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# Preface

Plant viruses are very important pathogens causing significant direct and indirect losses to crop production and threaten global food sustainability. Increase in human population and balancing the demand for more sustainable ways of crop and food production, while maintaining crop productivity and quality, pose continuous challenges to scientists, agronomists and farmers worldwide. Over the past decades, considerable progress has been made in the understanding of the molecular basis of plant pathogen interactions, epidemiology of diseases and their causal agents and the deployment of this knowledge to design suitable control and management methods. Plants have the ability to defend themselves against most types of pathogens including viruses. Breeding programs have successfully introgressed resistance genes in numerous plant species such as potato to provide means to minimise the impact of viruses. However, as for any biological entities, the continuous evolution of pathogens, in particular viruses such as *Potato virus Y* (PVY), to escape host defence mechanisms and to adapt to different environments represents a constant threat. Potato was recently ranked as the fourth most important crop in the world and the most important non-grain crop, while PVY was identified as one of the top ten most important pathogens due to its economic impact in all potato-growing areas worldwide. In 2009, the international "PVY-Wide" network was created with the aim to share and disseminate knowledge on different aspects of PVY research focussing on the PVY-potato pathosystem and on the interactions of PVY with other solanaceous and non-solanaceous plant species. This informal network initially comprised 26 laboratories from 20 countries and has expanded over the years to include up to 40 laboratories. The participants are from different types of organisations including academia, agricultural research organisations, plant health organisations, laboratories involved in certification schemes mainly on seed potato production and private companies involved in pathogen diagnostics, breeding, and so on. The objectives of this book is to review and disseminate information communicated by colleagues of the PVY-Wide network (including yet unpublished and many other published data) on PVY research worldwide spanning the past few decades, to report the most up-to-date research outputs of basic and of more applied nature and to identify knowledge gaps with the view to stimulate future research.

This book should appeal to plant virologists, plant pathologists and the broad diagnostic, breeding and agronomical industries. The nine chapters of the book cover the essential aspects of PVY research including structure-function and diversity of the PVY genome, plant responses, evolution, diagnostic, epidemiology and transmission, control and management, resistance and the interactions of PVY with other plant species. The editors and authors of this book are indebted to all our colleagues of the PVY-Wide network as well as colleagues from the European Association of Potato Research Virology section for their input. Finally, last but by no means least, we would like to thank our colleague Stuart Carnegie for his contribution, valuable comments and suggestions.

Edinburgh, UK — Christophe Lacomme
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# Chapter 1
# General Characteristics of *Potato virus Y* (PVY) and Its Impact on Potato Production: An Overview

**Christophe Lacomme and Emmanuel Jacquot**

**Abstract** Diseases caused by plant viruses can have significant and devastating impacts on many cultivated crops worldwide. The impact of disease caused by a virus depends on the virus species, strains, type of inoculum, host plant characteristics, vector pressure, climatic conditions, trade, changes in agricultural landscape and intensive production practices. Viruses affect plants by causing a large variety of symptoms such as alteration of shape, pigmentation, necrosis on different parts of the plant, thus affecting plant development. In most of the cases, these lead to a decrease in crop yield and quality. There are numerous viruses that affect potato; among them, *Potato virus Y* is considered to be one of the ten most important plant viruses of crops, because of its worldwide distribution and economic impact. Some PVY isolates are able to cause potato ringspot necrotic disease in infected tubers rendering them unmarketable. Understanding the genetic diversity and molecular biology of PVY is essential to understand its infectious cycle, epidemiology and developing efficient methods of control and management for the virus itself and its vector. In spite of an ever-increasing wealth of data in these topics, several major scientific challenges remain in understanding the molecular nature of the interaction between PVY, its hosts, aphid vector in different environments and the epidemiology of PVY. This and following chapters will present the context and current state of our knowledge for these different topics and attempt to provide some answers to these important questions.

