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► To cite this version:

Philippe C. Nicot, Claude C. Alabouvette, Marc Bardin, Bernard Blum, Jurgen Kohl, et al.. Review of factors influencing the success or failure of biocontrol: technical, industrial and socio-economic perspectives. IOBC WPRS Bulletin, 2012, 78, pp.95-98. hal-02643155

HAL Id: hal-02643155

<https://hal.inrae.fr/hal-02643155>

Submitted on 28 May 2020

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Review of factors influencing the success or failure of biocontrol: technical, industrial and socio-economic perspectives

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Abstract: Although their role in plant health management is still quite modest, ever increasing expectations are placed on biocontrol agents for the complementation or replacement of pesticide use. Despite decades of research and more than 12,000 scientific papers on biological control of plant diseases, little more than 14 microbe-based commercial products are presently registered for use against diseases in the European Union. Through a review of published scientific literature, economic and market analyses and a survey of 675 farmers in 9 European countries, difficulties and conditions for success have been identified. The most salient features and future outlook are presented in terms of scientific/technical aspects, production costs and return on investment as well as (somewhat unexpected) factors deemed to be most influential on the evolution of the biocontrol market in the coming decades.

Key words: successful biocontrol, field application, commercialisation, production costs

Introduction

In a context of increasing demand for alternatives to chemical control, the role of biological control in plant health management has remained quite modest despite decades of research efforts. A working group was established within EU project ENDURE to analyse the factors of success of biocontrol at field level against arthropod pests, diseases and weeds. The present report is mostly focused on the work conducted on biocontrol of plant diseases. It consisted of reviews of published scientific literature (complemented with the consultation of scientists), economic and market analyses and a survey of 675 farmers in nine European countries.

Contrast between the number of registered commercial products and the potential of biocontrol against plant diseases based on published research

Biocontrol agents registered against plant diseases in the EU

One key step in the registration of a plant protection product in the EU is its inclusion in the list of active substances (Annex I of former Directive 91/414/EEC). Based on a consultation of the EU Pesticide Database (http://ec.europa.eu/sanco_pesticides/), 14 microbial biocontrol

agents were included in the list as of April 26, 2010 (and 7 more indicated as "pending"). The geographical range of authorization for use of these products varies from 1 to 15 of the 27 EU countries.

Biocontrol agents described in scientific literature

A review of publications referenced in the CAB Abstracts® database between 1973 and 2008 showed a steady increase in the yearly numbers of published work on biological control against plant pathogens. Overall, more than 12,000 publications were produced over this period, approximately two thirds of which on biocontrol against soilborne pathogens and one third against airborne pathogens. A detailed analysis was conducted on a subsample of 1743 studies targeting five key airborne diseases relevant to the crops under study in the ENDURE project (*Botrytis* rot, powdery mildews, rusts, downy mildews + *Phytophthora infestans*, *Monilinia* rot).

One striking aspect of the review was the uneven distribution of published work depending on the type of target disease. The most numerous reports were on *Botrytis* (880 papers for the 10-year period 1998-2008) while reports on two other economically important diseases were relatively rare (154 and 349 papers for rusts and downy mildew/*P. infestans*, respectively, over the 35-year period 1973-2008).

Although there is a growing body of literature on plant extracts, the largest number of reported successes was achieved with microbial biocontrol agents. In total, 157 species of micro-organisms were described for their effect against a pathogen causing one of the five types of diseases in our survey. They belonged to 49 genera of fungi, yeasts or oomycetes and 25 genera of bacteria. Among these microorganisms, two species of *Trichoderma* (*T. harzianum* and *T. viride*) and the bacteria *Bacillus subtilis* and *Pseudomonas fluorescens* stood out with a range of effectiveness encompassing all five types of diseases. In contrast, the great majority (118 species) were described for their efficacy against only one of the target diseases.

Identified technical difficulties for success at field level

In the above literature review, reports of a significant effect were far more numerous in laboratory conditions (*in vitro* or *in planta*) than in field trials, with strains from only 58 of the 157 species reported as providing successful control at field level on at least on one crop-pathogen combination. It is generally accepted that transition from the optimised conditions of a laboratory experiment to the harsh conditions experienced in the field has so far proved more difficult for application of biopesticides in contrast to chemicals. While field efficacy of biocontrol agents can equal or surpass that of chemical pesticides, this may vary over time or from one region to another. The main hurdles most classically reported include intrinsic biological properties of the microbial strain (such as its "ecological competence") but also the quality of the formulated preparations used in the field or inadequate application timing or method.

Economic considerations: cost and profitability analysis

Figures were collected and estimations were made by the International Biocontrol Manufacturers' Association (IBMA) to compare costs for a typical chemical pesticide and for a microbial biocontrol product in terms of production costs (including raw materials, packaging, energy, manpower, consumables and amortisation), as well as costs of registration, sales, research and administration. They were compared to estimated early sales values

(increasing from year 1 to year 5) and plateau sales to provide a complete margin structure for the production and sales of the products. The data clearly showed that the profitability of a biocontrol business is currently less attractive than that for chemical pesticides. Estimated earnings before the deduction of investments/taxes/amortisation (EBITA) amounted to 46% and 14% of the sales value at plateau level for the chemical pesticide and the biocontrol agent, respectively and profit after taxes, provisions and amortisation were 18 and 2% of the sales value, respectively, for the chemical pesticide and for the biocontrol agent.

