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BARLEY YELLOW DWARF VIRUS (BYDV): CHARACTERISTICS, HOSTS, VECTORS, DISEASE SYMPTOMS AND DIAGNOSIS

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A B S T R A C T

Barley Yellow Dwarf (BYD) is a serious *Luteovirus* disease that affects small grain production worldwide. The aphid-transmitted virus (BYDV) infects practically all members of the *Graminae* (*Poaceae*) and is responsible for serious losses in cultivated species such as barley, wheat and oats. The study of BYD is complex, as it involves interactions among a vector, a plant and a virus. Hence, symptom expression is highly dependent on environmental conditions, serotypes plant genetic background and physiological stage of inoculation. Consequently, tolerance to BYDV is also difficult to study and understand. This review explores the basic biology of BYD, its symptoms, its viruses and yield losses it can cause.

Keywords: BYD, BYDV, aphid, symptoms, serotypes, tolerance, yield losses.

INTRODUCTION

Oswald and Houston identified the Barley yellow dwarf virus (BYDV) as a positive sense single-stranded RNA virus back in the mid of last century (Oswald and Houston, 1951). The BYDV, an ubiquitous *Luteovirus*, is the most destructive virus in cereal crops in the world (Lister and Ranien, 1995; Miller et *al*., 2002; Kennedy and Connery, 2005; Nancarrow et *al*., 2014). It is transmitted obligatory by aphid vectors in a persistent circulative manner and it is limited to the phloem tissue of the host plant. BYDV can cause significant yield losses in major cereal crops such as wheat, barley, maize, oat and ryegrasses (Rastgou et *al*., 2005). Global yield losses due to BYDV are difficult to estimate because of insufficient information. However, average yield losses attributable to natural BYDV infection can range between 11 and 33%. In some areas, losses have been reported to reach up to 86% (Miller and Rasochová, 1997). Different kinds of techniques have been used to detect BYDV but the biology of this virus complicates the diagnosis and the identification because it is confined to phloem tissue, occurs in low concentrations and is not mechanically transmissible (Comeau *et al.,* 1992).

VIRUS DESCRIPTION: Barley yellow dwarf virus (BYDV) is the type member of the *Luteovirus* group (Waterhouse et *al*., 1988; Francki et *al*., 1991; Ingwell et *al*., 2014) in the family *Luteoviridae* (Van Regenmortal et *al*., 2000; D'Arcy, 2000). This group includes many serious pathogens of crop plants (Rochow and Duffus, 1981; Waterhouse et *al*., 1987). Luteoviruses are not mechanically transmitted and are limited to the phloem tissue of the host plant. The physical properties of luteoviruses are similar in that they are 24 to 30 nm diameter isometric particles (Rochow and Brakke, 1964; Jensen, 1969) containing a positive-sense ssRNA genome of 5.6 to 6.0 kb (Miller et *al*., 1988; Veidt et *al*., 1988; Waterhouse et *al*., 1988; Mayo et *al*., 1989). The genomic RNA has a small protein (VPg) covalently attached to its 5' end (Murphy et *al*., 1989) but does not have a poly(A) tail (Mayo et *al*., 1982, 1989; Miller et *al*., 1988 ; Veidt et *al*., 1988). Viral particles have a buyant density in a Cesium Chloride gradient of 1.4-1.405 $g.cm^{-3}$. The thermal inactivation point of BYDV appears to be between 65 and 70°C. The positive sense single-stranded RNA of icosahedral virions is encapsidated by two

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proteins: a major 22 kDa coat protein and a minor 72 kDa read-through protein. Both proteins are involved in regulating virus transmission efficiency (Van Den Heuvel et *al*., 1993; Chay et *al*., 1996; Gildow, 1999; Brault et *al*., 2005). The read-through protein (RTP) is implicated in aphid transmission. Virions lacking the RTP are no longer aphid transmissible (Brault et *al*., 1995).

DIVERSITY OF VIRUSES CAUSING BARLEY YELLOW DWARF DISEASE: Early work by Rochow and others distinguished five different strains of the virus, based on their primary aphid vector (Rochow, 1969; Rochow and Muller, 1971). The cereal-infecting members of the family *Luteoviridae* comprise species BYDV-PAV, -MAV and -PAS within the genus *Luteovirus*; Cereal yellow dwarf virus-RPV (CYDV-RPV, formerly BYDV-RPV) and CYDV-RPS in the genus *Polerovirus*, as well as BYDV-SGV and -RMV, which have not yet been assigned to any genus (Ingwell et *al*., 2014). In China, four BYDV species, namely BYDV-GAV, -GPV, -PAV and -RMV, were reported (Zhou et *al*., 1987; Jin et *al*., 2004; Liu et *al*., 2007; Zhang et *al*., 2009; Wu et *al*., 2011). In the most recent report by the International Committee on Taxonomy of Viruses (King et *al*., 2011), BYDV-GPV is considered an as-yet-unassigned member of the family *Luteoviridae*. However, following analysis of the complete sequence, its classification in the genus *Polerovirus* and the new name Wheat yellow dwarf virus (WYDV)-GPV were proposed (Zhang et *al*., 2009).

