

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



# Introductory Chapter: Atlas of Ultrastructure Interaction Proteome between Barley Yellow Dwarf Virus and Gold Nanoparticles

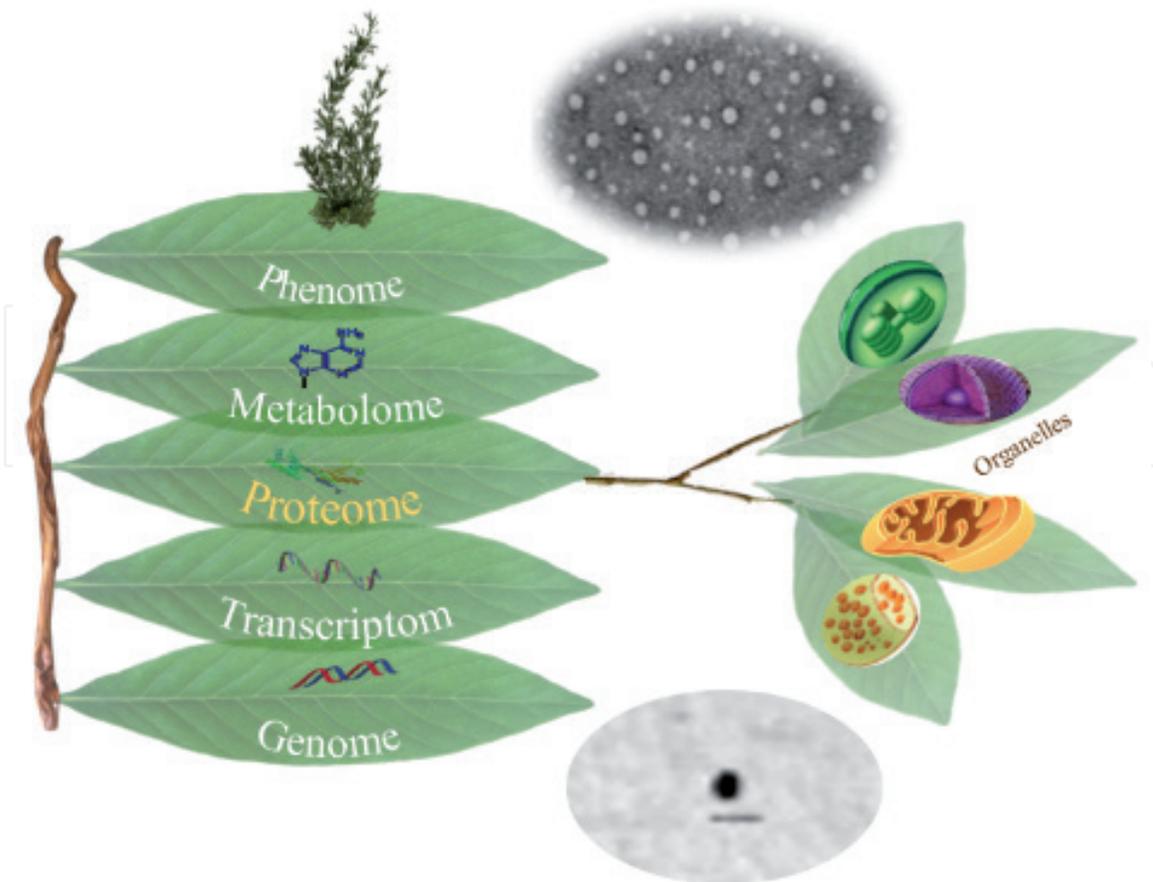
Noorah Abdulaziz Othman Alkubaisi  
and Nagwa Mohammed Amin Aref

## 1. Introduction

Interaction between Barley yellow dwarf virus, BYDV-PAV, and gold nanoparticles AuNPs application revealed great effect whether in *vitro* or *Vivo*. The significant effect of virus particles occurred inside the plant cell due to the existence of AuNPs treatment. It was clear that using tiny AuNPs 3.151 to 31.67 nm had a potential agent to ruined virus particles inside the infected cells. AuNPs cause damage to the virus-like particles (VLPs) of the barley yellow dwarf virus-PAV. Where they observed puffed and deteriorated VLPs decorated with AuNPs, as well as destroyed and vanished particles, using Transmission Electron Microscopy TEM. Generally, the plant cell contained different organelles that exhibited ultrastructure changes in Nucleus, Chloroplast, Plant cell wall, Mitochondria, cytoplasmic matrix, and viable cellular composition of the infected cell with AuNPs. TEM is a powerful tool in elucidating plant cells' fine details at the nanoscale. The present Atlas describes each organelle's structure of plant cells revealed by TEM in healthy, infected, and treated with AuNPs in **Figure 1**.

