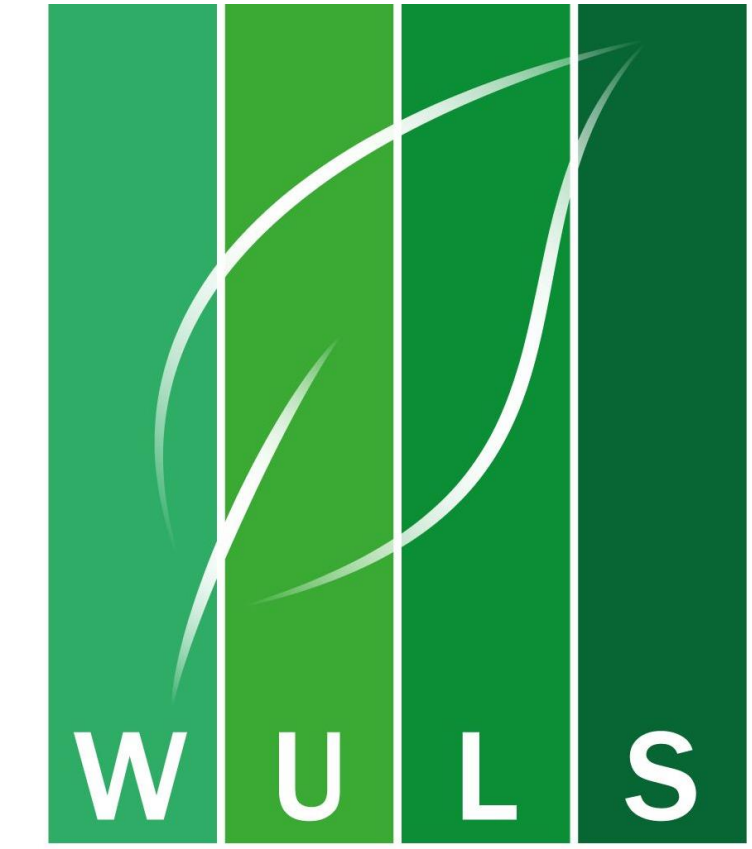
WULS Plant Health Project Final Report

01/11/2011 – 31/10/2015



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1. EXECUTIVE SUMMARY

The rapid increase in the demand of societies led by many non-governmental organisations (NGOs – representing consumers and ecological groups) for high quality but safe agricultural products and environmental and human health have had a strong impact on the political decisions made by the European Parliament related to agricultural production systems. Directive 2009/128/EC of the European Parliament and of the Council, in particular Article 14 concerning Integrated Pest Management (IPM) development and the obligatory implementation by farmers as of January 2014 is a primary example. Academics within the Faculty of Horticulture, Biotechnology and Landscape Architecture (FHB&LA) of Warsaw Life Sciences University – SGGW (WLSU) were convinced that integrated crop management based on IPM could link the public's demand for better quality products with guaranteeing the economic sustainability of farmers. They focused their efforts on vegetable and fruit crops where international and national data confirmed what was often unjustified overuse of pesticides by farmers.

The Warsaw Plant Health Initiative (WPHI) project was designed to enhance both the research and networking capacity of academia having expertise and an interest in participating in the holistic approach in their research from molecular factors responsible for plant resistance/tolerance to stresses of ecologically-based plant health. The Warsaw Plant Health Cluster (WPHC) is the expansion of the WPHI, breaking traditional administrative "walls" via the active involvement of experts from other University faculties and research institutes located in and around Warsaw. The project provided an extensive opportunity to strengthen and/or initiate new international contacts, send young researchers for advanced research training and work on joint projects. This attitude complies with the overreaching objectives of European research policy – aimed at enhancing the mobility of researchers, and the dissemination of knowledge and technology within the single EU market for research and innovation. The project was organised into a set of six goal-oriented Work Packages (WP), which constitute the core of the project's operations. Special attention was paid to ensure that they would encourage internal cross-disciplinary interactions among WPHC research teams, fill the SWOT identified competence gaps, open new avenues for research and international co-operation, and thus improve the research focus and impact of the participating research groups at national and international levels.

The WPHI project's achievements included activities such as:
(i) organisation of 7 mini-symposia and 13 workshops under the generic title "Frontiers of Plant Health", focused on select state-of-the-art topics related to the molecular, physiological, genetic and ecological bases of novel plant health management. Special attention was given to the issues related to the European plant health policy and on the protection of innovations through effective management of intellectual property; (ii) filling the competence gaps through 38 long outgoing visits of young researchers and 71 short outgoing visits/ international consultations by senior staff. Priority was given to strengthening co-operation with the Partner institutions; (iii) improving visibility, mobility & co-operation within ERA through promotion of WPHC accomplishments and competitive advantages implemented through 91 poster/oral presentations by 23 young and 80 experienced researchers during the international and national conferences, meetings and workshops; (iv) upgrading facilities by installing advanced analytical equipment in 3 laboratories and establishing two new ones: (a) a laboratory allowing identification of specialised, biologically-active plant compounds affecting pest behaviour and plant physiological conditions, and (b) the Bioinformatics research laboratory facilitating evaluation of high-throughout biological data, including massive genomic data sets from different sequencing technologies and approaches; and (v) a 51% increase in the total IF of published papers comparison to the 2009–2011 period.

2. A SUMMARY DESCRIPTION OF THE PROJECT'S CONTEXT AND THE MAIN OBJECTIVES

The WPH Initiative project was a result of discussion among scientists from different disciplines at the Faculty of Horticulture, Biotechnology and Landscape Architecture (Warsaw University of Life Sciences - WULS), facing new challenges posed by European policy development in plant health, e.g., Directive 2009/128/EC of the European Parliament and of the Council, in particular Article 14 concerning Integrated Pest Management (IPM) development and its mandatory implementation in 2014. IPM is a key component of sustainable farming (that is, good agronomy) with the objective of producing healthy crops. IPM is based on an understanding of ecology as well as the integration between crops and their pests (including pathogens and weeds), in addition to an understanding of the environment in which the antagonistic organisms operate.

In spite of existing recommendations on individual species control of pests, diseases and weeds, recent evidence confirms that crop plant health is continuously exposed to new emerging treats due to climate change and globalisation with intensifying market trends and agricultural practices. In consequence, "new crop pests and diseases" became the major factors of economic importance. They are responsible for **economic damages** to crops, not just causing injury on plants. Designating a species as a "new pest" takes place in two cases: (i) a phytophagous species has already occurred and was only occasionally noticed as a harmful organism to a crop; (ii) a new alien species (called an invasive organism) recently infests crop plants in Europe, including Poland. Their occurrence is a result of the large-scale monoculture of previous minor crops (some vegetables and fruits), growing cultivars of high aesthetic and nutritional value but often less tolerant to diseases, pests and climate change. Global and regional climate change is characterised by higher temperatures, altered precipitation regimes and an increased frequency of extreme events with earlier springs, so a modified growing season therefore may result in the modification of pests' and host plants' distribution range, the establishment of new pathogens and pest species or causing physiological disorders of crop plants.

Researchers currently developing and/or improving pro-ecological programmes on plant health should be aware that the concept of Integrated Pest Management itself has evolved over the last 30 years (see Agenda 21 of the UN Conference on Environment and Development – UNCED 1992). In the past, rather simple programmes were restricted both to a single pest species on a selected crop plant and to pure technical recommendations which shall, at present, be avoided. They were later expanded to include the social, economic and environmental aspects of the whole cropping system. Today, the development of the IPM programme should not only be considered as a technique using a computation of control methods instead of one single method of plant protection, but also as an approach based on interdisciplinary collaboration between agronomists, plant geneticists and breeders, plant protectionists, economists and sociologists.

Academics within the Faculty of Horticulture, Biotechnology and Landscape Architecture (FHB&LA) of Warsaw Life Sciences University – SGGW (WLSU) were convinced that integrated crop management based on IPM could link the public's demand for better quality products with guaranteeing the economic sustainability of farmers. They focused their efforts on vegetable and fruit crops where international and national data confirmed what was often unjustified overuse of pesticides by farmers. Vegetables, in addition to orchards and ornamental plant plantations (classified as minor crops but of an important nutritional value), became a benchmark for such environmental negative impacts.

Directive 2009/128/EC, through its recommendation on the obligatory implementation of integrated pest management by farmers as of 1 January 2014, has challenged both

government agencies and the scientific community to meet farmers' and consumers' demands for environmental safe plant protection methods. The project was therefore designed to enhance both the research and networking capacity of the Warsaw Plant Health Cluster (WPHC) and the mobility of its staff. This complies with the overreaching objectives of European research policy – aimed at enhancing the mobility of researchers, and the dissemination of knowledge and technology within the single EU market for research and innovation.

A number of scientists from the HB&LA Faculty initiated a number of goal-oriented projects on plant resistance to pests and diseases, biological control and pathogens, and crop management alternatives affecting plant health during the last 20 years. However, the SWOT analysis carried out in 2010 and 2011 demonstrated that the leading role of WULS academics in plant health initiatives in Poland may not be maintained, due to constraints such as:

- low funding for advanced equipment;
- international co-operation reducing full advantage of "intellectual critical mass" of some WULS departments, and
- existence of a "generation gap" in other departments.

The analysis also confirmed an increased need for inter-departmental and inter-institutional co-operation in carrying out holistic research and for developing a strategy to respond to the Europe 2010 Strategy, particularly to "Innovation Union" and the "Youth on the Move" initiatives and enhancing WPHC collaborative capacity and visibility within European Research Area (ERA).

The REGPOT project – the WULS Plant Health Initiative Warsaw University – was organised into a set of six goal-oriented Work Packages (WP), which constituted the core of the project's operations and, albeit interlinked, they operated as semi-autonomous units aimed at achieving improvement in a specific, well-defined area, such as an institutional environment (research policies and organisation), and in five specific thematic research areas:

WP1 – Update of research policy and enhancement of internal organisation.
WP2 – Upgrade of Entomology research team.
WP3 – Upgrade of Horticulture research team.
WP4 – Upgrade of Micro-ecology research team.
WP5 – Upgrade of Pathology research team.
WP6 – Upgrade of Functional genomics research team.

In addition to the above, two "general service" auxiliary Work Packages were also included: Project Management (WP7) and Ex-post Evaluation (WP8). In designing the five thematic research areas (WP2-6), special attention was paid to ensure that they would encourage internal cross-disciplinary interactions among WPHI research teams, fill the SWOT identified competence gaps, open new avenues for research and international co-operation, and thus improve the research focus and impact of the participating research groups' activities.

To achieve these goals, the Thematic Work Packages employed a coherent set of four measures, as stipulated by the REGPOT called:

(1) exchange of know-how and experience;
(2) recruitment by the applicant of experienced researchers;
(3) organisation of workshops and conferences, dissemination and promotional activities; and

(4) upgrading, development or acquisition of research equipment.

An important role in each thematic Work Package was assigned to international mini-symposia combined with two pre- and post-symposium workshops. Our experience has proved that this would enable competence gaps to be filled (lectures and workshops provided by invited experts), broad knowledge dissemination and the presentation of the WPHI profile and accomplishments to a national audience, both researchers and stakeholders. It is important to emphasise that the primary goal of all five thematic packages was to jointly create an effective concept-exchange platform and present the "panorama" of current interdisciplinary possibilities and trends within the Plant Health domain. The intention was to foster international compatibility and initiate collaboration, rather than to attempt to duplicate all these facilities/techniques within the WPHI.