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## 1 Introduction

Changes in the agricultural landscape, crop management, crop intensification, introduction of foreign plant material via increased trade and climate change favor the emergence of infectious diseases of plants (Fargette et al. 2006). Plant viruses, as causal agents of diseases, can have significant and devastating impacts on many cultivated crops worldwide. These impacts depend, among other parameters, on virus inoculum, host plant characteristics (genotype and development stage), vector pressure and climatic conditions (Anderson et al. 2004). Most viruses affect plants by altering their development, causing in most of the cases a range of symptoms such as alteration of shape, modification of pigmentation, elicitation of necrosis on leaves, fruit or tubers, and reduction in plant growth. These different symptoms lead to a decreased crop yield and/or crop quality. These effects can, however, vary greatly for each virus/host combination, and it is not uncommon for crop losses to be either moderate or dramatically high, as exemplified by tomato spotted wilt virus disease on lettuce in USA generating losses of 30–90% (Sherwood et al. 2003) and tomato yellow leaf curl disease on common bean and tomato reducing yield up to 80% (Anderson et al. 2004). Occurrences of virus diseases can sometimes spread over large areas within a relatively short timeframe, as it was the case of bunchy top virus disease that was introduced in Australia in 1913, wiping out banana production in New South Wales by 1927 (Magee 1927, reviewed in Smith et al. 1998). Epidemics of virus disease in a new ecological niche, especially in a suitable environment, can often be very difficult to control and regular outbreaks are likely to occur. The *Groundnut rosette virus* is a good example of pathogen associated to regular outbreaks as more than 15 epidemics of this plant virus were reported on groundnut since the beginning of the twentieth century with losses up to £200 million in sub-Saharan Africa (Sastry and Zitter 2014).

In order to develop effective virus management strategies, it is necessary to diagnose accurately the virus(es) associated with the disease and to understand the disease life cycle of etiological agents (Sastry and Zitter 2014). An accurate assessment of agronomical impacts of a virus disease will require further knowledge on its epidemiology by studying the dynamics and distribution of the disease in hosts and alternative hosts (including wild plants) that act as reservoir of inoculum (Sastry and Zitter 2014). The agronomical impact of a virus depends on the intended use and economic importance of its host plants (grown either as ornamental, staple crop, or cash crop). In 2013, potato was ranked as the fourth most important crop in the world behind corn, wheat, and rice and was ranked the most important non-grain crop with an annual production of over 364 million tons. The importance of potatoes as a staple food worldwide has increased in the past few decades (World Potato Statistics 2015). There has been a dramatic increase in production and demand in Asia, Africa, and Latin America. For the first time in 2005, the developing world's production exceeded that of the developed world. This trend is continuing and reached 52% of global potato output in 2013. China and India are now the greatest producers of potato with about 96 and 45 million tons in 2013, respectively (Table 1.1).

**Table 1.1** Top 25 potato producing countries in 2013

| Rank | Country | Potato production [tons] |
|---|---|---|
| 1 | China | 95,987,500 |
| 2 | India | 45,343,600 |
| 3 | Russian Federation | 30,199,100 |
| 4 | Ukraine | 22,258,600 |
| 5 | The United States of America | 19,843,900 |
| 6 | Germany | 9,669,700 |
| 7 | Bangladesh | 8,603,000 |
| 8 | France | 6,975,000 |
| 9 | The Netherlands | 6,801,000 |
| 10 | Poland | 6,334,200 |
| 11 | Belarus | 5,913,710 |
| 12 | The United Kingdom | 5,580,000 |
| 13 | Iran (Islamic Republic of) | 5,560,000 |
| 14 | Algeria | 4,928,030 |
| 15 | Egypt | 4,800,000 |
| 16 | Canada | 4,620,000 |
| 17 | Peru | 4,570,670 |
| 18 | Malawi | 4,535,960 |
| 19 | Turkey | 3,948,000 |
| 20 | Pakistan | 3,802,200 |
| 21 | Brazil | 3,553,770 |
| 22 | Belgium | 3,479,600 |
| 23 | Kazakhstan | 3,343,600 |
| 24 | Romania | 3,289,720 |
| 25 | Nepal | 2,690,420 |

