



Xylella, from emergency to management

Integrated Management Strategies for
mitigating *Xylella fastidiosa* impact in Europe



List of the most active EF against spittlebug vectors and of the viruses associated with *Philaenus spumarius*

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Author(s): Domenico Bosco (P6-UNITO) – Enrique Quesada-Moraga (P3-UCO)

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1. BACKGROUND

To fill existing gaps in the knowledge of biological control agents, fungi (EF) and viruses, research activities have been carried out in the laboratories of the University of Cordoba, Spain (P3-UCO) and University of Torino, Italy (P6-UNITO).

The list of the most effective EF against the spittlebug is provided in Table 1. The activity (mortality) recorded in experimental trials is also reported.

Viruses were identified by RNAseq in insect pools; only viruses whose RdRp sequences were identified were selected for further confirmation of their prevalence in the individuals that made up the RNAseq pools and are listed in Table 2.

2. DATA LIST

Table 1. List of entomopathogenic fungal strains showing potential for *Philaenus spumarius* control

Strain	Species	Origin	Agroecosystem	Target	Mortality (%)
EAMa 10/01-Fil	<i>Metarhizium guizhouense</i>	Adamuz (Córdoba, Spain)	Olive weed phylloplane	adults	100% (conidia)
EAMa 00/19-Su	<i>Metarhizium</i> sp.	Abla (Almería, Spain)	Olive crop soil	adults	100% (conidia)
EAMa 01/58-Su*	<i>Metarhizium brunneum</i>	Hinojosa del Duque (Córdoba, Spain)	Wheat crop soil	adults	95% (conidia)
EAMb 09/01-Su	<i>Metarhizium brunneum</i>	Castilblanco de los Arroyos (Sevilla, Spain)	Oak ecosystem	adults	71% (conidia)
EABb 01/126-Su	<i>Beauveria bassiana</i>	Bornos (Cádiz, Spain)	Olive crop soil	adults	68% (conidia)
EAMa 09/01-Su	<i>Metarhizium</i> sp.	Valbom de Baixo (Portugal)	Olive crop soil	adults	67% (conidia)
EAMa 01/158-Su	<i>Metarhizium robertsii</i>	Utrera (Sevilla, Spain)	Olive crop soil	adults	67% (conidia)
EABb 04/01-Tip [§]	<i>Beauveria bassiana</i>	Écija (Sevilla, España)	<i>Iraella luteipes</i> larvae	2nd-3rd stage nymphs	54% (conidia)
EAMa 01/58-Su* [§]	<i>Metarhizium brunneum</i>	Hinojosa del Duque (Córdoba, Spain)	Wheat crop soil	2nd-3rd stage nymphs	52% (conidia)
CnV2i	<i>Metarhizium anisopliae</i>	Canale (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	98% (conidia)
BP1q	<i>Metarhizium anisopliae</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	98% (conidia)
BP1k	<i>Metarhizium robertsii</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	96% (conidia)
BP1o	<i>Metarhizium anisopliae</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	94% (conidia)
BP1r	<i>Metarhizium</i> sp.	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	94% (conidia)
BP1f	<i>Metarhizium robertsii</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	92% (conidia)
ATCC 74040	<i>Beauveria bassiana</i>	from commercial product - Naturalis®		2nd-3rd stage nymphs	92% (conidia)
BP1l	<i>Metarhizium anisopliae</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	90% (conidia)
BP1e	<i>Metarhizium anisopliae</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	84% (conidia)
BV1a	<i>Ophiocordyceps heteropoda</i>	Barolo (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	82% (conidia)
Cas1h	<i>Clonostachys rosea</i>	Castiglione (Torino, Italy)	Conventional vineyard soil	2nd-3rd stage nymphs	82% (conidia)
Cg2b	<i>Beauveria pseudobassiana</i>	Costagrande (Torino, Italy)	Woodland soil	2nd-3rd stage nymphs	74% (conidia)
FV1c	<i>Metarhizium anisopliae</i>	La Morra (Cuneo, Italy)	Organic vineyard soil	2nd-3rd stage nymphs	74% (conidia)
DSF **	<i>Lecanicillium aphanocladii</i>	Torino (Italy)	Semi-field maintenance rearing	2nd-3rd stage nymphs	78% (conidia)
DSF	<i>Lecanicillium aphanocladii</i>			3rd-4th stage nymphs	50% (conidia)
DSF **	<i>Lecanicillium aphanocladii</i>			2nd-3rd stage nymphs	90% (blastospores)

* Yousef-Yousef M., Morente M., González-Mas N., Fereres A., Quesada-Moraga E., Moreno A., 2023. Direct and indirect effects of two endophytic entomopathogenic fungi on survival and feeding behaviour of meadow spittlebug *Philaenus spumarius*. *Biological Control* 186, 105348.

** Bodino N., Barbera R., González-Mas N., Demicheli S., Bosco D., Dolci P., 2024. Activity of natural occurring entomopathogenic fungi on nymphal and adult stages of *Philaenus spumarius*. *Journal of Invertebrate Pathology* 204, 108078.