Following activities were undertaken to reach the planned objectives:

(a) critical assessment of research and development priorities in relation to societal expectations and the EC and national Plant Health regulations;
(b) exploring and protecting innovations through effective management of intellectual property;
(c) organising mini-symposia and workshops on selected topics under the generic title "Frontiers of Plant Health" under sustainable crop and pest management. Special attention was given to the molecular, physiological, genetic and ecological bases of novel management of crop plant resistance/tolerance to abiotic and biotic stresses. International and national authorities were invited to share their experience with young WPHI scientists;
(d) the WPHI young staff advanced training for 3-4 months in leading research centres (preferably of Partner institutions) in their discipline;
(e) offering potential international research collaboration by presenting actual scientific achievements of the WPHI staff at international conferences;
(f) short-term isits of senior WPHI staff to European research centres for joint project writing
(g) incoming consultation visits of selected European authorities in plant health, including international members of the WPHI Advisory Committee; presentation of upgraded facilities and competent staff prepared for new scientific challenges as the result of REGPOT support;
(h) hiring internationally-recognised scientists to maintain and expand their previous links with international advanced research teams;
(i) active participation in international networks, e.g., COST actions; working groups of International Organization of Biological Control; expert networks of the European Food Safety Authority and other international scientific organisations; and
(j) enhancing material capacity by purchasing advanced equipment and new instruments for existing laboratories and the creation *de novo* of two laboratories as: (1) an analytical laboratory for bio-active semiochemical identification affecting pest behaviour and responsible for plant resistance to pests and pathogens, and (2) a bioinformatics centre.

The past experience of the Faculty of Horticulture, Biotechnology and Landscape Architecture showed the need for inter-departmental and inter-faculty co-operation between traditional academic disciplines such as entomology, plant pathology, botany, plant genetics and physiology, plant ecology and crop production, located in various faculties of the Warsaw University of Life Sciences. Therefore the Warsaw Plant Health Cluster (WPHC) network was formulated as an expansion of the WPHI by breaking traditional administrative barriers and involving experts and researchers of various disciplines in the Project's activities. The

WPHC aspires to become one such centre by renewing and undertaking new initiatives integrating not only various University faculties and their departments, but also relevant research institutes and industries. The Project has already provided both encouragement and means to create a more innovation-friendly institutional environment, fill competence gaps, absorb new methodologies and approaches, publicise accomplishments and the existing competitive advantages and strengths (http://horizon2020projects.com/special-reports/the-integration-), improve networking skills, visibility and co-operation within the ERA, and build a portfolio of collaborative grants using national and FP-7 instruments.

The WPHC's integrated inter-disciplinary approach to plant health research and technology development has been confirmed by recent recommendations of the European Academies/Science Advisory Council 24's policy report on "Risks to plant health: European Union priorities for tackling emerging plant pests and diseases" (2014), e.g., "Putting in place the necessary scientific infrastructure and networks to support surveillance, regulation and innovation" and "Supporting this multi-disciplinary research strategy by reducing fragmentation in research capacity and priority-setting across Member States to sustain critical mass" (2014, p. vii, <www.easac.eu>).

3. DESCRIPTION OF MAIN S & T RESULTS/FOREGROUNDS

3.1. Institutional background of the project

The WPHC was created at the Warsaw University of Life Sciences (WULS), which is a well established, widely recognised "academic brand" of over a century of tradition. It is the oldest, largest and highest-rated agricultural and environmental science academic institution in Poland, the fourth-oldest in Europe. Its status and role in social and economic development (especially of rural areas) has been recently confirmed by being granted such honourable titles as: (i) The most innovative and creative university in Poland in creation of professional careers; (ii) "The student-friendly university"; (iii) Certificate of "Good university – good job"; (iv) Laurel of Agro-Partner of the twenty-fifth anniversary; Certificate of "International student satisfaction" granted by international students and second place in the "TOP 10 Start-up Friendly" by the Academic Incubator of Enterprise.

On 1 March 2013, the Centre for Innovation and Technology Transfer was organised at the university to strengthen co-operation with the industry, SMEs and other economic entities in joint innovative technology development. The Rector's Plenipotentiary for Co-operation with Economy was nominated. This decision follows the recent Government decision to increase financial support for developmental projects carried out by industry-research organizations.

The WPHC's home Faculty of Horticulture, Biotechnology and Landscape Architecture (FHB&LA) is presently responsible for managing its four main programmes – General Horticulture, Biotechnology, Landscape Architecture and, since October 2015, Plant Health Protection (with 60 enrolled students). The HB&LA Faculty maintains its position as part of a group of the three most active university faculties in winning grants in basic and applied science and technology development. Today, the Faculty is in first place for being granted financial support per a faculty staff between agriculture projects allocated by the National Research Centre.

In 2012, a special accreditation procedure was carried out that resulted in extending accreditation for all study programmes until 2016. After evaluating all Polish universities offering courses in General Horticulture, the State Accreditation Committee changed the grade "positive" granted previously to "outstanding"; this accreditation will be valid until 2019–2020.

The scientific position and excellence of the Faculty's staff representatives was confirmed by their election by the national community of relevant disciplines to the following committees of the Polish Academy of Sciences: (i) chairman and 3 members of the Plant Protection Committee; (ii) deputy chairwoman and 2 members of Committee of Horticulture Sciences and (iii) deputy chairwoman and 2 members in the presidium of Committee of Plant Physiology, Genetics and Breeding; and (iv) a secretary and a member of the Biotechnology Committee presidium.

The WPHI REGPOT project substantially contributed to further improvement of the Faculty research infrastructure and capacities, and influenced other Faculty academics in using molecular techniques more frequently in their research and education.

The WPHI project's major achievements includes milestones in the following areas: (i) policy enhancement and updated research policy related to the national and global challenges in plant health; (ii) upgraded human and material capacity of participating research teams; and (iii) improved research potential and visibility of scientists involved in activities of six goal-oriented Work Packages related to:

WP1 – Research policy and enhancement of internal organization related to the plant health research and technology development.

WP2 – Upgraded Entomology research teams.
WP3 – Upgraded Horticulture research teams.
WP4 – Upgraded Micro-ecology research teams.
WP5 – Upgrade of Pathology research teams.
WP6 – Upgrade of Functional genomics research teams.

In addition to the above, two "general service" auxiliary Work Packages were also included: Project Management (WP7) and Ex-post Evaluation (WP8).

The Steering Committee and the Advisory Committee of the WPHI project patiently and persistently supported multi-disciplinary research strategy by reducing fragmentation in the research capacity of individual Departments and the WPHI teams.

Research policy and enhancement of internal organisation related to plant health research and technology development.

The importance of WPHI activities to research policy on plant health has been confirmed by European Commission debates to upgrade the existing plant health regime with legislation aimed to introduce better detection systems' surveillance and early eradication of new pest species (EC, 2013). The WPHI project organised three international meetings and produced a paper on consolidated policy and intellectual property relevant to national and international plant health development. On 6 March 2013, a workshop on: "Critical assessment of research priorities in relation to societal expectations and EC and national Plant Health regulations" gathered representatives from research and plant protection regulatory institutions in the Czech Republic, France, Denmark and Poland. The policy regulations in plant health care in different EU countries were compared and the need for an innovative systems analysis approach for a complex of pests and diseases in developing and improving current Integrated Pest Management of crucial crops for a country economy was emphasised. The discussion on challenges created by new plant health problems continued during the mini-symposium on "Updated policy on plant protection research in response to new pathogens, pests and weeds emerging in the European Union". The presentations and discussion led to following conclusions:

(i) The status of major pest species threatening crop quality in Europe is not only affected by intensive production systems (high input of mineral fertilizers, pesticides and reduced rotation) but also by the potential effects of the recent policy on the substantially reduced availability and use of registered pesticides. Elimination of a number of pesticides was justified by their environmental and human health hazards, but there are limited options for rotation of pesticides of different chemical groups. Intensive education for farmers and government incentives are needed to convince farmers of the biological and economic effectiveness of bio-pesticides (antagonistic microorganisms) and biological control agents (predators and parasitoids).
(ii) In the absence of available or unused alternative prevention and control methods, minor pest species have recently become major ones for a number of economically important crops.
(iii) The need for objective identification of the main goals in plant protection research and extension, referring to Directive 2009/128/EC of the European Parliament and of the Council, including recommendations on "Integrated Pest Management" in force from January 2014, were discussed with the active participation of policymakers (Ministry of Agriculture and Rural Development) and representatives of the plant and seed protection service, which is responsible for administrative control of plant health and IPM implementation by farmers.

(iv) The response of academic institutions in some EU countries to the need for highly qualified graduates understanding complex relations between pest/disease – crop plant – environmental interactions by establishing new B.Sc. and M.Sc. programmes in plant medicine and plant health protection were given as an example of the academics' understanding of inter-disciplinary and inter-institutional responsibility to the society's need for environmental safe plant protection, based on knowledge. Such education programmes include students' research projects using the newest molecular, biological and ecological methods.

(v) Intensive international trade in fruits and vegetables on the European market and climate change stimulate the establishment of invasive (alien) species in new regions. Therefore, the necessity of using novel molecular diagnostic techniques was discussed in detail. Integration of molecular diagnostic techniques with computer decision support programmes represents the future of modern plant protection technology.

(vi) The possibilities for creation of integrated centres for education and advanced research on plant health was demonstrated by the example of Wageningen University and research institutes located in its vicinity.

To fill gaps in the academics' and researchers' knowledge of intellectual property associated with patenting inventions in the field of biotechnology, registering new varieties (UPOV), as well as the commercialisation of patents, prominent international and national experts led a discussion during the workshop entitled "Exploring and protecting innovations through effective management of Intellectual Property" (9 March 2013). The following topics were discussed:

1. The relationship between the exclusion of patenting plant varieties on the one hand and the patentability of processes for the production of plants or animals on the other.
2. The specific scope of protection resulting from patents for biotechnological inventions.
3. Possible conflicts between two sources of intellectual property law and the independence and convergence of the two regimes, especially with regard to protectable subject matters, the provisions of farmer privilege and farm-saved seed, licensing, the scope of protection and enforcement provisions.
4. Assessment of the future of plant variety rights (PVRs) and what changes could be made to strengthen PVRs and still ensure that they are an appropriate and effective way to protect the results of the plant breeding programme.
5. The Polish Patent Office's approach to the process of biotechnological inventions was presented, with GMOs as an example.
6. Intensive participatory "brainstorming" session on protecting intellectual property, patent filing processes, evaluating the size of potential markets, preparing and presenting the idea to "early stage" investors, and strategic decisions involving licensing and registering a company took place at the end of workshop.

Consolidated policy on plant health protection

The post-WPHI sustainable research policy, as well as those at the university and national levels, should adopt the European Union's goals and regulations undertaken and those required for research and development strategy. The impact of the WPHI project on skill-building and human resource development (especially for young scientists) has already provided evidence of its parallel priorities and recommendations, as recently published in EASAC Report 24 (2014) prepared by experts of the European Academies/Science Advisory Council (www.easac.eu). The first priority of this policy is innovative action with the goals improving plant health, protecting the environment, and making agriculture more sustainable

and competitive. This includes actions necessary to ensure food security and sustainable use of biological resources. It can provide high-quality research with innovative approaches to solving problems and an assertion of social acceptance (important aspects in plant protection), both being conditions of achieving final success. The era of cheap resources is coming to an end: access to raw materials and clean water has become limited, with direct consequences for agriculture. These challenges are consequences of climate change, pressures of conventional agriculture on the ecosystem, and migration of people from rural to urban areas. Population growth in cities (in Europe, 74% of people live in cities) also challenges research priorities of the Faculty of Horticulture, Biotechnology and Landscape Architecture, having human potential to implement a postulate of "a nature to the city". The WPHI's new initiatives on plant health improvement in cities coincides with the EC's strategic plan on "healthy plants – healthy environment – healthy society" – one health. To meet these standards, new investments in innovation and support for a green and low-pollution emitting economy is needed. The WPHI project has already initiated international discussion and preparation of a grant under Horizon 2020 on the role of microbes living in association with plants on phytoremediation in cities.