Socio-economic aspects: market analysis and outlook for future use of biocontrol products

Beyond the general observation that the use of biocontrol products has remained modest in the EU, little quantitative information is available on their actual market size and on the variety of possible socio-economic factors that could explain this situation. A study was conducted by IBMA within the ENDURE project to gather quantitative data.

Methodological approach

The first step consisted in the localisation of the main crops and cropping systems and in the construction of a model of European agriculture using the data from EUROSTAT. In a second step the model was used for the randomised selection of a sample of 2000 farmers representing 12 production systems on 25 sites in 9 European countries. Twenty one suppliers of biocontrol products were also included. A complete questionnaire was sent to those who agreed to participate and 675 full responses were received and analyzed. To validate the process, more specific data were collected in a survey focused on the biological control of wood diseases of grapevine in France.

The estimated market of biocontrol in Europe

Based on the results of the survey, the estimated European market of biocontrol products amounted to 204 million Euro with a distribution of 79 Mio € for beneficial insects, 52 Mio € for microbials, 43 Mio € for semiochemicals, 18 Mio € for natural substances and 12 Mio € for beneficial nematodes. As the sales of microbial biocontrol agents include preparations against insects, these figures confirm that the current use of biocontrol agents against plant diseases is quite low.

The main use of biocontrol products was on protected crops (over 50% of the sales value and over 70% of treated acreage), followed by grapes (ca. 10% of sales), and fruit and field vegetables (each ca. 8% of sales). The lowest use was for arable crops, with ca. 6% of total sales.

Important factors for the development of biocontrol use

The analysis of the survey led to the identification of 12 factors deemed to have a significant influence on the future development of biological control use. The estimated influence was positive for nine of the factors and negative for three others.

A quantitative estimation of the weight of each factor was obtained by asking a subsample of the respondents (320 contacts) to rate the expected impact of each factor on a scale from -20 to +20. Among factors deemed to carry the most (positive) impact on future use of biological control by European farmers, the one by far the most cited was the establishment of incentives for farmers. This factor carried a relative weight of 157, far ahead of the three next most important factors, all related to the influence of key economic actors

("Pull from the fresh food wholesalers and from the food industry", "Size / strength of the manufacturers of biocontrol products" and "Involvement of leading distributors"). These three factors carried a relative weight of 66.8, 66.0 and 52.0, respectively. Among those with the lowest anticipated impact, there were three factors related to scientific innovation ("Progress in R&D of biocontrol", "Availability of Decision Support Systems" and "Development of new resistant varieties"), each carrying a relative weight of 11.2, 7.2 and -6.4, respectively. Two factors related to regulatory aspects ("Stringent registration of chemicals" and "Continued stringent registration for biological control products") had a lower than expected weight (22.4 and -18.0, respectively). The influence of these factors was considered no more important as measures for "Educating advisors and growers", which carried a relative weight of 21.6. The registration requirements are obviously more a concern for the industry than for the users of the plant protection products.

Surprisingly, the efficacy and the price of the biologicals, usually considered as two critical factors, were not mentioned as real constraints. This may be due to two reasons:

(1) It is anticipated that only "effective" solutions will be registered in the EU, showing the high confidence of the farmers and the retailers in the registration systems.

(2) The selling price of the new solutions (biological control products) will necessarily cope with the current price levels. Too highly priced, the new solutions will likely be ignored.

Conclusions and perspectives

The main technical conclusions of the study and perspectives for future R&D projects pointed out the need to devise better strategies for the screening of biocontrol agents, to further improve knowledge on efficacy-related issues, to promote multi-disciplinary approaches to integrate better biocontrol with IPM and other production issues, to develop adapted delivery technologies and to safeguard the durability of biocontrol.

Identified future issues for development included the training of advisers and farmers, the development and dissemination of Decision Support Systems and the establishment and development of farmers' networks. Future issues for industry will need to include quality control and the improvement of distribution systems. The results of the socio-economic survey provided a unique (and somewhat unexpected) perspective from the viewpoint of the users of plant protection products. They should prove useful for all stakeholders interested in promoting the use of biological control methods for plant health management.

Acknowledgements

This study was carried out in the framework of the European Network for the Durable Exploitation of Crop Protection Strategies (ENDURE; EU FR6 project 031499) and was funded in part by the European Commission.

IOBC-WPRS

Working Group “Biological Control of Fungal and Bacterial Plant Pathogens”

Proceedings of the Meeting

at

Graz (Austria)

07 – 10 June, 2010

Edited by

Pertot, I., Elad, Y., Gessler, C., Cini, A.

IOBC-WPRS Bulletin

Bulletin OILB-SROP

Vol. 78, 2012

The content of the contributions is in the responsibility of the authors.

The IOBC-WPRS Bulletin is published by the International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section (IOBC-WPRS).

Le Bulletin OILB-SROP est publié par l'Organisation Internationale de Lutte Biologique et Intégrée contre les Animaux et les Plantes Nuisibles, section Regionale Ouest Paléarctique (OILB-SROP).

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ISBN 978-92-9067-256-2

<http://www.iobc-wprs.org>

Darmstadt (Germany), 2012