	Mites	10	9	–	–	10	1
Nematoda	Nematodes	45	3	–	–	48	7
Mycota	Fungi	8	16	–	–	24	3
	No identified vectors	84	60	19	3[d]	166	24
	Total	233	268	167	30	697	
	%	33	39	24			

[a]Includes 110 virus species of the genus *Potyvirus*, family *Potyviridae*;
[b]Virus species of the genus *Begomovirus*, family *Geminiviridae*;
[c]These are all tenuiviruses that have multiple shapes;
[d]These viruses probably have insect vectors.

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Can insect vectors transmit viroids?

Viroids lack coat protein
Viruses have coat protein

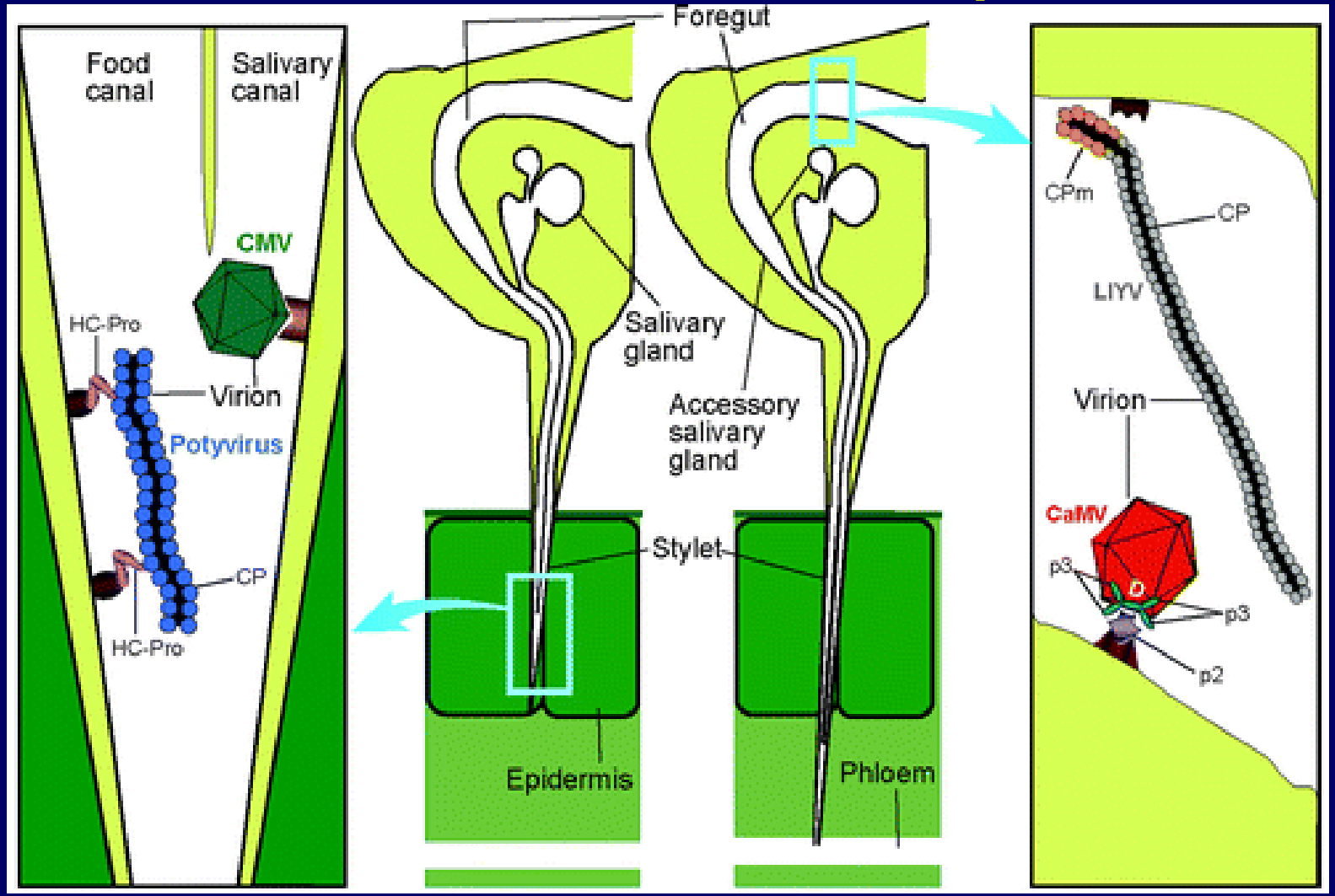
Coat protein play a key role in vector transmission