In Poland, a government research programme is specified in the document called National Research Program, which consists of seven strategic directions of interdisciplinary scientific research and development areas:

1. New technologies in the field of energy.
2. Diseases of civilisation, new drugs and regenerative medicine.
3. Advanced information technology, telecommunications and mechatronics.
4. Modern material technologies.
5. Environment, agriculture and forestry.
6. Social and economic development of Poland in increasing global markets.
7. Security and defence of the state.

The national programme fits well with the European Union development strategy, supporting activities across the cycle from research to innovation and allowing for: (i) building of research teams where the research and innovation potential is not fully exploited, and (ii) intensifying training of researchers including an exchange of researchers and ideas with leading teams in Europe. The programme promotes and creates a favourable environment for international co-operation in research and innovation and, as such, would help to fill the gap between innovative research and its application. Simultaneously, attention is paid in the EU to important goals including increased human wellbeing and quality of life by the proactive protection of citizens from health risks, maintaining a high standard of food and product safety.

The Warsaw University of Life Sciences (WULS), as a state institution, has developed and implemented its own development programme called Strategy for 2011–2020, which fulfils directions of research and development recommended by the state authorities. Faculties within their specialties also try to conduct research in recommended areas as the majority of funds are now granted to science–industry integrated programmes. The Faculty of Horticulture, Biotechnology and Landscape Architecture (FHB&LA), with its research potential and expertise, fits to goal area number five, i.e., ***Environment, agriculture and forestry***. In fact, the WPHI project significantly upgraded the Faculty's potential to move on to higher levels of research in both agriculture and the environment. The WPHI Project supported and created new opportunities for the implementation of the objectives outlined in the university strategy through 2020. The WPHI project, with additional funds allocated for human and material capacity enhancement, is already playing and will continue to play an

important role not only in increasing the scale of research activities at the Faculty itself but also in raising excellence and the ranking level of research projects (e.g., Horizon 2020 and ERA projects). The experience of the senior WPHI staff has equipped them with skills to develop and coordinate international projects. The experience of the WPHI project provided added value in the planning of interfaculty co-operation by showing benefits of inter-disciplinary and inter-departmental co-operation in advanced research and technology development in plant health. The collaborative linkage documented in a number of common grant applications between WPHI teams doubled compared to the pre-WPHI period (the same project length). This should be continued and strengthened, but on a greater scale. Collaborative linkage grants should not only be restricted to particular teams of the WPHI but also include other Faculty staff members, other WULS faculties, and they should be addressed to other national and international institutions of the ERA. The positive role played by the WPHI programme must be emphasised, e.g., initiation of creating joint projects by a group of scientists from Ukraine, Belarus and Poland with a Partner from the UK on the emergence and prevention of weed resistance to ALS herbicides or expanding to China and USA in other projects.

The REGPOT project, in principle, excludes support for education but the WPHI project again confirmed that education cannot be separated from research activities at a university. As recently observed, a decreased number of students increases the role of research in university activities. This is closely related to and requires changes in the teaching and learning processes from a scholar system to problem-solving systems and working in teams, especially in such interdisciplinary science as the plant health. In the academic community, the biggest strength to carry out advanced research are graduate students, i.e., working on their M.Sc. and Ph.D. theses. The new laboratory equipment provided under the WPHI project gives students a chance to apply new analytical methods of biologically-active plant compounds, to use new molecular diagnostic methods of pathogens and pest species and biotypes of weeds and to identify genetic and molecular interactions between host plant and pests and diseases.

In 2011, the WPHI senior staff initiated the national debate and activity on establishing new education and research programmes on plant health as a consequence of: (i) demographic effects on the students' enrolment, affecting a reduced number of teaching hours allocated to the number of teachers' positions and the resulting employment problems of young Ph.D. graduates as teachers and researchers, and (ii) the response to the Ministry of Agriculture and Rural Development's request to increase the number of graduates in sustainable plant protection to implement Directive 2009/128/EC, establishing a framework for Community action to achieve the sustainable use of pesticides and obligatory implementation of Integrated Pest Management and National Action Plan on reduced risk on pesticides' application. A participatory meeting called by the Project's senior staff at the WULS in 2012 gathered leading plant protection academics and researchers, representatives of the Ministry of Agriculture and the Polish Association of Plant Protection to discuss proposed programmes' content as regards meeting farmers', extensions' and research needs in integrated plant health. Three universities initiated their programmes on Plant Medicine (Lublin, Wroclaw and Poznan) in 2012–2013 and Plant Health Protection at WULS (2015).

3.2. Upgraded material and human capacity

ENTOMOLOGY research teams (WP2)***:*** Regular surveys on Knowledge, Attitude and Practices related to crop and pest management between farmers, especially fruit and vegetable growers between 2009 and 2012, identified priorities for research and development to address

missing recommendations for effective implementation of IPM, as required by European Parliament Directive 2009/128/EC. The following needs for farmers were identified: improvement of pest-monitoring techniques; use of plant cultivars' resistance to pests and disease; and effective exploration of functional biodiversity. Three working teams were established to address the gaps in knowledge, such as: "Functional agro-biodiversity", "Applied insect ethology" and "Induced plant resistance to insect pests". The main efforts were concentrated on upgrading human and material capacities in the following areas: (i) establishing a new analytical laboratory capable to identified new semiochemicals that manipulate the behaviour of pests and their natural enemies; (ii) using stochastic models of insect behaviour under field conditions; (iii) identifying the physiological and molecular bases of induced plant resistance to pests; and (iv) using molecular techniques in studies on trophic relations between plant communities – pests and their natural enemies, enhancing presently used methods in studies on functional biodiversity between crops and their surrounding landscape; and (v) strengthening WULS expertise in the environmental risk assessment of GMOs as the only scientific team in Poland. The results of the three teams' research will be integrated into the "push and pull strategy" of crop-pest management under various agricultural production systems, enriching present recommendations of Directive 2009/128/EC.

Organisation of the Applied Ethology Team and laboratories was undertaken to (i) enhance the research capacity of the WULS' Applied Entomology Department, (ii) create a state-of-the-art research facility for applied insect ethological research and induced resistance, and (iii) recruit and train young researchers in order to fill the generation and competence gap. These goals are fully consistent with the general REGPOT framework and reflect the key objectives of WULS' REGPOT project, identified during the pre-project SWOT analysis. The current laboratory on induced plant resistance was also equipped with additional tools. The organisation of new laboratories started in May 2012 with the recruitment of a researcher experienced with projects, who was mandated to create an Applied Insect Ethology Team and specialised laboratories *de novo* for the micro-encapsulation of biologically-active chemicals and ethological experimental work, both to be located within the Applied Entomology Department at SGGW. From May 2012 to April 2015, both laboratories were designed, rooms technically adapted, and the appropriate specialised equipment was purchased and installed.

The laboratory for supercritical CO_2 extraction of bioactive chemicals from plant material, trapping bioactive volatiles from the ambient air, their chemical analysis, and immobilisation through micro- and nano-encapsulation became fully operational in late 2014. In addition, a specialised laboratory of insect ethology, adapted for video recording and analysis of insect behaviour, performing pharmacological manipulations in insects, conducting various behavioural experiments and raising/handling insects in fully-controlled conditions became fully operational in late 2014. Two highly-qualified young researchers were recruited in 2013: an analytical chemist and a pharmaco-ethologist. Both received on-site training in addition to specialised training provided by the producers of the newly purchased equipment. During staff exchange visits, they received training at various collaborating institutes and through participation in international training courses.

In 2014, the Applied Ethology Team embarked on research on the behaviour, chemical ecology, stochastic modelling and integrated management of the cherry fruit fly, *Rhagoletis cerasi*. This is the key pest infesting sweet cherries just before harvest, and thus hampering consumer-safe fruit production and its organic farming. The team quickly attained substantial visibility within the relevant sectors of ERA. It established appropriate international co-operation, which includes active participation in the relevant COST (FA 1104) project, and direct cooperative activities undertaken with partners from Greece, France, Italy, Germany, Austria, Belgium, etc. In addition, the team established internal co-operation with other

scientists of the hosting Department: on volatiles of *Cleome spinosa*, behaviour of *R. cerasi* and food volatiles modifying behaviour of Acari.

HORTICULTURE research team (WP3)***:*** The Department of Vegetable and Medicinal Plants comprises scientists working on the effects of genetic, physiological, technological and ecological factors affecting yield and accumulation of active substances in plants. Growing a healthy crop is the basic principle of Integrated Crop and Pest Management (ICPM). To meet present consumers' high demands for nutritious (functional) food and high-quality horticulture products under societal pressure on environmental protection, researchers need to critically evaluate production and post-harvest systems, "from field to fork". The effect of a vegetable and medicinal plant cultivar, various cropping systems, integrated nutrient management and application of bioactive compounds may affect the value and quality of a crop. All these factors were included in the team's activities related to the human resource development and capacity building.

To enhance the Department's potential to evaluate biologically-active substances' content in the harvested plants and during storage, a range of analytical equipment was purchased to fill gaps in the material base for qualitative research that substantially improved the staff's research potential. Some major items included: (i) an automatic extractor under high pressure and high temperature conditions enables extraction of different chemical compounds from plants using only small amounts of solvents, in rapid extraction time; (ii) a microwave device of the NEOS GR system for gravitational extraction of volatiles without solvents, with additional equipment serves for rapid and simple extraction of volatiles from experimental raw plant material; (iii) a complete kit of equipment for fluorescence measurement, with a data acquisition and elaboration system, to evaluate the physiological status of different plant organs of various plant species and their cultivars, grown under different cropping systems; (iv) advanced fluorescence detectors with data storage and data analyses to study the effects of plants' stresses on their physiology; and (v) network equipment with specialist computer programs for sensory analytical laboratory for research on the quality of vegetables, fruits and herbs and on factors affecting their quality. The experienced researcher was hired to strengthen the analytical potential of the team in: (i) modern methods of quality assessment of fresh vegetable and medicinal plant material; (ii) training of young researchers in advanced application of quantitative analytical methods, chromatography in particular. Later employed skilled technician operated equipment and test new quantitative analytical methods of biologically-active compounds of high value to human nutrition and health.

The scientists of the ***MICRO-ECOLOGY research team*** (WP4) are part of the Laboratory of Basic Research in Horticulture staff and used the WPHI project opportunity to strengthen existing capacity and initiate new avenues enhancing crop plant tolerance to stresses and upgrade their research in already internationally recognised areas. For over 15 years, the scientific interest of WP4 team members has been focused on lowering chemical inputs to the environment and to clean it up using challenging, innovative but simultaneously sustainable agro-technology and environmental biotechnology – i.e., phytoremediation. The effectiveness of the latter can be significantly improved by exploitation of positive interactions between plants and endomicrobes. The positive role and use of plants' microbes in plants' health enhancement is a new discovery and was included in WPHI activity. Another team's research objective relates to the newly emerged European and global problem of weed resistance to herbicides. Their studies included physiological, molecular and ecological mechanisms responsible for weed tolerance to herbicides inhibiting acetolactate synthase (ASL herbicides), especially in cereal production.