The purpose of this work is expressed via TEM, which is a very accurate tool for judging the AuNPs behavior inside the plant infected cell. Recent remarkable innovations in KSU. Platforms [1, 2] provide crucial resources to promote research in AuNPs applications and applied plant species as *Hordeum vulgare* (Barley) due to lacking knowledge in the field of virus pathogenicity at the level of ultrastructure. A combinatorial approach using the integration of virus with AuNPs in our proteome platform is now an effective strategy for clarifying molecular systems integral to improving plant productivity of the frequency and importance of ultrastructure abnormalities in Barley crop development caused by BYDV-PAV. It was finding out the critical feedback of using AuNPs applications on plant cells by examining the virus's behavior conjugated with AuNPs by ultra-structure in TEM on the diseased plants.

The method of inhibiting a plant virus using AuNPs is a method of inducing plant resistance against viral disease caused by BYDV by introducing a thoracically adequate amount of polydispersed AuNPs system integrated with the virus particles wherein virus particles were dissolved and melted in **Figure 2**. The application of



**Figure 1.**

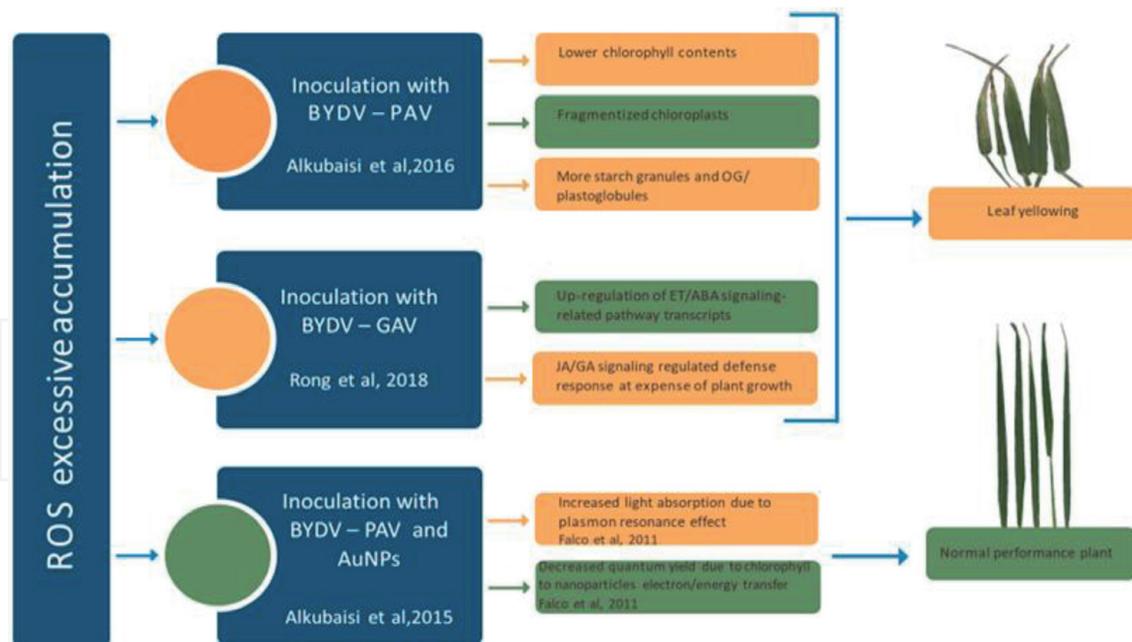
*The plant cell contained different organelles that exhibited ultrastructure changes in nucleus, chloroplast, plant cell wall, and mitochondria that describes each of them by TEM in healthy, infected, and treated with (AuNPs) as interaction preteome of BYDV- PAV.*

nanotechnology in agriculture, even at its global level, is at its nascent stage. The most crucial moment of plant virus entry considering is inducing viral infection crossing the cell/wall barriers. In our study, we knocked out and interfered with the virus as bio Nanoparticles with other metal AuNPs on the plant; [3] we selected the most severe BYDV isolates for Nano application on the plants [4].

The studied BYDV is the type member of the luteovirus group [5]. The Latin "luteo" name means yellow [6] and describes the most typical infected plants by luteoviruses. BYDV considered a model for dealing with the "yellowing" virus diseases, as reported [7]. Most infections appear as necrosis in the phloem, which leads to external symptoms such as stunning and leaf chlorosis [5]. The exact symptoms were reported [8] that might cup inward, tender, and show more stiffness than usual. BYDV is spread by aphids and induces the most widely and most distributed and most destructive virus disease globally.