[§] capable of endophytic colonization in olive covers

Table 2. List of insect viruses associated with *Philaenus spumarius*, as identified by RNAseq and confirmed by specific PCR assays. All viruses have been identified in adult spittlebugs.

Temporary Virus name	Viral genome structure	Putative viral order	Origin	Agroecosystem
Ps_Nido	ss+RNA Monopartite	Pisoniviricetes	Valenzano (Bari, Italy)	Olive grove
Ps_ifla1	ss+RNA Monopartite	Picornavirales	Sault (Provence, France)	Woodland/meadow
Ps_ifla1	ss+RNA Monopartite	Picornavirales	Chieri (Torino, Italy)	Meadow
Ps_ifla1	ss+RNA Monopartite	Picornavirales	Bellino (Cuneo, Italy)	Alpine meadow
PS_ifla2	ss+RNA Monopartite	Picornavirales	Bellino (Cuneo, Italy)	Alpine meadow
PS_ifla3	ss+RNA Monopartite	Picornavirales	Sault (Provence, France)	Woodland/meadow
PS_ifla3	ss+RNA Monopartite	Picornavirales	Bellino (Cuneo, Italy)	Alpine meadow
PS_ifla4	ss+RNA Monopartite	Picornavirales	Chieri (Torino, Italy)	Meadow
PS_ifla4	ss+RNA Monopartite	Picornavirales	Bellino (Cuneo, Italy)	Alpine meadow
PS_Bunya1	ss-RNA Segmented	Elliovirales	Bellino (Cuneo, Italy)	Alpine meadow
PS_Bunya2	ss-RNA Segmented	Elliovirales	Sault (Provence, France)	Woodland/meadow
PS_Bunya3	ss-RNA Segmented	Elliovirales	Sault (Provence, France)	Woodland/meadow
PS_Bunya3	ss-RNA Segmented	Elliovirales	Canale di Verde (Corse, France)	Woodland/meadow
PS_Bunya3	ss-RNA Segmented	Elliovirales	Arnasco (Savona, Italy)	Olive grove
Ps_BUNYA 4	ss-RNA Segmented	Elliovirales	Sault (Provence, France)	Woodland/meadow
Ps_BUNYA 4	ss-RNA Segmented	Elliovirales	Chieri (Torino, Italy)	Meadow
Ps_BUNYA 5	ss-RNA Segmented	Elliovirales	Sault (Provence, France)	Woodland/meadow
PS_Rhabdo1	ss-RNA Segmented	Mononegavirales	Sault (Provence, France)	Woodland/meadow
PS_Rhabdo1	ss-RNA Segmented	Mononegavirales	Canale di Verde (Corse, France)	Woodland/meadow
PS_Rhabdo1	ss-RNA Segmented	Mononegavirales	Arnasco (Savona, Italy)	Olive grove
PS_Rhabdo1	ss-RNA Segmented	Mononegavirales	Cisano (Savona, Italy)	Olive grove
PS_Rhabdo 2	ss-RNA Segmented	Mononegavirales	Sault (Provence, France)	Woodland/meadow
PS_Reo	dsRNA Segmented	Reovirales	Sault (Provence, France)	Woodland/meadow
Ps_REO2	dsRNA Segmented	Reovirales	Chieri (Torino, Italy)	Meadow
PS_Narna1	ss+RNA Monopartite	Wolframvirales	Bellino (Cuneo, Italy)	Alpine meadow
Ps_Narna2	ss+RNA Monopartite	Wolframvirales	Bellino (Cuneo, Italy)	Alpine meadow
Ps_Narna3	ss+RNA Monopartite	Wolframvirales	Bellino (Cuneo, Italy)	Alpine meadow
PS_Tomb	ss+RNA Monopartite	Tolivirales	Sault (Provence, France)	Woodland/meadow
PS_Tomb	ss+RNA Monopartite	Tolivirales	Chieri (Torino, Italy)	Meadow
PS_Ortho	ss-RNA Segmented	Articulavirales	Bellino (Cuneo, Italy)	Alpine meadow
Ps_Queny	ss+RNA Segmented	Unknown	Sault (Provence, France)	Woodland/meadow
Ps_Partiti	dsRNA Segmented	Durnavirales	Canale di Verde (Corse, France)	Woodland/meadow
Ps_Partiti	dsRNA Segmented	Durnavirales	Chieri (Torino, Italy)	Meadow
Ps_Flavi	ss+RNA Monopartite	Amarillovirales	Sault (Provence, France)	Woodland/meadow
Ps_MITO 1	ss+RNA Monopartite	Cryppavirales	Chieri (Torino, Italy)	Meadow
Ps_MITO 2	ss+RNA Monopartite	Cryppavirales	Chieri (Torino, Italy)	Meadow
Ps_Quaranja	ss-RNA Segmented	Articulavirales	Bellino (Cuneo, Italy)	Alpine meadow
Ps_Ourmia 1	ss+RNA Segmented	Ourlivirales	Bellino (Cuneo, Italy)	Alpine meadow
Ps_Ourmia 2	ss+RNA Segmented	Ourlivirales	Bellino (Cuneo, Italy)	Alpine meadow