Viroids are spread via farming implements as contaminants and by contact

Modes of insect vector transmission

- Non-persistent (or) stylet-borne
- Semi-persistent (or) foregut-borne
- Persistent
  - circulative
  - circulative-propagative

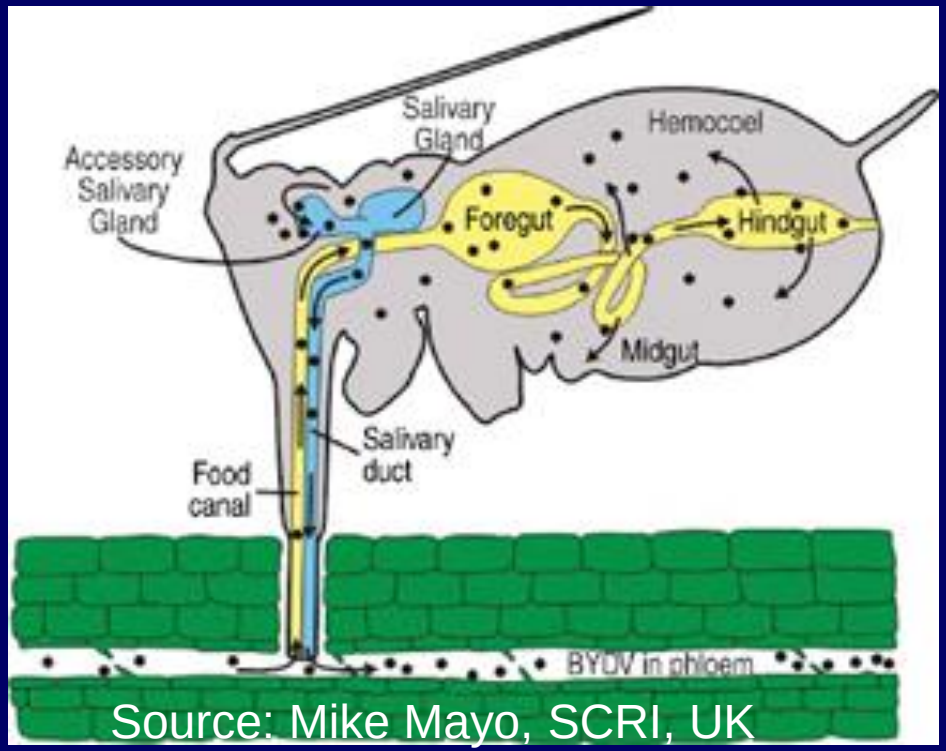
Non-persistent Semi-persistent



differences in the sites of virus retention in the vector

Source: Annual Review of Phytopathology 44 (2006): 183-212.

Modes of insect vector transmission



Source: Mike Mayo, SCRI, UK

Persistent
- **circulative (no virus replication)**
- **circulative-propagative (virus replication)**

Virus moves through the insect vector gut lumen, cross the gut wall barrier into the hemolymph (hemocoel), cross salivary gland barrier into the salivary glands.

Virus introduced back into the plant during salivation during insect feeding.

Circulative-propagative transmission

Source: Zenkoko Noson,
Kyoiku Kyoiku Co. Ltd, Japan.