## 2. Gold nanoparticles have adual positive effect

The prospect antiviral characteristic of Metal nanoparticles (MeNPs) in nano-agriculture drive them as a potential factor for commanding these histological agents. It is essential to detect the dosage of NPs, the application intervals, their effect as a biostimulant. The clarification of the mechanisms of action, are not fully understood [9]. Application of AuNPs in the presence of virus infection encourages the plants to produce Reactive Oxygen Species (ROS) continually in structures such as chloroplasts, mitochondria, peroxisomes, the endoplasmic reticulum (ER),



**Figure 2.** Methodology, pathological alternation of the plant cellular components, and the dual beneficial effect of AuNPs on the plant performance through the following treatments in the electron micrographs; I. healthy cells from barley leaves, II. Infected cells from by BYDV- PAV from barley leaves, III. Pretreated leaves of barley with AuNPs and infected by BYDV-PAV.

and plasma membranes [10]. These resemble components of the defensive system that have been classified according to their catalytic activity, molecular weight, the compartment where they act, and level of defense or mechanism of action [11]. The positive effect of AuNPs, therefore, needs further study to explore the physiological and molecular mechanisms. However, due to the tiny size, reactivity, and efficient penetration ability, metal nanoparticles could reach many intracellular and extracellular plant sites. That may trigger a set of physiological processes such as senescence affecting plant growth, crop yield, and ecological productivity [12]. Nanoparticles (NPs) have unique physicochemical properties, i.e., high surface area, high reactivity, tunable pore size, and particle morphology. The appropriate elucidation of the physiological, biochemical, and molecular mechanisms of nanoparticles in plants leads to better plant growth and development [13]. The chemical reactions, especially reduction–oxidation reactions, were catalyzed by Ag, Au, Fe, and Co. The released nano ions may alter proteins while entering into cells. Mechanical effects rely on the size of nanoparticles [14]. For example, the cell wall damage can be caused by the high concentration adsorption of hydrophobic nanoparticle retention and may cause clog pores, which can interfere with water uptake [15]. The ability to pass through the cell wall might not be a prerequisite for causing oxidative stress and toxicity. Some researchers suggest that despite nano-materials' inability to pass through plants' cell walls, they can cause oxidative stress and eventually lead to chromosome condensation [16].

Similarly, CuO nanoparticles can also cause oxidative damage to plant DNA and can be detected in plant cells [17]. Particles with anoxic surface often form a layer of OH– groups at the surface; these negatively charged groups attract positively charged side groups of proteins [14]. Surface effects have engaged a great deal of attention in the field of nanotoxicology.

The positive, neutral, and negative charge of Au nanoparticles are resemble hydroponic exposure to Rice plants. The distribution of the bioaccumulated Au nanoparticles due to the negative surface charge of the nanoparticles, which is more toxic in above-ground organs [18]. The small particle modulation of 15 nm or 25 nm AuNPs

was transported to the shoot in poplar. At the same time, larger particles (50 nm) could hold their size *in vivo*. AuNPs were located within the roots in a large amount than in leaves. AuNPs were detected in different tissues, phloem complex, xylem, cell wall, plastids, mitochondria, and more abundantly in the plasmodesmata [12]. Negatively charged, anionic carboxylate AuNPs conferred protection to the model lipid membrane against the extreme pH (=12) via shielding effects, whereas positively charged, cationic amino-AuNPs could penetrate and disrupt the model membrane [19].

Nanotoxicity is based on empirical data by an exact predictive model, which is explained by the interaction between surface charge and particle size that affects AgNPs toxicity in both the prokaryotic and eukaryotic model organisms [20]. The interaction between particle size and potential surface charge influencing ENM phytotoxicity has not received much attention. Therefore, the potential effect surface charge density remains to be tested in plants. ORF3 encodes a major coat protein (CP) of 22 kDa [21]. The coat protein plays a crucial role in maintaining a high level of accumulation of genomic RNA, though unnecessary for PAV replication [22]. ORF4 is entirely nested within ORF3 and codes for a 17 kDa nonstructural protein required for BYDV-PAV to spread systemically in plants [23]. The expression of ORF 4 is associated with a unique regulatory mechanism of the ribosome leaky scanning mechanism [24]. The ORF4 translation product is similar to that of the homology of ORF4 in potato leafroll virus (PLRV), which has biochemical properties specific to known movement proteins, including the ability to be phosphorylated, binding nonspecifically to nucleic acids [25, 26] and localization to the plasmodesmata [27]. PAV ORF5 is fused to CP as a readthrough domain and encodes a 50 kDa protein expressed as a 72 kDa fusion protein via a readthrough suppression of the ORF3 stop codon [23, 28–30]. A frameshift mutation within ORF6 was reported to be incompatible with BYDV-PAV RNA replication in protoplasts [31]. In [32], it is found that the RNA sequence encoding or flanking ORF6, rather than the protein product of ORF6, is required for PAV replication in oat protoplasts [33].