Source: World Potato Statistics, FAOSTAT, 2014

## 2 Viruses Infecting Potato

The importance of viruses as agents of infectious disease of plants was emphasized by Anderson et al. (2004). Viruses represent almost half (47%) of emerging infectious diseases surveyed between 1996 and 2002. A virus can infect many different plant species and a single plant can be infected by many different virus species, strains or isolates. Viruses are submicroscopic obligate intracellular parasites living and replicating in host cells. With some rare exceptions, viruses are assembled into particles made of a nucleic acid core that can be of different nature (see Table 1.2) and encapsidated into a matrix essentially composed of coat protein (CP) and in some cases, additional viral-encoded "accessory" proteins facilitating virus movement and/or transmission. Many diseases of potato are caused by viruses and can be transmitted to succeeding crops through infected seed tubers. Virus disease leads to an ongoing decline in health of a propagated crop, which in early descriptions was generically reported as "degeneration". These pathological phenotypes were further distinguished by the names of leaf roll, mosaic and streak (reviewed by Salaman 1949).

**Table 1.2** List of viruses infecting potato and their prevalence in cultivated potato. (*tentative species)

| Acronym | Species | Family/(Subfamily)/Genus | Type of genome | Geographical distribution | Transmission/Vector |
|---|---|---|---|---|---|
| AMV | *Alfalfa mosaic virus* | *Bromoviridae/Alfamovirus* | ssRNA+ | Worldwide | Aphids |
| APLV | *Andean potato latent virus* | *Tymoviridae/Tymovirus* | ssRNA+ | South America | TPS, Beetles. |
| APMoV | *Andean potato mottle virus* | *Secoviridae/Comovirinae/Comovirus* | ssRNA+ | Latin America | Contact, Beetles |
| AVB | *Arracha virus B* | *Secoviridae/Comovirinae/Cheravirus* | ssRNA+ | South America | TPS |
| BCTV | *Beet curly top virus* | *Geminiviridae/Curtovirus* | ssDNA | Worldwide (arid regions) | Leafhoppers |
| CMV | *Cucumber mosaic virus* | *Bromoviridae/Cucumovirus* | ssRNA+ | Worldwide (rare) | Aphids |
| EMDV | *Eggplant mottle dwarf nucleorhabdovirus* | *Rhabdoviridae/Nucleorhabdovirus* | ssRNA− | Iran | Aphids |
| GBNV | *Groundnut bud necrosis virus* | *Bunyaviridae/Tospovirus* | ssRNA− | India | Thrips |
| GRSV | *Groundnut ringspot virus* | *Bunyaviridae/Tospovirus* | ssRNA− | Argentina | Thrips |
| INSV | *Impatiens necrotic spot virus* | *Bunyaviridae/Tospovirus* | ssRNA− | Iran | Thrips |
| PAMV | *Potato aucuba mosaic virus* | *Alphaflexiviridae/Potexvirus* | ssRNA+ | Worldwide (uncommon) | Contact, Aphids |
| PBRSV | *Potato black ringspot virus* | *Secoviridae/Comovirin ae/Nepovirus* | ssRNA+ | Peru, others Andean countries? | TPS, Contact, Nematodes? |
| PLRV | *Potato leaf roll virus* | *Luteoviridae/Polerovirus* | ssRNA+ | Worldwide | Aphids |
| PMTV | *Potato mop top virus* | *Virgaviridae/Pomovirus* | ssRNA+ | Europe, America, Asia | Fungi (*Spongospora subterranea* ) |
| PotLV | *Potato latent virus* | *Betaflexiviridae/Quinvirina e/Carlavirus* | ssRNA+ | North America | Aphids |
| PVA | *Potato virus A* | *Potyviridae/Potyvirus* | ssRNA+ | Worldwide | Aphids |