Thrips palmi

vector of Peanut bud necrosis virus

Non- and Semi-persistent transmission

- virus is not internalized in the vector
- virus do not enter the hemocoel and salivary glands of the vector

Persistent circulative transmission

- virus is internalized in the vector
- virus enters the hemocoel and salivary glands of the vector

Persistent circulative-propagative transmission

- virus is internalized in the vector
- virus enters the hemocoel and salivary glands of the vector
- virus multiplis in the insect vector

Principal characteristics of the modes of virus transmission by insects

	External (noncirculative)		Internal-circulative[a]
Feature	**Nonpersistent**	**Semipersistent**	**Persistent**
Duration of retention	**Brief (few hours)**	**Intermediate (few days)**	**Long (days to months)**
Duration of acquisition and transmission	**Brief (seconds)**	**Intermediate (hours)**	**Long (hours to days)**
Latent period	**Not required**	**Not required**	**Required**
Tissue where virus is acquired and inoculated	**Epidermis and parenchyma**	**Epidermis, parenchyma and phloem**	**Mostly parenchyma and phloem**
Pre-acquisition fasting	**Increase transmission**	**No effect**	**No effect**
Passage through moult	**Negative**	**Negative**	**Positive**
Insect species specificity	**Low**	**Intermediate**	**High**
Sequential inoculation	**Poor**	**Intermediate**	**Good**

[a]Internal-circulative = virus cross gut and salivary gland barriers.

Source: Raccah, B; and, Fereres, A . 2009. Plant Virus Transmission by Insects. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester.

Insect vectors show marked specificity in virus transmission

e.g. aphid-borne viruses are not transmitted by whiteflies or thrips or nematodes

Virus	Aphid	Leafhopper	Thrips	Whiteflies
Bean common mosaic virus	Yes	No	No	No
Cucumber mosaic virus	Yes	No	No	No
Tomato leaf curl virus	No	No	No	Yes
Tomato spotted wilt virus	No	No	Yes	No
Maize mosaic virus	No	Yes	No	No

A single virus can be transmitted by more than one vector species

Virus	Thrips vector
Tomato spotted wilt virus	*Frankliniella occidentalis* *F. fusca* *F. intosa* *F. bispinosa* *F. schultzei* *Thrips tabaci* *T. setosus*
Impatiens necrotic spot virus	*F. occidentalis* *F. fusca* *F. intosa* *F. schultzei*

A single species of vector can transmit more than one virus

Thrips vector	Virus
Frankliniella occidentalis	*Tomato spotted wilt virus* *Impatiens necrotic spot virus* *Tomato chlorotic spot virus* *Groundnut ringspotvirus* *Chrysanthemum stem necrosis virus*
Thrips palmi	*Peanut bud necrosis virus* *Watermelon silver mottle virus* *Watermelon bud necrosis virus* *Melon yellow spot virus* *Capsicum chlorosis virus*

A single insect vector species can spread viruses by different modes of transmission

***Myzus persicae* (green peach aphid)**

Potato virus Y

– non-persistent transmission

Potato leaf roll virus

– persistent, circulative transmission

***Aphis craccivora* (cowpea aphid)**

Peanut stripe virus

– non-persistent transmission

Groundnut rosette assistor virus

– persistent, circulative transmission

Modes of transmission of plant viruses by insect groups of the Hemipteroid assemblage

Vector taxa	Vector species	Modes of transmission NPV[a]	SPV[b]	PCV[c]	PPV[d]	Totals	%
Hemiptera	Aphids	161[e]	19	12	5	197	49.4
	Whiteflies	5	9	115[f]	–	129	32.3
	Leafhoppers	–	4	13	10	27	6.7
	Planthoppers	–	–	–	18	18	4.5
	Other hemiptera	2	9	1	–	12	3.0
Thysanoptera	Thrips	2	–	–	14	16	4.0
	Totals	170	41	141	47	399	
	%	42.6	10.3	35.3	11.8		

[a]NPV, nonpersistent (or) stylet-borne viruses;
[b]SPV, semi-persistent (or) foregut-borne viruses;
[c]PCV, persistent, circulative (mostly non-propagative) viruses;
[d]PPV, persistent, propagative viruses;
[e]Includes 110 virus species of the genus *Potyvirus*, family *Potyviridae*;
[f]virus species of the genus *Begomovirus*, family *Geminiviridae*.

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Take home message

Viruses & vectors have no passports

Spread of viruses to new locations can occur via seed, vegetative cuttings, movement of vectors, shipment of seedlings, international trade or accidentally.

Questions ?