The new equipment increased the team research capacity and potential, especially for studies on the newly initiated area on interactions between plants and endophytic bacteria, as well as those of mycorrhizal fungi at the morphological, biochemical and molecular levels. In addition, some of the analytical apparatuses enhanced and strengthened the advanced research potential on the identification and confirmation of a phenotypically described type of weed resistance to herbicides and identified biochemical and molecular mechanisms of resistance. The new equipment allowed the use of more technologically advanced methodologies in the newly started areas of research as: (i) high-performance liquid chromatography (HPLC) with a fluorescence and diode detector (Shimadzu), used in the determination of biologically-active compounds and PAHs; (ii) DCode System for DGGE – set for denaturing gradient gel electrophoresis (DGGE), which allows, inter alia, monitoring of the microbial community; (iii) GelDoc XR+ (BioRad) – enabling easy visualisation, documentation and analysis of nucleic acids and protein gels, blots and microarrays; (iv) Hitachi U2900 spectrophotometer – used in analytical measurements, including components of antioxidant systems involved in scavenging free radicals; (v) Sanyo Mir-254 cooled microbial incubator – used to amplify microbial material to obtain adequate amounts of DNA; and (vi) benzene and other VOCs in the air meter, PHOTOVAC 2020PRO, ATUT – a portable instrument for measuring single-ring organic hydrocarbons in the field.

PLANT PATHOLOGY research team (WP5)***:*** After the retirement of 6 professors, including 5 mycology and fungus disease specialists, over last 8 years, the status of the Department of Plant Pathology was reduced to the Section of Plant Pathology at the Faculty of Horticulture, Biotechnology and Landscape Architecture (FHB&LA). The Section maintained its national leading position in virology, well equipped with modern analytical apparatuses by special grants from national donor agencies. Therefore, the majority of WPHI's REGPOT efforts was directed to fill competence gaps and enhance international recognition and co-operation in such areas of mycology and fungus diseases such as: taxonomy using molecular techniques, genetics of genera Fusarium or disease of cereals.

Upgraded material facilities include the modernisation of existing mycology laboratories with the following equipment: a nucleic acid isolation system, freeze-drying machine, autoclave, stereoscopic microscope and homogeniser. All items mentioned are absolutely basic tools, without which modern or even middle-ranking phytopathological and/or microbiological research is impossible. The nucleic acid isolation system allowed for the use of an efficient and fast technique to isolate DNA and RNA from various plant tissues, especially the woody parts. A newly-established modern flow cytometry laboratory was equipped with the flow cytometer (Facs Verse) with configuration system consisting of 3 lasers (blue, red, violet), supporting detection up to 8 parameters per analysed particle/cell. This allows for the possibility of applying a completely new research direction in molecular variations in the pathogen species populations, pathogenesis of plant diseases, aging and host as well as microbe apoptosis. The new equipment significantly strengthened research capacity and contributed to improving the efficiency, capabilities and qualities of the analytical work in mycology, bacteriology and virology. The upgraded facilities of the Pathology Section fulfil one of the recommendations of the WPHI symposium on "Critical assessment of research priorities in relation to societal expectations and EC and national Plant Health regulations" (2013) – "The changes in pest and pathogen populations cannot only be based on a species level. A more important change may occur at an infra-specific level such as pathotypes, pathovars and lineages of pests and pathogens. This will require work on the gene level to recognise changes in pathogens, such as identifying genetic markers for pathogenic trends."

FUNCTIONAL GENOMICS research teams (WP6)***:*** This segment is composed of two research teams: Plant Physiology and Plant-nematode Interaction have expanded already internationally recognised expertise of Department of Plant Genetics, Breeding and Biotechnology (DPGB&B) in: (i) cucumber genome sequencing and characterisation, molecular markers and mapping, molecular biology and physiology, photosynthesis and signalling in plants, regulation of development and growth, quantum biology of computing processes in plants, cytogenomics and phylogenomics; (ii) development of new breeding methods and cultivars of selected vegetables; and (iii) biotechnology: development of new gene constructs, improving the transformation efficiency with *Agrobacterium tumefaciens* (cucumber and tomato), functional analysis of genes, gene cloning and sequencing, and molecular breeding.

To improve existing material capacity, a selected list of equipment was procured to complete the existing capacity and its modernisation with the following items: growth chambers, a real-time qPCR system, a water purification system, a deep freezer, incubators, a chlorophyll imaging system, a laboratory dishwasher, an ice maker, and centrifuges. Except for the qPCR and chlorophyll imaging systems, the purchased items belong to common laboratory equipment and upgraded laboratories by exchanging them for the old, often after more than 20 years of intense operation, contributing to better performance of the analysis. The chlorophyll imaging system is composed of a Dual-PAM-100, which is a sophisticated instrument optimised for simultaneous measurements of chl *a* fluorescence from PSII and P700 (photosystem I, PSI) absorbance, thus providing information on the efficiency of light energy conversion in PSI and PSII. Moreover, Dual-PAM-100 provides the possibility for measurements on whole leaves and suspensions, e.g., isolated chloroplasts, algae, etc. The Imaging-PAM Mini-version is a second component of the purchased system and it belongs to the family of Imaging-PAM-Chlorophyll-Fluorimeters for measuring images of chlorophyll and fluorescence from PSII on a wide range of plant samples. The Mini-version is compact and best suited for both laboratory and field measurements. It allows for imaging of small leaves showing specific details, such as a leaf venation. The measurements obtained with these devices provide a lot of information concerning photosynthetic electron transport in intact leaves and isolated chloroplasts. Chl *a* fluorescence can be especially useful in studies of plant responses to various abiotic and biotic stress factors, e.g., drought, salinity, excess light, and plant-pathogen interactions. The real-time qPCR system is composed of two kinds of apparatuses: the qPCR device itself and the Bio-Rad CFX96 Touch real-time PCR machine is a six-channel system combining advanced optical technology with precise thermal control to deliver sensitive, reliable detection and quantification of RNA and DNA molecules in analysed samples, allowing for measurement of the transcription levels of specific genes (mainly representing plant reaction to biotic and abiotic stress) or detection of pathogen and parasite presence in infected samples. The other component of the qPCR system is the Bio-Rad Experion automated platform for chip electrophoresis of nucleic acid and protein providing accurate, sensitive and reliable analysis of complex samples during preparation for next generation sequencing or protein mass spectroscopy. More common laboratory equipment includes 4 Panasonic MLR-352H growth chambers with humidity regulation. This largely increases the capacity to grow model plants in programmed conditions and to run experiments in the planned new projects.

The new Bioinformatics Research Laboratory was equipped with a Dell PowerEdge R910 server (4 Intel Xeon E7 processors, 256GB RAM) with a PowerVault MD3200 storage matrix (24TB) and CLC Genomics Workbench 6.0 software. In addition, there are 25 PC terminals – 20 Dell Optiplex 9010MT and 5 Dell Latitude E64302, two colour laser printers and a multimedia projector. This facility is currently used to analyse high-throughput biological data, including massive genomics datasets from different sequencing technologies and

approaches. The upgraded laboratory was focused on host-plant and pest interaction on plant/pathogen genome assembly and annotation, plant/stressed plant transcriptome analysis, and data visualisation, helping to discover new genes beneficial to plant health. The effective tender procedure allowed us to save money sufficient for accessory laboratory equipment: a thermocycler, refrigerators, electrophoresis units, pipettes and air conditioners for the server room belonging to the bioinformatics laboratory.
The operation of newly-acquired equipment allows for the planning and generation of new, more precise and reproducible results. Modern equipment also provides much higher reliability simultaneously reducing losses generated during the maloperation of old machinery. In addition, the new apparatuses provide higher processivity in generating massive, high throughput data. Their analysis, with the help of our bioinformatics facility, meet current standards leading to the system's level of understanding in modern biology. The development of the bioinformatics laboratory is also of special value because of its collaborative potential, especially in Poland.

3.3. Filling competence gaps and opening new collaborative avenues.

An important role in each thematic Work Package was assigned to international mini-symposia combined with two pre- and post-symposium workshops. Our experience has proved that this enabled competence gaps to be filled (lectures and workshops provided by invited outstanding experts), broad knowledge dissemination and the presentation of the WPHI profile and accomplishments to a national audience, both researchers and stakeholders. It is important to emphasise that the symposia have created an effective concept-exchange platform and presented the "panorama" of current interdisciplinary possibilities and trends within the worldwide Plant Health domain and has fostered international compatibility and initiated, rather than attempted to duplicate, all these facilities/techniques within the WULS. To ensure better integration within the WPHC, all mini-symposia and workshops were organised under the generic title "Frontiers of Plant Health". Due to the participation of world-class scientists, the mini-symposia provided an overview of modern interdisciplinary methods, approaches and applications and broad cross-departmental attendance and integration. The WPHI project staff, via oral/poster presentations, demonstrated the Project's and the University's accomplishments to the invited national and international audience. The pre- and post-symposia workshops, which applied a participatory training approach, offered direct interaction with the invited experts. Their outcome led to new grant preparation, arrangement of out-going visits for advanced training and encouraged the selection of topics for national conferences.

The organised mini-symposium on: **"Opportunities for enhancement of Integrated Pest Management"** (1-2.04.2014**)** promoted up-to-date concepts on Integrated Pest Management and offered the opportunity to share views and experience on the latest developments in this field. Special attention was given to the following issues: (i) current advances and perspectives in induced plant resistance to pests and disease; (ii) functional biodiversity affected by ecological infrastructures, invasive (alien) pests and natural enemies; and (iii) perspectives and bottlenecks in the manipulation of insect behaviour for enhancement of IPM. A total of 70 participants from 15 countries (Spain, Italy, Sweden, Austria, France, Germany, China, the United States, the UK, Greece, Switzerland, Denmark, Turkey, Netherlands and Poland) attended the symposium. The 10 speakers invited from Polish academic and research institutions presented a wide range of achievements and expertise in the plant health science. Ph.D. and M.Sc. students from the Faculty of Horticulture, Biotechnology and Landscape Architecture at WULS-SGGW were allowed to attend the

meeting for free, thus enabling them to see how basic research could be used in developing and improving actual IPM recommendations in practice.

The molecular and physiological basis of induced plant resistance to stress factors included research progress in the assessment of molecular and biochemical mechanisms of crop resistance against insect-, mite- and nematode-herbivores. Special attention was paid to: (i) an increase of crop health by using the newest and best molecular breeding methods to enhance crop resistance towards pests and (ii) the modulation of crop defence capacity when biotic (herbivores) and abiotic (soil drought) stresses overlap. The session on functional biodiversity included examples of how EU agricultural policy on biodiversity facilitated national and international research and development initiatives in enriching various types of ecological infrastructures alongside existing agri-environmental schemes (UK, Spain, Poland). The role of the spatial scale in qualitative and quantitative optimisation of ecological infrastructures' design and modification was emphasised in the evaluation of the ecological infrastructures' impacts on functional biodiversity. Lower pest populations were frequently observed with higher diversity (often on a kilometre scale), but neutral or opposite effects do occur. Implementation of Directive 2009/128/EU on enhancement of sustainable biological control will require solid knowledge on the influence of factors such as cultivation, climate, landscape and rotation on the natural enemy and pest populations. In addition to classical ecological methods, novel techniques using the molecular food web approach allows for obtaining a better understanding of how species are functionally linked in trophic networks and which role biodiversity plays in sustaining the ecosystem service of pest control. The present Polish strategy for diversified sustainable agriculture should be explored as a benchmark in new joint EC projects on biodiversity management in intensive agriculture systems. Based on the symposium lectures and the subsequent discussion, the WPHI staff established the following recommendations for future work on: (i) the application of trophic molecular ecology to improve our functional understanding of species assemblages in the context of pest control; (ii) the effect of various ecological infrastructures and local climate conditions on antagonistic microorganisms of pathogens and pests; (iii) the evaluation of the degree to which the present mosaic landscape in the traditional farming area supports stable pest populations at an acceptable level; (iv) whether high diversity of flora and fauna always leads to the stability in agroecosystems; (v) what level of agroecosystem simplification (enlarging field size, reduction of field margin and patchy woodlands) may guarantee sustainable occurrence of natural enemies that can maintain pest population at an acceptable level.