VECTORS AND VIRUS-VECTOR INTERACTIONS: A distinctive feature of Luteoviruses is their mode of transmission. Luteoviruses are phloem restricted and transmitted in a specific manner by one or a few species of aphid (Bruehl, 1961). Transmission is non-propagative (no virus multiplication in the vector) and circulative (Rochow and Duffus, 1981; Gildow, 1987; 1991; Gray and Gildow, 2003). Ingested virions are actively transported across gut epithelial cell cytoplasm in vesicles and released into the hemocoel. To be transmitted into a plant, the virions accumulate at the surface of the accessory salivary glands and are actively transported across the cells and deposited into the salivary duct (Gray and Gildow, 2003). Each strain of BYDV is only transmitted efficiently by corresponding aphid species; one species aphid usually can efficiently transmit more than one virus strain (Rochow, 1969). Virus-aphid specificity seems to be related to the recognition of particular receptors in the accessory salivary glands of aphid (Bencharki et *al*., 2000). Various studies have been conducted that verify BYDV is vectored by more than 25 species of aphids (Halbert and Voegtlin 1995). But only some species can play an important role such as: *Barley yellow dwarf virus*-MAV (BYDV-MAV) is transmitted by the grain aphid *Sitobion avenae; Barley yellow dwarf virus*-PAV (BYDV-PAV) is transmitted by *S. avenae* and the bird-cherry aphid *Rhopalosiphum padi; Cereal yellow dwarf virus*-RPV (CYDV-RPV) is transmitted by *R. padi* (Ingwell et *al*., 2014).

SYMPTOMS OF DISEASE: The type and severity of host reaction to virus infection depend greatly on the crop genotypes, virus strains, age of plant at the time of infection and are influenced by environmental conditions. Host reactions to virus diseases are therefore extremely variable, as are the resulting losses (Bos, 1982). Infection by BYDV causes destructive effects on yield and quality of cereal crops. The most severe effects have been reported on oats, where reddening of the leaves and blasting of the florets are easily observed (Oswald and Houston, 1953; Burnett, 1984; D'Arcy, 1995). Other symptoms are stunted growth and late heading (Yount *et al*., 1985). Symptoms on barley and wheat consist primarily of chlorosis and stunting and usually are less pronounced than in oats. Plant physiological processes are interfered by the virus that multiplies specifically within the phloem of the host plant. The infected phloem cells are destroyed and translocation of assimilates produced by leaves is reduced. This result in carbohydrate accumulation, which in turn increases dry weight, inhibits photosynthesis and reduces chlorophyll content that subsequently cause discoloration and thickening of leaves (Jensen, 1968). The severity of BYD effect on plants is determined also by the time of infection (Smith, 1967), the virus species involved (Rochow, 1969; Baltenberger *et al.*, 1987), and the cultivar genotype (Jedlinski, 1972).

YIELD LOSSES: The cereal viruses of the family *Luteoviridae* can cause considerable yield losses especially in winter barley but also in winter wheat, depending on climatic conditions, vector incidence, and cultivation practices (Comeau *et al.,* 1993). This disease may cause considerable losses of small grain cereals worldwide, such as yield losses of up to 46% in *Triticum aestivum* (wheat), 25% in *Hordeum vulgare* (barley) and 15% in *Avena sativa* (oat) (Larkin et *al*., 2002; Ordon et *al*., 2009). The most effective and environmentally sound

approach to prevent yield losses is breeding for resistance cultivars (Chéour *et al.,* 1989).

RESISTANCE / TOLERANCE TO BYDV: Chéour *et al.* (1989) classify resistance into two categories: tolerance (symptoms and yield losses are reduced though virus multiplication is not altered) and resistance (virus multiplication and spread are reduced). BYDV resistance has been reported in oats and barley transformed with the polymerase (Koev *et al.*, 1998) and coat protein (McGrath *et al.*, 1997) sequences and recently, immunity of barley plants to BYDV-PAV has been obtained by using a transgene that encodes a self-complementary "hairpin" RNA containing the polymerase-gene sequence of BYDV-PAV (Wang *et al.*, 2000). In wheat, transgenic resistant lines obtained by the use of the CP gene were reported once (McCarthy *et al.*, 1996).

DIAGNOSIS: Visual assessment of BYD symptoms in field surveys and in evaluation of breeding lines under field conditions is inadequate for diagnosis and discrimination among strains of BYDVs (D'Arcy, 1984; Qualset, 1984). Consequently, it has been necessary to develop alternate techniques to assay plants for the presence of virus. The use of Enzyme-Linked Immunosorbent Assays (ELISA) has proven to be an efficient means to assess BYDV infection (Rochow and Carmichael, 1979; D'Arcy and Hewings, 1986; Chéour *et al.,* 1993). More recently, techniques employing monoclonal antibodies, cDNA probes and polymerase chain reaction have been used to discriminate between strains of BYDVs and provide more sensitive probes for virus diagnosis (Hsu et *al*., 1984; Disco et *al*., 1986; Torrance et *al*., 1986; Waterhouse et *al*., 1986; D'Arcy et *al*., 1989, 1990; Lister et *al*., 1990). Robertson et *al*., 1991; Nucleic acid hybridization is a powerful technique for detection of specific, complementary nucleic acid sequences used for the detection of viruses in plant extracts (Feinman *et al.,* 1984; Hull and Al-Hakim, 1988).

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