The viral infection starts with virus replication in the infected cell initially and spread to neighboring cells through plasmodesmata which are considered intercellular conduit connecting cell walls. This process is called cell-to-cell (short-distance) movement, facilitated by viral movement protein (MP). The following phase is termed (long-distance) movement which viruses could enter the vascular tissue, dispense, and flood into non-infected tissues, helped by the phloem stream [34]. It is presumed that the cell-to-cell movement is an active function, requiring specific interaction between the virus and plasmodesmata, whereas systemic viral spread through the vascular tissue is a passive process, driven by the flow of photoassimilates [35]. The discovery that a 30 kDa movement protein (MP) encoded by the Tobacco mosaic virus (TMV) was required for viral cell-to-cell movement [36, 37] exploring the trafficking mechanisms of a more comprehensive viral array opened a new path. Trafficking viral protein and RNA by viral MP into the phloem and their inter-organ regulation of plant development were rarely studied for some viruses [38] and [39]. The viral nucleic acid conjugate with the MP, which could transport it through plasmodesmata. The first viral MP of the Tobacco Mosaic Virus (TMV) was discovered that had 30 kDa protein (P30) and was able to bind single-stranded nucleic acid [40], mediated by two independently active domains of the MP [41]. The P30-TMV RNA complex measures a diameter of 1.5–3.5 nm [41] and [42] and may interact with the cytoskeletal elements to facilitate the transport of the P30- TMV RNA complex from cytoplasm to plasmodesmata [43] and [44]. The diameter is even smaller than a protein-free, folded TMV RNA, allowing easy access through dilated plasmodesmata [45, 46]. The MP could bind nonspecifically to single-stranded RNA and DNA *in vitro* [25] and associate with plasmodesmata in host plants [47]. ORF 4 proteins in luteo-viruses may provide a clue for assisting virus cell-to-cell spread in host plants [48] as

there is a high similarity of amino acid sequence between ORF 4 protein encoded by luteoviruses and PLRV MP [49, 50]. BYDV-PAV MP may also help transport the viral genome into the nucleus as the MP is present in the cytoplasm and the nucleus [51]. After entry into the cytoplasm, protein synthesis is initiated [52] and enhances replication and transcription efficiency; viruses use the strategy of compartmentalization in specific intracellular components [53]. Its replication is almost totally restricted within the plant phloem tissue [54, 55], i.e., phloem parenchyma cells, companion cells, and sieve tubes. The restricted site of infection in phloem tissue is an essential feature of the *Luteoviridae* [56].

The systemic spread is suspected to be associated with vascular transport of virions due to the discovery of BYDV particles in vasculature samples [57, 58]. The critical role of MP was emphasized by the association between the long-distance movement of some viruses and viral gene expression. For example, geminiviruses coded two proteins responsible for long-distance transportation and viral DNA with a single-stranded genome in and out of the nuclei [59, 60]. However, studies of the function of putative luteoviral MPs remain limited [61]. A 17 kDa protein encoded by ORF 4 is required for BYDV-PAV to spread systemically in plants [62, 63]. The replication of the plant virus genome occurs in host cells [64]. The genome of viruses must be transported into the nucleus by mechanisms requiring viral MP [65].

Three stages of infection were proposed by [57, 33]. At the first stage, densely staining material appeared in plasmodesmata, and an amorphous substance and viral RNA containing filaments appeared in the host cytoplasm, Figures 5 (I)-(M) in chapter 3. In the second stage, filaments became visible in the nuclear pores. During this stage, the nuclear outline became distorted and massive clumping of heterochromatin occurs, Figures (5) and (6) in chapter 1. In the nucleus, viral particles were seen at the last stage after the disintegration of the nuclear membrane. The virus could only infect phloem parenchyma, sieve elements, and companion cells, while it could not be seen in the mestome sheath or the xylem.

The characterization of VLPs was defined by their diameter, their circular outlines, and high electron opacity. Viral particles were detected within areas containing filamentous material Figures (2) and (3) in chapter 4.