The increased needs and role played by computer models on pest biology, ecology and behaviour in the IPM implementation was discussed during a session on "Perspectives and bottlenecks in manipulation of insect behaviour for enhancement of IPM" and following the workshop entitled, "On-farm behaviour of *Rhagoletis cerasi* and *Drosophila suzuki* and its modelling for enhancement of IPM". The main objective of the meetings was planned as the scientific complementary packet increasing the research potential of Polish entomologists, including the WULS PHI team working on insect behaviour. Presentations of world-class experts from the USA, the UK, Greece, Germany, Denmark, Sweden and Poland included a wide range of topics ranging from regional alien pest dispersion to ecology and pest behaviour. As reported, exotic pest invasions have, in recent years, been so numerous that the budgets of many importing countries have been reduced, the tools to control them are deficient, public health concerns are intense, the livelihoods of growers are threatened, export markets are at risk, and policies for mitigating their impact are in need of modernisation. These problems are increasing because of the ability of exotic insects to invade virtually all regions of the world. This has been aided by climate change, increased international travel, and on-going difficulties of detection in the early stages of invasion. Based on the detailed

studies on fruit fly ecology and behaviour, some semiochemicals of host plant origin were tested as attractants for various species of tephritid flies with the potential use for more effective traps. The concept of Area Wide Integrated Pest Management for Europe was discussed as one of the options for international co-operation. For monitoring purposes, PESTonFarm was presented as an agent-based, pattern-oriented stochastic model emulating the behaviour of large cohorts of individual insects within the seasonally-changing mosaic of the farming landscape under the challenge of IPM actions.
The most important added value of the workshop was based on the exchange of experimental data on fruit fly ecology and behaviour, important for population dispersion modelling, as well as the subsequent participatory discussion effected in planning international three-way collaboration between WULS, the Julius Kuhn Institute (Germany) and the University of Thessaly (Greece).

To enhance expertise on the effect of GMOs on the environment is currently restricted to a small team of scientists of the WPHI project in Poland, as a workshop on: "Implications of biodiversity in genetically modified plants and participatory training on the risk assessment of the GM trees" was organised. The following controversial issues were addressed: (i) acceptance of the EFSA Environmental Risk Assessment (ERA) by European societies and scientists; (ii) chances of using GM food crop plants resistant to pests and tolerant to herbicides as a part of the IPM systems; and (iii) the relevance of actual EFSA ERA recommendations on GM crop plants for the GM trees, presently under experimentation in some European countries, including Poland. Present recommendations on Environmental Risk Assessment (ERA) for annual crops (EFSA Journal 8: 1879, 2010) were used as a baseline for preparation of the ERA methodology for GM trees. The GMO participatory exercises were carried out by five groups of participants on problem formulation using the GM poplar as an example: (i) GM characterization; (ii) receiving environment; (iii) persistence and invasiveness; (iv) target organisms; (v) non-target organisms; and (vi) biogeochemical cycles. In addition, differences such as the long life cycles of wild compatible tree populations and related species and a wide range of ecological functions and associations need to be considered in the GM trees ERA.

The added value of the symposiums and workshop for the WULS PHI project includes: (i) increased competence of the project staff as the only research team in Poland actively involved in research on GM plant effects on the environment since 2004; (ii) familiarisation of the project staff and representatives of other institutions forming the WULS PH Cluster with the newest data on GMO ERA provided by the national project in Spain and international projects such as AMIGA, PREICE, GRACE and COST Action FP0905 in Biosafety of Forest Transgenic Trees; (iii) active participation on developing a proposal for ERA methodology for GM poplar carried out by staff of the GMO division of the German Federal Office for Consumer Protection and Food Safety; (iv) using the experience in the planning of future research on GM poplar ERA for Poland as the project contribution to the actual work of the WP6 on GM poplar as the obligatory step prior to releasing GM poplar cultivars into commercial use and environment.

A mini-symposium and 2 workshops entitled, **"Quality of fresh produce, herbs and vegetables – from field to fork"** presented current scientific and technological aspects of the production and post-harvest practices for vegetable and medicinal plants. Special attention was given to product quality in all production and post-harvest chains. The main topics of the experts' presentations from the Czech Republic, Denmark, Germany, Italy, Lithuania, Poland, Norway and Spain were the following:

(i) factors affecting the content of the biologically-active compounds in vegetable and medicinal plants;
(ii) integrated crop production methods in open fields and those grown under protection;

(iii) integrated and ecologically-friendly methods of crop protection against biotic and abiotic stresses;
(iv) effect of post-harvest technologies on quality of vegetable and medicinal plants;
(v) quality evaluation methods and their application in modern plant production.

Special attention was given to alternative methods enhancing plant tolerance to biotic and abiotic stresses such as: (i) a potential of plant volatiles to strengthen IPM strategies in fresh produce supply chains; (ii) mode of action of Atonik: physiological, biochemical and molecular approach; (iii) effect of mycorrhizal symbiosis on the nutritional value of vegetables; (iv) mycotoxins in plants and food: metabolism of the fusarium toxin deoxynivalenol; (v) Biospeckle – the application for evaluating fruits and vegetables; and (vi) quality-affecting factors of carrots from field to fork.

The symposium also provided an overview and exchanges of up-to-date interdisciplinary research methods and their applications in the sustainable horticultural production systems in Europe. It also provided the opportunity to increase integration between the University departments and other Polish and international research institutions.

Two specialised workshops included the following subjects:

(i) **"**Modern scientific and analytical equipment and its application for the quality evaluation of plant materials"; and
(ii) "Biostimulators and pro-ecological plant protection methods – in theory and practice".

The mini-symposium on **"Resistance to acetolactate synthase inhibiting herbicides: mechanisms, epidemiology and prevention"** was entirely devoted to plants' response to biotic and abiotic stress factors – herbicide- and pest-induced resistance with herbicide as abiotic stress and the development of herbicide-resistant biotypes generating biotic stress to crops when dominating in an environment. Although the problem of weed resistance to herbicides in Poland has not yet appeared very serious (probably due to the less intensive application of herbicides than in other countries), this has in consequence led to a relatively low number of weed scientists working in this area. As a result, the knowledge of agronomy advisers is also limited. Therefore, a follow-up training workshop on **"Molecular identification of mutation in the ALS gene"** was given by Polish scientists with experience in study of ALS herbicides. Such lectures and practical trainings were devoted to the newest methods of using molecular techniques in studies on resistance. Training materials with theoretical backgrounds and protocols were provided to each participant. Two world-leading scientists (Israel, France) and five experts from Poland presented up-to-date information on: mechanisms involved in breaking plant susceptibility to herbicides, the molecular basis of resistance and better systems of resistance management in crop production. Also, a current assessment of the scale of herbicide resistance in Poland in comparison with actual problems was presented by invited international weed scientists, indicating the need for field monitoring, further research on the ecological and genetic mechanisms of resistance and developing practical integrated weed management. The lecture entitled, "Why repeat mistakes? Analyses to design better resistance management" by Prof. Jonathan Gressel showed priorities in research and practice. During discussions, it was recommended to establish contacts and possibly co-operation with Dr Robert Edwards from the Centre for Novel Agricultural Products, Department of Biology, University of York, UK, which is a world-leading centre for research in metabolic resistance. Subsequent correspondence resulted in the preparation of a joint project under Horizon 2010.

The 2nd Mini-Symposium entitled, **"Plant-associated bacteria: an important key to the successful application of phytoremediation"** was devoted entirely to plant-microbiome interactions and their responses to abiotic stress factors, with a main emphasis on their effect on air pollution and the possibility of improving air quality. The newly open studies at the WPHI project fits well with the recent EC appeal to integrate "health plants – healthy

environment – healthy society". Presentations by 4 international experts and 9 national experts, as well as 36 posters, covered identified interactions between micro-organisms and plant tolerance to stresses. The invited lecturers addressed subjects such as: (i) Plant-associated bacteria: an important key to the successful application of phytoremediation; (ii) Plant microbe interaction and the role of endophytes in the phytoremediation of pharmaceuticals; (iii) Hydrocarbon degradation potential and the plant growth-promoting activity of endophytic bacteria; and (iv) The relationship between successional vascular plant assemblages and their associated microbial communities on coal mine spoil heaps. Ninety-one (91) participants, including University staff and students, attended the symposium.

Because of the scientific and practical importance of plant-associated micro-organisms in plant tolerance to stresses, the follow-up practical workshop was organised for 20 participants under restricted laboratory space and repeated at the insistence of symposium attendees. Three lectures were delivered, but the majority of time was devoted to practical experiments on bacterial DNA isolation, multiplication using a PCR reaction, and searching for data in the available bioinformatics databases. Training materials were distributed to participants.

Due to achievements of both Horticulture and Micro-ecology research teams being recognised, they were requested to organise the 2nd National Conference, entitled: **"Biostimulators in Modern Plant Cultivation"**, with 9 plenary lectures, 9 short communications and 48 posters. In addition to the Polish lecturers, four speakers from Belgium, actively involved in either research on biostimulators or on the European Industry Biostimulants Council, were invited and also presented plenary lectures. Over 250 attendees participated in this conference.

In summary, lectures, poster presentation, formal and informal discussion and exchange of ideas all: (i) increased the visibility of WP4 team members and invited Polish scientists; (ii) showed the increased potential for new research challenges enhancing plant tolerance to abiotic and biotic stresses; (iii) documented an increased interest in reducing the input of chemicals to the environment by biological agents; and (iv) showed the need for organising such events, bringing together international top experts and Polish scientists.

Presentations of the mini-symposium **"Classical and molecular approaches in plant pathogen taxonomy**" and two follow-up practical workshops concentrated on current challenges in plant pathogen taxonomy using molecular techniques, sequencing, diagnostic methods and identification of plant pathogenic viruses, bacteria and fungi. Seven experts from various Polish scientific institutes and universities held lectures on classical methods and molecular approaches in plant pathogen taxonomy that are used in the isolation and identification of fungi, bacteria and viruses. The main issues discussed were focused on changes in the potato virus population and the newest methods of variability testing, the importance of traditional and molecular methods in taxonomy of plant pathogenic fungi, and the current approach to detecting *Erwinia amylovora* and bacteria species from the genera Pectobacterium and Dickeya.

During the session "*Topics in taxonomy and identification of Plant Pathogenic Viruses and Bacteria*", seven speakers (including three from France, Germany and the Czech Republic) presenting lectures were devoted to the recent evolution in the taxonomy of grapevine leafroll- and rugose wood-associated viruses (Potyviridae, Secoviridae and the characterisation of two new members of the genera Tritimovirus and Poacevirus isolated from grasses), the application of molecular and immunological methods for direct detection of potato viruses, high throughput sequencing methods, detection methods of plant pathogenic bacteria of the Rhizobium/Agrobacterium complex and modern diagnosis of quarantine pathogen – *Clavibacter michiganensis* ssp. *sepedonicus* based on colloidal gold as a sensitive marker. The session on "*Plant Pathogenic Fungi"*, with the participation of four international

experts (from Hungary, Sweden, Italy and Belgium) focused on three related topics: molecular markers applied in fungal taxonomy and barcoding of fungi, the significance of new Fusarium species of Liseola section, systematics of mucoralean fungi and the molecular and cellular mechanism of gall formation in clubroot-infected Arabidopsis.