**Our study concludes** that Nanoscience leads to developing a range of inexpensive nanotech applications for enhanced plant growth. The included data proved an efficient means to control virus infection in a fashion way to reduce collateral damage. AuNPs have a dual positive effect on controlling the plant viral disease and enhance strong plant growth performance.

|                                  |          |
|----------------------------------|----------|
| Transmission electron microscope | TEM      |
| Gold nanoparticles               | AuNPs    |
| King Saud University             | KSU      |
| Barley Yellow Dwarf Virus        | BYDV-PAV |
| Reactive Oxygen Species          | ROS      |
| Endoplasmic reticulum            | ER       |
| Silver                           | Ag       |
| Gold                             | Au       |
| Iron                             | Fe       |
| Cobalt                           | Co       |
| Copper oxide                     | CuO      |
| Hydroxide                        | OH       |

|                             |       |
|-----------------------------|-------|
| NanoMeter                   | nm    |
| Silver nanoparticles        | AgNPs |
| Engineered nanomaterial     | ENM   |
| Metal nanoparticles         | MeNPs |
| Open Reading Frame          | ORF3  |
| Coat protein                | CP    |
| kilodalton                  | kDa   |
| Ribonucleic Acid            | RNA   |
| Potato leafroll Polerovirus | PLRV  |
| Movement protein            | MP    |
| Tobacco mosaic virus        | TMV   |
| Deoxyribonucleic Acid       | DNA   |

## Author details

Noorah Abdulaziz Othman Alkubaisi<sup>1\*</sup> and Nagwa Mohammed Amin Aref<sup>2</sup>

<sup>1</sup> Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Kingdom of Saudi Arabia

<sup>2</sup> Department of Microbiology, College of Agriculture, Ain Shams University, Cairo, Egypt

\*Address all correspondence to: [nalkubaisi@ksu.edu.sa](mailto:nalkubaisi@ksu.edu.sa)

## IntechOpen

© 2021 The Author(s). Licensee IntechOpen. Distributed under the terms of the Creative Commons Attribution - NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>), which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited. 

## References

- [1] N. Alkubaisi, N. Aref, A. Hendi, Method of inhibiting plant virus using gold nanoparticles, US Patents US9198434B1 1 (2015).
- [2] NA. Alkubaisi, N.M. Aref, Dispersed gold nanoparticles potentially ruin gold barley yellow dwarf virus and eliminate virus infectivity hazards, *Applied Nanoscience* 7(1-2) (2017) 31-40.
- [3] W. Falco, E. Botero, E. Falcão, E. Santiago, V. Bagnato, A. Caires, In vivo observation of chlorophyll fluorescence quenching induced by gold nanoparticles, *Journal of photochemistry and Photobiology A: Chemistry* 225(1) (2011) 65-71.
- [4] W. Rong, X. Wang, X. Wang, S. Massart, Z. Zhang, Molecular and ultrastructural mechanisms are underlying yellow dwarf symptom formation in wheat after barley infection yellow dwarf virus, *International journal of molecular sciences* 19(4) (2018) 1187.
- [5] P.H. Nass, L.L. Domier, B.P. Jakstys, C.J. D'Arcy, In situ localization of barley yellow dwarf virus-PAV 17-kDa protein and nucleic acids in oats, *Phytopathology* 88(10) (1998) 1031-1039.
- [6] N. Hardwick, D. Jones, J. Slough, Factors affecting diseases of winter wheat in England and Wales, 1989-98, *Plant Pathology* 50(4) (2001) 453-462.
- [7] N. Pal, J.S. Moon, J. Sandhu, L.L. Domier, C.J. D'Arcy, Production of Barley yellow dwarf virus antisera by DNA immunization, *Canadian Journal of Plant Pathology* 22(4) (2000) 410-415.
- [8] A.M. French, California plant disease host index, California Department of Food and Agriculture, Division of Plant Industry 1989.
- [9] M. Vargas-Hernandez, I. Macias-Bobadilla, R.G. Guevara-Gonzalez, E. Rico-Garcia, R.V. Ocampo-Velazquez, L. Avila-Juarez, I. Torres-Pacheco, Nanoparticles as Potential Antivirals in Agriculture, *Agriculture* 10(10) (2020) 444.
- [10] T. Karuppanapandian, J.-C. Moon, C. Kim, K. Manoharan, W. Kim, Reactive oxygen species in plants: their generation, signal transduction, and scavenging mechanisms, *Australian Journal of Crop Science* 5(6) (2011) 709.
- [11] E. Pradedova, O. Isheeva, R. Salyaev, Classification of the antioxidant defense system as the ground for the reasonable organization of experimental studies of the oxidative stress in plants, *Russian Journal of plant physiology* 58(2) (2011) 210-217.
- [12] Y. Zhai, X. Liu, H. Chen, B. Xu, L. Zhu, C. Li, G. Zeng, Source identification and potential ecological risk assessment of heavy metals PM<sub>2.5</sub> from Changsha, *Science of the Total Environment* 493 (2014) 109-115.
- [13] M.H. Siddiqui, M.H. Al-Whaibi, M. Firoz, M.Y. Al-Khaishany, Role of nanoparticles in plants, *Nanotechnology and Plant Sciences*, Springer 2015, pp. 19-35.
- [14] K.-J. Dietz, S. Herth, Plant nanotoxicology, *Trends in plant science* 16(11) (2011) 582-589.
- [15] Z. Guo, H. Xu, S. Su, J. Cai, S. Dang, S. Xiang, G. Qian, H. Zhang, M. O'Keeffe, B. Chen, A robust near-infrared luminescent ytterbium metal-organic framework for sensing of small molecules, *Chemical Communications* 47(19) (2011) 5551-5553.
- [16] G.X. Shen, Oxidative stress and diabetic cardiovascular disorders: roles of mitochondria and NADPH oxidase,

Canadian journal of physiology and pharmacology 88(3) (2010) 241-248.

[17] D.H. Atha, H. Wang, E.J. Petersen, D. Cleveland, R.D. Holbrook, P. Jaruga, M. Dizdaroglu, B. Xing, B.C. Nelson, Copper oxide nanoparticle mediated DNA damage in terrestrial plant models, *Environmental science & technology* 46(3) (2012) 1819-1827.

[18] J. Koelmel, T. Leland, H. Wang, D. Amarasiriwardena, B. Xing, Investigation of gold nanoparticles uptake and their tissue level distribution in rice plants by laser ablation-inductively coupled-mass spectrometry, *Environmental pollution* 174 (2013) 222-228.

[19] S. Tatur, M. Maccarini, R. Barker, A. Nelson, G. Fragneto, Effect of functionalized gold nanoparticles on floating lipid bilayers, *Langmuir* 29(22) (2013) 6606-6614.

[20] T. Silva, L.R. Pokhrel, B. Dubey, T.M. Tolaymat, K.J. Maier, X. Liu, Particle size, surface charge and concentration-dependent ecotoxicity of three organo-coated silver nanoparticles: comparison between general linear model-predicted and observed toxicity, *Science of the Total Environment* 468 (2014) 968-976.

[21] J.E. Miller, Effects on photosynthesis, carbon allocation, and plant growth associated with air pollutant stress, *Assessment of crop loss from air pollutants*, Springer1988, pp. 287-314.

[22] KVK. Mohan, B. Ghebrehiwet, C.D. Atreya, The N-terminal conserved domain of rubella virus capsid interacts with the C-terminal region of cellular p32 and overexpression of p32 enhances the viral infectivity, *Virus research* 85(2) (2002) 151-161.

[23] C. Chay, U. Gunasinge, S. Dinesh-Kumar, W. Miller, S.M. GRAY, Aphid

transmission and systemic plant infection determinants of barley yellow dwarf luteovirus-PAV are contained in the coat protein readthrough domain and 17-kDa protein, respectively, *Virology* 219(1) (1996) 57-65.

[24] R. Di, S. Dinesh-Kumar, W. Miller, Translational frameshifting by barley yellow dwarf virus RNA (PAV serotype) in *Escherichia coli* and in eukaryotic cell-free extracts, *Molecular plant-microbe interactions: MPMI* 6(4) (1993) 444.

[25] E. Tacke, J. Schmitz, D. Prüfer, W. Rohde, Mutational analysis of the nucleic acid-binding 17 kDa phosphoprotein of potato leafroll luteovirus identifies an amphipathic  $\alpha$ -helix as the domain for protein/protein interactions, *Virology* 197(1) (1993) 274-282.

[26] E. Tacke, D. Prüfer, J. Schmitz, W. Rohde, The potato leafroll luteovirus 17K protein is a single-stranded nucleic acid-binding protein, *Journal of General Virology* 72(8) (1991) 2035-2038.

[27] D. Beebe, W. Russin, Plasmodesmata in the phloem-loading pathway, *Plasmodesmata*, Springer1999, pp. 261-293.

[28] S.-L. Cheng, L.L. Domier, C.J. D'Arcy, Detection of the readthrough protein of barley yellow dwarf virus, *Virology* 202(2) (1994) 1003-1006.