The poster session gave an opportunity to report on 32 on-going research projects at other Polish universities and research institutes and to discuss the methods used and the results. In both events, 84 scientists participated**.**

Two follow-up workshops: **"Real-time PCR technique for the detection of the plant viruses"** (30 participants) and **"Flow cytometry as a tool in microbiology",** included a theoretical segment and a practical course. During the lectures, key topics in real-time PCR were presented, i.e., principles of the techniques, application possibility and criteria for selecting a real-rime PCR machine, depending on specific needs. The practical course included application of plant virus detection. The workshop on using flow cytometry for the detection and analysis of microbe populations attracted 64 scientists and students. The lectures presented by international experts (German, Portugal, Estonia) mostly concerned assessing microbial community dynamics, aging, autophagy and cell death, estimation of fungal genome size by flow cytometry, and the implementation of new possibilities of apoptosis research, among others. The practical exercises were held by experts of the BD Biosciences company.

The Functional Genomic research teams, with permission of the Project Officer, instead of a mini-symposium planned the special FP7 Plant Health sessions during the **11th International Conference on Reactive Oxygen and Nitrogen Species in Plants** (http://www.pogwarsaw2013.org/) were organised at WULS. Reactive Oxygen and Nitrogen Species are key regulators and signalling molecules of plants' response to pathogen and pest attacks, environmental stress as well as normal variations in the environment. They also regulate the trade-off between plant immunity and development. Therefore, ROS and RNS are regarded as the primary mediators of plant health at the cellular and systemic levels. With the total number of participants reaching 310, including 19 speakers invited from WULS Plant Health, the conference gathered an excellent set of the world's most cited experts on ROS and RNS in plants, including representatives of WPHC's institutional partners. Within the conference, three WULS Plant Health special sessions were organised and their topics corresponded to the goals of the project (similar to other sessions). This organisation of WULS Plant Health special sessions allowed many scientists from WULS and other closely collaborating institutions to attend the conference, scientists who otherwise would not have much opportunity to meet such a complete and competent group of international experts. The meeting gave them an opportunity to create and intensify many bi- and multidirectional co-operative initiatives aiming to prepare common projects and experiments. The post-conference correspondence supports this statement and offers the excellent opinions of participants on this event.

The great success of the conference provided exceptional WULS visibility, that was achieved by: (i) participation of 310 scientists from all over the world; (ii) presentation of the WPHI objectives and an inter-disciplinary approach to plant health at the conference's opening ceremony; (iii) the WULS Plant Health Special Sessions (clearly distinguished in the programme) included: ROS Production, Signalling and Homeostasis; Abiotic and Biotic stresses; ROS in plant development. The abstract book is available in a special issue of the BioTechnologia international journal (Journal of Biotechnology, Computational Biology and Bionanotechnology) vol. 94(2) – http://www.biotechnologia-journal.org/11-th-International-POG-Conference-Reactive-Oxygen-and-Nitrogen-Species-in-Plants-17-19-th-July-2013-Warsaw-Poland,85,23818,1,1.html.

The workshop on "Mechanism of plant-pest interaction - discovery and characterisation" included lecturers from leading European universities and institutes, such as: University of Leeds (UK), Institute of Biochemistry and Biophysics (Poland), University of Bonn (Germany), James Hutton Institute (UK), Ghent University (Belgium), BOKU (Austria) and the Warsaw University of Life Sciences (Poland). The lectures were focused on the molecular, physiological and biochemical interaction of plants with insects, nematodes and microbes, with particular emphasis on identifying effectors and signalling pathways triggered in the host plant. The workshop attracted 71 participants (mainly young people) from several Polish research institutions working on plant disease resistance and pest biology. The discussions were extended and personal contacts were made during coffee breaks. The workshop was highly successful and generated substantial publicity. A detailed agenda and abstracts of presentations can be found at the following website:
http://marcin_filipecki.users.sggw.pl/PDFY/Abstracts.pdf.

3.4. Improved research potential and visibility of scientists

The SWOT analysis indicated the following gaps within WPHI: insufficient or missing modern cross-disciplinary developments, such as molecular bar-coding taxonomy, GIS-based predictable modelling of pest distribution and shifts due to climate change, genetic tracing of pest population origins, micro- and nano-encapsulation of semi chemicals, professional bioinformatics support, system level understanding of signalling machinery in biotic and abiotic stresses, microbe and pathogen molecular identification, micro-ecology of endosymbionts, novel indicators of the quality of fresh and stored produce.

To fill the gaps, the following activities were executed in addition to previously reported mini-symposia and workshops on the newest developments in research, such as: (i) 38 long outgoing visits of young researchers to learn advanced methods and participate in the novel projects at leading European research centres; (ii) 71 short outgoing visits/ international consultations by senior staff (priority was given to strengthening co-operation with the Partner institutions); and (iii) improving visibility, mobility and co-operation within ERA by promoting the accomplishments and competitive advantages of WPHC implemented through 91 poster/oral presentations by 23 young and 80 experienced researchers during the international and national conferences, meetings and workshops. Trained young scientists working in the research projects at the Faculty and abroad, participation of the WPHI and other Faculty staff in workshops and international conferences enhanced their competence in modern methods and filled the gaps in the majority of fields shown in the SWOT analysis. The 13 experienced researchers recruited extended and upgraded the previously used research methods, especially in applying molecular techniques in research projects on stress tolerance of plants to abiotic and biotic factors. Four of them retained contracts at the University and five others did the same at other Polish research and technology development institutions. Three are developing interdisciplinary grant proposals with other departments at the University. Unfortunately, two experienced researchers of international status, specialised in micro-and nano-encapsulation and modelling of insect behaviour and in molecular biology, could not secure funding for their position by winning new research grants. The Faculty counts on their successful return and continuation of their studies and training of Ph.D. students and young researchers. A new study programme on "Plant health protection" with more than 60 enrolled students should open new teaching/research positions for the well-trained young researchers in the WPHI project.

The research potential and visibility of the **ENTOMOLOGY** team included the following activities:

(i) twenty-three (23) outgoing visits by junior (7) and senior staff (16) including: participation in the joint project on the validation of the scholastic model on insect behaviour under field conditions; active participation in national and international specialised conferences, working meetings within international networks (two COST networks, EFSA, 3 working groups of the International Organization of Biological Control) and working training courses on using molecular techniques in studies on tritrophic relations;
(ii) twelve (12) oral and poster presentations reporting the WPHI project achievements on national conferences;
(iii) twenty-three (23) oral and poster presentations on international conferences;
(iv) participation in six (6) international meetings on the status of advances science related to biotechnology and plant health (ENDURE, PURE, COGEN, etc.);
(v) four (4) WPHI staff participation in 12 international organizations;
(vi) publication of 13 papers (5 with IF);
(vii) preparation of 17 grant proposals (Table 1).

The **HORTICULTURE** research team improved its research potential and visibility of scientists by:

(i) twenty-one (21) outgoing visits by junior (9) and senior (12) researchers including: participation in international training workshops, e.g., modern scientific and analytical equipment and its application in the quality evaluation of plant material (University of Messina and University of Turin, Italy or CAMAG of Muttenz, Switzerland). Future collaboration between the Horticulture group was discussed with the following research institutions: BOKU (Austria), Polytechnical University of Valencia (Spain). Latvia University of Agriculture in Riga (Latvia), University of Almeria (Spain);
(ii) twenty-two (22) oral and poster presentations presenting the Horticulture group's achievements at international conferences;
(iii) publication of 23 papers (10 with IF);
(iv) preparation of 11 grant proposals (Table 1).

The **MICRO-ECOLOGY** team

(i) twenty (20) outgoing visits by junior (3) and senior (17) researchers including: three months' advanced research training at the Centre for Environmental Sciences, Hasselt University under a member of the Advisory committee (Belgium) and Centre for Functional Ecology, Faculty of Sciences and Technology, University of Coimbra (Portugal) on plant-microbe interactions and plant tolerance to stress. The senior researchers' visits were focused on joint project preparation and included visits to: Centre for Novel Agricultural Products, Department of Biology, University of York (UK); Hasselt University (Belgium), Newcastle University (UK), Louisiana State University, Baton Rouge (USA)
(ii) twenty-one (21) oral and poster presentations presenting the Horticulture group achievements at national (3) and international (19) conferences;
(iii) publication of 23 papers (15 with IF);
(iv) preparation of 9 grant proposals (Table 1).

The **PLANT PATHOLOGY** team

(i) seven (7) outgoing visits by young (4) and senior (3) researchers including: five months' advanced training on techniques and methods used in molecular plant

pathology in studies on metabolic reprogramming and the regulatory role of key enzymes at Technical University of Munich (Germany) and three month study on mechanisms of resistance and cereal breeding for Fusarium sp. Resistance, University of Guelph (Canada) and North Dakota State University (USA). A potential co-operation in research on cereal pathogens, especially the Fusarium genus, was discussed by experienced researchers with the staff of Cereal Research Non-Profit Ltd. in Hungary.

(ii) 11 presentations on national and international conferences with participation of 2 young and 6 experienced researchers;

(iii) publication of 17 papers (15 with IF);

(iv) preparation of 9 grant proposals (Table 1).

The **FUNCTIONAL GENOMIC** teams was leading research group in absorbing new molecular and plant physiology techniques and methods used in their studies on plant tolerance/resistance to abiotic and biotic factors as proofed by:

(i) twenty-eight (28) outgoing visits by young (8) and experienced (20) researchers. The two to three-month research training of young researchers (and Ph.D. students, with approval of the Project Officer) included: molecular techniques in studies on the LSDI protein in programmed cell death at the Department of Plant System Biology, Ghent University (Belgium); advanced transcriptomic analyses-microarrays at the University of Essex (under supervision of a member of Advisory Committee); methods in studies on glutathione transport from cytoplasm to the cell nucleus and the effect on plant growth and photosynthesis or functional analysis of gene coding for the resistance genes in plants and pathogen effectors.

(ii) eighteen (18) oral and poster presentations reporting the WPHI project achievements on national (2) and international (16) conferences;

(iii) publication of 23 papers (22 with IF)

(iv) preparation of 18 grant proposals (Table 1).

Table 1. Grant proposals. Submitted international vs. awarded and expected outcome and amount. Submitted national vs. awarded and expected outcome and amount.