[29] S. Dinesh-Kumar, V. Brault, W. Allen, Precise mapping and in vitro translation of a trifunctional subgenomic RNA of barley yellow dwarf virus, *Virology* 187(2) (1992) 711-722.

[30] S. Filichkin, R. Lister, P. McGrath, M. Young, In vivo expression and mutational analysis of the barley yellow dwarf virus readthrough gene, *Virology* 205(1) (1994) 290-299.

- [31] P. Larkin, M. Young, W. Gerlach, P. Waterhouse, The Yd2 resistance to barley yellow dwarf virus is effective in barley plants but not in their leaf protoplasts, *Annals of applied biology* 118(1) (1991) 115-125.
- [32] B. Mohan, S. Dinesh-Kumar, W.A. Miller, GENES AND CZS-ACTING SEQUENCES INVOLVED IN REPLICATION OF BARLEY YELLOW DWARF VIRUS-PAV RNA, *Replication of barley yellow dwarf luteovirus-PAV RNA* (1995) 58.
- [33] S. Choudhury, H. Hu, H. Meinke, S. Shabala, G. Westmore, P. Larkin, M. Zhou, Barley yellow dwarf viruses: infection mechanisms and breeding strategies, *Euphytica* 213(8) (2017) 168.
- [34] E. Waigmann, S. Ueki, K. Trutnyeva, V. Citovsky, The ins and outs of nondestructive cell-to-cell and systemic movement of plant viruses, *Critical Reviews in Plant Sciences* 23(3) (2004) 195-250.
- [35] S. Ghoshroy, R. Lartey, J. Sheng, V. Citovsky, Transport of proteins and nucleic acids through plasmodesmata, *Annual review of plant biology* 48(1) (1997) 27-50.
- [36] C.M. Deom, M.J. Oliver, R.N. Beachy, The 30-kilodalton gene product of tobacco mosaic virus potentiates virus movement, *Science* 237(4813) (1987) 389-394.
- [37] T. Meshi, Y. Watanabe, T. Saito, A. Sugimoto, T. Maeda, Y. Okada, Function of the 30 kd protein of tobacco mosaic virus: involvement in the cell-to-cell movement and dispensability for replication, *The EMBO Journal* 6(9) (1987) 2557-2563.
- [38] W. Jin, X. Gu, S. Li, P. Huang, N. Xu, J. Shi, Experimental and simulation study on a catalyst packed tubular dense membrane reactor for partial oxidation of methane to syngas, *Chemical Engineering Science* 55(14) (2000) 2617-2625.
- [39] V. Haywood, F. Kragler, W.J. Lucas, Plasmodesmata: pathways for protein and ribonucleoprotein signaling, *The Plant Cell* 14(suppl 1) (2002) S303-S325.
- [40] V. Citovsky, D. Knorr, G. Schuster, P. Zambryski, The P30 movement protein of tobacco mosaic virus is a single-strand nucleic acid-binding protein, *Cell* 60(4) (1990) 637-647.
- [41] V. Citovsky, M.L. Wong, A.L. Shaw, B. Prasad, P. Zambryski, Visualization and characterization of tobacco mosaic virus movement protein binding to single-stranded nucleic acids, *The Plant Cell* 4(4) (1992) 397-411.
- [42] O. Kiselyova, I. Yaminsky, E. Karger, O.Y. Frolova, Y.L. Dorokhov, J. Atabekov, Visualization by atomic force microscopy of tobacco mosaic virus movement protein-RNA complexes formed in vitro, *Journal of General Virology* 82(6) (2001) 1503-1508.
- [43] M. Heinlein, B.L. Epel, H.S. Padgett, R.N. Beachy, Interaction of tobamovirus movement proteins with the plant cytoskeleton, *Science* 270(5244) (1995) 1983-1985.
- [44] B.G. McLean, J. Zupan, P.C. Zambryski, Tobacco mosaic virus movement protein associates with the cytoskeleton in tobacco cells, *The Plant Cell* 7(12) (1995) 2101-2114.
- [45] E. Waigmann, A. Turner, J. Peart, K. Roberts, P. Zambryski, Ultrastructural analysis of leaf trichome plasmodesmata reveals major differences from mesophyll plasmodesmata, *Planta* 203(1) (1997) 75-84.
- [46] S. Malysenko, O. Kondakova, J.V. Nazarova, I. Kaplan, M. Taliansky, J. Atabekov, Reduction of tobacco mosaic virus accumulation in transgenic plants producing non-functional viral

transport proteins, *Journal of general virology* 74(6) (1993) 1149-1156.

[47] J. Schmitz, C. Stussi-Garaud, E. Tacke, D. Prüfer, W. Rohde, O. Rohfritsch, In Situ Localization of the putative movement protein (pr17) from potato Leafroll Luteovirus (PLRV) in infected and transgenic potato plants, *Virology* 235(2) (1997) 311-322.

[48] T. Xia, M. Kovochich, M. Liong, L. Madler, B. Gilbert, H. Shi, J.I. Yeh, J.I. Zink, A.E. Nel, Comparison of the mechanism of toxicity of zinc oxide and cerium oxide nanoparticles based on dissolution and oxidative stress properties, *ACS Nano* 2(10) (2008) 2121-2134.

[49] J. Han, Y. Lee, K.-H. Yeom, Y.-K. Kim, H. Jin, V.N. Kim, The Drosha-DGCR8 complex in primary microRNA processing, *Genes & development* 18(24) (2004) 3016-3027.

[50] M.C.S. Lee, E.A. Miller, J. Goldberg, L. Orci, R. Schekman, BI-DIRECTIONAL PROTEIN TRANSPORT BETWEEN THE ER AND GOLGI, *Annual Review of Cell and Developmental Biology* 20(1) (2004) 87-123.

[51] P.H. Nass, L.L. Domier, B.P. Jakstys, C.J. D'Arcy, In Situ Localization of Barley Yellow Dwarf Virus-PAV 17-kDa Protein and Nucleic Acids in Oats, *Phytopathology*® 88(10) (1998) 1031-1039.

[52] J.A.d. Boon, P. Ahlquist, Organelle-Like Membrane Compartmentalization of Positive-Strand RNA Virus Replication Factories, *Annual Review of Microbiology* 64(1) (2010) 241-256.

[53] R.R. Novoa, G. Calderita, R. Arranz, J. Fontana, H. Granzow, C. Risco, Virus factories: associations of cell organelles for viral replication and morphogenesis, *Biology of the Cell* 97(2) (2005) 147-172.

[54] M. Irwin, J. Thresh, Epidemiology of barley yellow dwarf: a study in ecological complexity, *Annual review of phytopathology* 28(1) (1990) 393-424.

[55] G. Delogu, L. Cattivelli, M. Snidaro, A. Stanca, The Yd2 gene and enhanced resistance to barley yellow dwarf virus (BYDV) in winter barley, *Plant breeding* 114(5) (1995) 417-420.

[56] J. Kehr, A. Buhtz, Long-distance transport and RNA movement through the phloem, *Journal of experimental botany* 59(1) (2008) 85-92.

[57] C. Gill, J. Chong, Development of the infection in oat leaves inoculated with barley yellow dwarf virus, *Virology* 66(2) (1975) 440-453.

[58] S.G. Jensen, Systemic movement of barley yellow dwarf virus in small grains, *Phytopathology* 63(7) (1973) 854-856.

[59] A.O. Noueir, W.J. Lucas, R.L. Gilbertson, Two proteins of a plant DNA virus coordinate nuclear and plasmodesmal transport, *Cell* 76(5) (1994) 925-932.

[60] E. Pascal, A.A. Sanderfoot, B.M. Ward, R. Medville, R. Turgeon, S.G. Lazarowitz, The geminivirus BR1 movement protein binds single-stranded DNA and localizes to the cell nucleus, *The Plant Cell* 6(7) (1994) 995-1006.

[61] Z. Xia, Y. Wang, Z. Du, J. Li, R.Y. Zhao, D. Wang, A potential nuclear envelope-targeting domain and an arginine-rich RNA binding element identified in the putative movement protein of the GAV strain of Barley yellow dwarf virus, *Functional Plant Biology* 35(1) (2008) 40-50.

[62] C.A. Chay, D.M. Smith, R. Vaughan, S.M. Gray, Diversity among isolates within the PAV serotype of barley yellow dwarf virus, *Phytopathology* 86(4) (1996) 370-377.

[63] G. Koev, B. Mohan, S. Dinesh-Kumar, K.A. Torbert, D.A. Somers, W.A. Miller, Extreme reduction of disease in oats transformed with the 5' half of the barley yellow dwarf virus-PAV genome, *Phytopathology* 88(10) (1998) 1013-1019.

[64] L. Hanley-Bowdoin, S.B. Settlage, B.M. Orozco, S. Nagar, D. Robertson, Geminiviruses: models for plant DNA replication, transcription, cell cycle regulation, *Critical Reviews in Plant Sciences* 18(1) (1999) 71-106.

[65] H.B. Scholthof, Plant virus transport: motions of functional equivalence, *Trends in plant science* 10(8) (2005) 376-382

IntechOpen