WP	Department	Number of Grant proposals					
		National			International		
		Submitted	amount applied (€)	Awarded	Submitted	amount applied (€)	Awarded
		Indicated Title		Y/N/TBA (if TBA indicated expected date)	Indicated Title		Y/N/TBA (if TBA indicated expected date)
2	Department of Applied Entomology	'Metabolomic and transcriptomic background of eggplant (Solanum melongena L.) defence and protection against herbivorous pests upon pre-treatment with chemical stimulant'	155654.57	N	'INHABIT: Invasive species on habitat boundaries: Impacts of common goldenrod and giant goldenrod on ecosystem functioning in riparian wetlands (WULS and SLU)'	124900	N
2	Department of Applied Entomology	'Changes in composition of secondary metabolites in fruits of eggplant (Solanum melongena) induced by herbivorous pests'		N	'How plant fertilization affect arthropod food web?'	16800	N
2	Department of Applied Entomology	'Systemic excess light stress signals in defences against aboveground and belowground herbivores in Arabidopsis' strategies'	246000	N	'Understanding the role of pathogens in bumble bee pollinated agro-ecosystems'	9000	N
2	Department of Applied Entomology	'Analysis of Arabidopsis thaliana small RNA-mediated defence responses to infestation by two-spotted spider mite (*Tetranychus urticae* Koch)'	321985	N	'Endophytic entomopathogenic Metarhizium anisopliae as a novel biocontrol mechanism in a different host plant'	6500	N

2	Department of Applied Entomology	'Precision Area-wide Management of Pests: native and alien plant pests in natural and manmade ecosystems'		N	'Native and alien pests in agriculture and forestry'	250000 (Part for WULS)	N
2	Department of Applied Entomology	'A broad and complex characteristics of the world wide collection of hulled wheat - spelt, emmer and einkorn accessions'	250000 (Part for WULS, Submitted with wp5)	N	'Insect ageing ethological aspects mechanisms and implications'		N
2	Department of Applied Entomology	'A broad and complex characteristics of the world wide collection of hulled wheat - spelt, emmer and einkorn accessions'	250000 (Part for WULS, Submitted with wp5)	TBA			
2	Department of Applied Entomology	'Pharmacological modulation of sucrose responsiveness and olfactory associative learning performance in European cherry fruit fly, Rhagoletis cerasi'	82700	N			
2	Department of Applied Entomology	'Research on semiochemicals emitted by plants and simulation of their volatile profiles'	7388400	N			
2	Department of Applied Entomology	'Pharmacological modulation of sucrose responsiveness and olfactory associative learning performance in European cherry fruit fly, Rhagoletis cerasi'	79946	N			

2	Department of Applied Entomology	‘Badania substancji semiochemicznych emitowanych przez rośliny pod kątem symulacji ich profili zapachowych’	7388400	N			
3	Department of Vegetable and Medicinal Plants	‘Application of biospeckle method for postharvest evaluation of quality of cucumber fruits, with emphasis on detection of chilling injuries’	8000	Y	‘Agricultural residues charring and torrefaction with a mobile unit for soil enrichment, carbon storage and use as a fuel’	400000	N
3	Department of Vegetable and Medicinal Plants	‘The influence of 5-aminolewulic acid and its derivatives on growth and physiological activity of tomato plants in conditions of high concentration of fertilizer (EC) in hydroponic culture’	200000	N	Innovative biodegradable mulching materials from organic waste products for horticultural application (INNOVAMULCH)	500000	N
3	Department of Vegetable and Medicinal Plants	‘Use of horseradish roots as a source to technological extraction of horseradish peroxidase (HRP)’	800000	N	‘Improvement of resilience and robustness in horticultural plants by their root system in segmented pot’	50000	TBA
3	Department of Vegetable and Medicinal Plants	‘Developmental and phytochemical variability of Stevia rebaudiana Bertoni in Polish climatic conditions to optimise micropropagation methods, cultivation and the quality and standardisation of raw material’	500000	N			

3	Department of Vegetable and Medicinal Plants	'Influence of the development phase and post-harvest activities on the quality of products processed with aromatic medicinal plants and antibiotic activity against hospitals the strains. Evaluation synergistic action of selected antibiotics'	500000	N			
3	Department of Vegetable and Medicinal Plants	'Implementation of spectrally-optimised LED sources of light to plant production under protection'	700000	N			
3	Department of Vegetable and Medicinal Plants	'Direct and indirect interactions between medicinal plants in designing polyculture'	40000	N			
3	Department of Vegetable and Medicinal Plants	'Study on optimisation of storage method for carrots grown for processing industry'	6000	Y			
4	Section of Basic Natural Sciences in Horticulture	'The role of trees and shrubs in the phytoremediation of PM in urban areas'	9000	Y	'An innovative strategy to exploit plants and their associated microbiomes for improving air quality and reducing the ecological footprint in cities, acronym: Plants4Cities'	7500000	N

4	Section of Basic Natural Sciences in Horticulture	'Enhancement of the degradation of polycyclic aromatic hydrocarbons in urban soils'	3000	Y	'Phyllosphere-microbe synergy: an innovative, eco-friendly, solar-powered Tool for better Air Quality, acronym: PhylloTAQ'	400000	N
4	Section of Basic Natural Sciences in Horticulture	'Molecular identification of mycorrhizal fungi accompanying trees cultivated in urban areas'	12500	Y	'Air Quality Monitoring and Awareness Technologies for Green City Infrastructures in Europe, acronym: AIRCITIES'	211000	Y in 1st stage, during preparation for the 2nd stage
4	Section of Basic Natural Sciences in Horticulture				'Post-Doc Fellowship for research in Azerbaijan'	1500	Y (awarded to Dr Robert Popek, but due to a time conflict he had to resign)
4	Section of Basic Natural Sciences in Horticulture				'Ecophysiological responses of urban trees to experimental drought condition'	1927,6	Y
4	Section of Basic Natural Sciences in Horticulture				'Response of isoprene emission and photosynthetic apparatus to urban stresses in sweet gum (Liquidambar styraciflua L.)'	1650,3	Y
5	Section of Plant Pathology	'Molecular marker for effective selection of rye (Secale cereale L.) with higher disease and sprouting resistance'	250000	Y	'Response of wheat genotypes to Fusarium species and influence of these pathogens on cell cycle of host plants'	without subsidy	TBA

5	Section of Plant Pathology	‘A broad and complex characteristics of the world wide collection of hulled wheat - spelt, emmer and einkorn accessions’	250000 (Part for WULS, Submitted with WP2)	N	
5	Section of Plant Pathology	‘A broad and complex characteristics of the world wide collection of hulled wheat - spelt, emmer and einkorn accessions’	250000 (Part for WULS, Submitted with WP2)	TBA	
5	Section of Plant Pathology	‘Fusarium temperatum significance and harmfulness in maize production, searching and characteristic of resistance sources’	62500	Y	
5	Section of Plant Pathology	‘Valdensinia heterodoxa biology and epidemiology’	50000	N	
5	Section of Plant Pathology	‘QTL responsible for F.subglutinans pathogenicity’	50000	N	
5	Section of Plant Pathology	‘Polish isolates of Allexivirus garlic viruses - detection, serological characteristics and molecular differentiation’	37500	Y	
5	Section of Plant Pathology	‘Correlation analysis between pathogenicity and genetic polymorphism of Blueberry Scorch Virus’	25000	Y	

6	Department of Plant Genetics, Breeding and Biotechnology	'Elucidation of the biological function of WD-40 domain-containing proteins in regulation of Arabidopsis seeds dormancy alleviation and germination'	75000	Y	'Plant parasitic nematode-informed strategies for sustainable broad-spectrum crop resistance'	239850	N
6	Department of Plant Genetics, Breeding and Biotechnology	'Role of CUL4-DDB1-based E3 ubiquitin ligases in the regulation of seed germination and dormancy alleviation of Brassicaceae seeds'	240000	Y	'Intelligent light systems for industrial plant production'	594000	Y
6	Department of Plant Genetics, Breeding and Biotechnology	'Tomato mRNA dynamics during cyst nematode pathogenesis'	100000	Y	'Tomato root proteome dynamics in response to potato cyst nematode infection'	269750	N
6	Department of Plant Genetics, Breeding and Biotechnology	'The analysis of inter-cellular photo electrophysiological signalling, ASCORBATE PEROXYDASE 2 expression, non photochemical quenching of excess excitation energy and their role in regulation of integrated stress responses in Arabidopsis'	188000	Y	'Chloroplast to nucleus signalling underpinning plant stress response'	320000	N
6	Department of Plant Genetics, Breeding and Biotechnology	'Identification and functional analysis of genes encoding putative factors involved in chloroplast to nucleus retrograde signalling during acclamatory and defence responses in Arabidopsis'	453000	Y	'Intelligent systems for breeding and cultivation of economically important trees optimised for biofuels, paper and modified wood production'	4000000	N

6	Department of Plant Genetics, Breeding and Biotechnology	'Novel molecular and cellular mechanisms of cell death regulation that depend on the chloroplast retrograde signalling and their influence on productivity and environmental stress tolerance in Arabidopsis thaliana'	680000	Y	'From poplar trees to synthetic petrol: Optimisation of the poplar cell wall composition and structure for hydrolysis and alcoholic fermentation'	1800000	N
6	Department of Plant Genetics, Breeding and Biotechnology	'Analysis of differences in transcriptomes of Medicago truncatula and Lotus japonicus root nodules in optimal and drought stress conditions using Next Generation sequencing (NGS)'	75000	Y	'From field-to-laboratory and crop-to-model: Rapid identification of novel genes responsive to high light in a crop in the field'	2300000	N
6	Department of Plant Genetics, Breeding and Biotechnology	'The relationship between plant response to parasitic nematodes and genetic control of programmed cell death'	304250	Y			
6	Department of Plant Genetics, Breeding and Biotechnology	'Systemic excess light stress signals in defences against aboveground and belowground herbivores in Arabidopsis'	246000	N			
6	Department of Plant Genetics, Breeding and Biotechnology	'The roles of small RNAs in plant-Tetranychus urticae interaction'	321985	N			
6	Department of Plant Genetics, Breeding and Biotechnology	'Tomato root proteome dynamics in response to potato cyst nematode infection'	271500	TBA			

3.5. Contribution to the Warsaw Plant Health Initiative project of the Faculty of Horticulture, Biotechnology and Landscape Architecture

The Project's impact on the research capacity, quality and international visibility of the Faculty and the university as a whole is presented in reference to the identified weaknesses of the SWOT analysis (original headings have been maintained for consistency).

Divergent research profiles of Departments within the FHB&LA.

Description: The FHB&LA consists of 13 Departments, each with its own research agenda, which could be broadly categorised into two groups: those dealing with Plant Health issues, and those dealing with environmental/landscape issues.

Comments: The problem of divergent research profiles and lack of co-operation among disciplines was already recognised by the Faculty staff during last 15 years. Several inter-departmental and inter-faculty projects were developed prior to REGPOT. Through the project activities within 'The Centre of applied biology' (5 Faculties, 13 departments, including laboratories on the arthropod pests and natural enemies' behaviour; molecular techniques in plant-pathogen studies, bio-technical methods in plant protection, started in 2005, were resumed.

While divergence still exists, the project has contributed significantly to shaking up the stagnating situation. The project (2011–2015) has greatly facilitated the implementation of interdisciplinary approach in plant health from the molecular to the landscape level on a wider scale. A number of initiatives in actual research as well preparation of new project proposals were undertaken during the execution of the WPHI project. The Government policy on financing the research and development projects involving interdisciplinary teams and industry has also contributed to a more active integration and opening to other disciplines at the University. Moreover, planned preparation of research and development projects under "Horticulture platform" (coordinated by the Research Horticulture Institute) will use the WPHI experience and include other research teams operating at the HB&LA Faculty, strengthening the Warsaw Plant Health Cluster.

Inadequate internal co-operation within the FHB&LA.

Description: Scarcity of funding and typically small project size, and also limited practical experience in networking and collective problem solving, all result in inadequate internal collaboration.

Comments: The results of the REGPOT WPHI project indisputably showed that the WPHI participants could work collectively on problem solving following the invaluable advice of the Steering Committee, sharing the use of advanced equipment, carrying out joint experiments and preparing new research proposals. Again, a new Government policy on the large research and development project supported by the National Centre of Research and Development as well the Horizon 2020 will force researchers into interdisciplinary collaboration. It should be noted that previous Ministry policy on research priorities and financial support favoured small projects under inadequate budgets for interdisciplinary research.

The recent organization of a Faculty scientific seminar, mandatory for Ph.D. students (and open to staff), as recommended by the REGPOT Advisory Committee, was one of the main first positive steps undertaken to widen participation of your scientists in interdisciplinary research.

The WPHC efforts in breaking the silos of traditional disciplines at the University is further confirmed by the recommendation listed in EASAC Report 24 (2014): "Supporting this multi-

disciplinary research strategy by reducing fragmentation of research capacity and priority-setting across Member States to sustain critical mass" (www.easac.eu.; p. vii).

Unclear research strategy and priorities at the WPHC level.

Description: Inadequately defined research strategy and priorities, divergent and opportunistic (grant-dependent) growth resulted in scattered research efforts with reduced impact chances.

Comments: The key WPHI project achievements are related to closer integration of the researchers involved through regular management meetings on problem solving, again fostered by the Steering Committee as well as by participation in symposia and workshops to improve the understanding of the molecular, physiological and ecological mechanisms of plant health. All together, the activities have brought innovation to Integrated Crop and Pest Management and at the same time, meeting farmers' and politicians' expectation to maintain the position of Poland as a leading producer and exporter of horticulture products in Europe and globally. The short- and long-term strategy on research and technology development of integrated production and protection of fruit and vegetables were extended.

The general problem of integrating horticulture enterprises and organisations with research institutes, due to their dispersion and small size in Poland, still remains: mainly low budget, joint project between some industrial and business entities and the Faculty researchers are in operation at the Faculty.

Skewed staff age structure and "competence vanish".

Description: During a period of political transformation and economic hardships, the influx of young scientists was substantially reduced. As a result, the staff age structure is now heavily skewed, with unsustainable dominance of senior staff. Lack of trained successors in some disciplines results in "competence vanish".

Comment: Some progress took place in the staff age structure as the result of the WPHI project at the Faculty. In the Department of Applied Entomology, one assistant professor specialised in host plant-pest interaction and biological control returned from maternity leave, and the opening of another position is under consideration; in the Section of Plant Pathology, 3 retired professors were replaced by an assistant professor (2014) and are there are plans to open a position for one research associate (2015). Five young researchers, financed by the REGPOT project, continue their employment in the Department of Genetics, Breeding and Biotechnology or other institutions and one was offered the position of assistant professor at the Department of Botany, closely co-operating in the plant health programme on host plant-nematodes' molecular and biochemical interactions. There are submitted grant proposals still awaiting a final decision (some with high chances) including Postdoctoral research positions.

The REGPOT project prompted the establishment of the new undergraduate programme of studies on 'Plant Health Protection': 63 new students, starting 1 October 2015, at the HB&LA Faculty will increase demand for at least 3 new academic positions. The REGPOT project trained young scientists, and with their international training they will be considered as potential candidates in crucial departments for plant health education and for continuing research projects.

Competence gaps within WPHC.

Description: Insufficient or missing modern cross-disciplinary developments, such as molecular barcoding taxonomy, GIS-based predictive modelling of pest distributions and shifts due to climate change, genetic tracing of pest population origins, micro- and nano-encapsulation of semiochemicals, professional bioinformatics support, system level understanding of signalling machinery in biotic and abiotic stresses, microbe and pathogen molecular identification, micro-ecology of endosymbionts, novel indicators of fresh produce quality, etc.

Comment: The progress on the acquisition of specialised expertise has been largely satisfactory (see above). Training of young scientists, working on the project as well participation of the WPHI and other Faculty staff in workshops and international conferences enhanced their competence in modern methods and filled knowledge gaps. Unfortunately, two experienced researchers of international status, specialised in micro-and nano-encapsulation and modelling of insect behaviour, and in molecular biology could not secure further funding and could not be retained. The Faculty is currently undertaking negotiations to evaluate their possible return.

Insufficient staff mobility.

Description: Lack of explicit and operable policy-links between international staff mobility and staff career progress hamper staff mobility. Shortage of resources for: staff exchange, foreign visiting scientists, and experienced Polish returnees, attending conferences.

Comments: There is actually no strict system in place at the University to evaluate staff performance with regard to their international mobility. As demonstrated by the WPHI, the staff training and their participation in the research of EU leading laboratories often resulted in faster publication in journals with higher impact factor. The enhanced competence of the WPHC's young and senior participants should increase their chances in the highly competitive application process for new grants, including staff exchange and participation in the international conferences. Documented activity of the Faculty staff representatives in the COST action programmes and other EU networks (e.g., IOBC, EFSA), organisations and scientific societies, indicates a good level of staff mobility in some departments. It should be emphasised that the mobility of other departments with previously low level of participation in the international activities was significantly activated by the REGPOT WPHI project and should continue after the project's termination.

Still insufficient visibility and co-operation within ERA

Description: Although good examples exist, engagement in organising international workshops and conferences, presentation and promotion of strengths and achievements, networking and collaboration, capacity to develop international projects (especially FP-7) – all need to be substantially enhanced.

Comments: The number of the Faculty staff, national and international experts in the executed symposia, workshops and out-going visits indicates substantial growth in the visibility and dissemination of the Faculty achievements in the plant health science: 8 national conferences (23 poster/oral presentation) and 66 international conferences (91 poster/oral presentations).

4. POTENTIAL IMPACT AND MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION RESULTS

Both the Advisory committee and the Evaluation team members acknowledge that the project has vast social and economic impact because of steady demand for "green" and healthy fresh fruit and vegetables produced in a sustainable manner, especially in the context of climate change and pest translocation. Since its beginning, the WPHI project emphasized the importance of molecular techniques in basic research but also tried to implement one of the EASAC recommendations: "Assigning higher priorities to better use of research advances in support of innovation and the translation of knowledge from research centres to practical application in support of plant health" (EASAC Report 24, p. viii).

NATIONAL IMPACTS - creation of the long-term partnership with end users, public institutions, farmers and advisers.

During the reported period, the WPHC, with a long track record of close co-operation with government agencies and practitioners, continued to support their new initiatives related to the implementation of EU Directive 2009/128/EC and the National Action Plan on sustainable use of pesticides and obligatory implementation of Integrated Pest Management (IPM). Various groups of stakeholders, especially SMEs and agro-business, were engaged in the organised events (mini-symposia, workshops and national meetings with practitioners), implementing results of innovative research and its products, thus enhancing WPHC contribution to economic and social development.

These activities were carried out at four levels:

(a) contribution to the improvement of national recommendations for pro-ecological plant protection methods of field crops and grown undercover. Participatory approach based on results of regular surveys on knowledge, attitude and plant protection practices in orchards and field vegetables among 1300 farmers (2004–2014) indicated their need for improvements and priorities for additional research. These needs and the project research results were presented regularly between 2012–2015 at the national meetings on plant protection to representatives of the Ministry of Agriculture and Rural Development, the State Inspection of Plant and Seed Protection, agriculture research institutes, state and private extension services and farmers. The WULS scientists chaired sessions, gave 4-5 oral and poster presentations during annual meetings and conferences organised by the Plant Protection Institute (Poznan) (750 participants in 2012; 600 in 2013; 500 in 2014; and 550 in 2015). The WULS scientists actively participated in work of the programme committee, chaired session and contributed with presentations and discussion during annual conferences on integrated plant protection of orchards organised by the Horticulture Research Institute (HRI) (Ossa, Warsaw). The majority of the 600–1200 participants (2012 – 1100 participants; 2013 – 900; 2014 – 1100 and 2015 – 600) at the HRI meetings were always fruit growers and staff of extension services and private firms. The WULS staff presentations contributed to improving the recommendations on present national IPM programmes by: using more sensitive detection and identification methods of pathogens intra-species variation, suggesting protection methods against new or lesser-known diseases, improved monitoring techniques of orchard pests, promotion of bio-stimulants and other biological methods strengthening plant tolerance to pests and pathogens and enriching and/or maintenance of ecological infrastructures inside and outside fields to minimised crop losses. The need for protection and/or enhancement of antagonistic organism populations by implementation of alternative plant protection methods was always emphasised.

(b) influence of the WULS PHI staff on research strategy and policy on plant health in Poland by active participation in the scientific committees of the Polish Academy of Science. Some WULS staff were elected as: the chairman of Plant Protection Committee, deputy chairperson of Committee of Horticulture Sciences and secretary of Biotechnology Committee; a presidium member of the Committee of Plant Physiology, Genetics and Breeding, in addition to 4 other WPHC staff as the committee's elected members. Some themes of the REGPOT mini-symposia evoked wide interest of scientists, practitioners and industry and were later expanded to the national conferences organised under the Plant Protection Committee, e.g., "Current problems in weed science" (5/02/2014, Poznan) or "Possibilities of using molecular methods in detecting pest resistance to pesticides" (11/02/2015, Poznan). Three participants of the WULS PHI are members on the Scientific Boards of three research institutes: the Horticulture Research Institute, the Institute of Plant Breeding and Acclimatization and the Institute of Agriculture and Forestry Environment, evaluating their performance and formulating their research policy.

The Committees of the Polish Academy of Sciences, through their released statements and memoranda, tried to attract the attention of the politicians, the public and government authorities on urgent problems affecting science such as the problem of IPM on minor horticulture crops; inadequate government support for basic and applied research (only 0.9% versus European 1.9% GDP), rapid 30% budget reduction for agriculture research (2000–2009) or on health and environmental controversial issues related to GMOs.

(c) integrating students' research and education using an integrated and holistic approach to plant health in Poland. In response to the request of the Ministry of Agriculture and Rural Development on filling gaps in professional staffing of plant protection extensions capable of implementing the knowledge-based Integrated Pest Management, a conference was organised by the Project staff (but not financed by the REGPOT project) on: "Changes in education programmes on plant protection in the perspective of Directive 2009/128/EC implementation" (2012, WULS, Warsaw for members of the Plant Protection Committee and other university academics. Invited lectures on requirements expected from university graduates by plant protection firms and enterprises were included in the programme. As a result, four new B.Sc. and M.Sc. education programmes on plant medicine, based on a new curriculum emphasising the pro-ecological paradigm were established at the Universities in Lublin and Wrocław 2012), Poznań in 2013 and at WULS in 2015.

The urgent need for additional training of specialists in Integrated Crop and Pest Management (ICPM) came from the National Action Plan on IPM. The shortage of plant protection specialists in the national extension service was caused by the political and economic changes in Poland in '90s. The previous role of Plant Protection and Quarantine Service in providing expertise on plant health to farmers was adopted to other European services and the professional advisement service for farmers was deleted from their duties. At the same time, the new responsibilities of the state extension service were mainly concentrated on implementing the EC recommendation on sustainable farming systems, allocation of subsidies and preparation of plans for farm adjustment to new regulations.

Currently, the role of plant protection extensions is supported by a private advisory service (a number of WULS graduates are involved) or additionally trained staff of the national extension service. The WULS staff contributes to their advanced training in ICPM by participating in the post-graduate weekend schools on integrated crop production and protection (training of trainers). The impact of upgraded research facilities and increased scientific competence of the REGPOT scientists will also enhanced professional quality of the university graduates in plant health at WULS.

(d) creation and fostering direct collaborative interactions with agro-business and industry.

Three WPs (2-4) continue close co-operation with: (i) Arysta Life Science Poland on introducing pro-ecological methods of plant protection against diseases and pests based on bio-stimulants and biological products; (ii) BASF Poland and Bayer Crop Science in demonstration and dissemination of knowledge between farmers and advisers on functional biodiversity enhancing population of the pest natural enemies and pollinators; (iii) Syngenta and Koppert Biological Systems on the introduction of new species of natural enemies into horticulture crops. As a result of the mini-symposium on weed resistance to herbicides (WP 4), Bayer Crop Science and Du Pont Polska expressed their interest in supporting additional research in this field and Bayer co-financed national conference (approx. 80 participants) on using molecular methods in studies on pests, disease and weeds resistance to pesticides (emerging consequence of reduced rotation between pesticides followed by the EC pesticide legislation reducing number of approved pesticides affecting the range of the chemical control options).

In addition, the WP 3 team expanded its collaboration with several SMEs in two areas: (i) improving plant health by crop management and (ii) maintaining high nutritional value and eliminating its postharvest deterioration (e.g., COOLEX Karczew Poland (postharvest technology of vegetable crops, controlled atmosphere and ULO technologies), AgroFresh Poland (1-MCP application in postharvest), PUH Chemirol (innovative fertilizers for vegetable production), SVZ Tomaszow Lubelski (integrated production of root vegetables for processing industry), Syngenta (testing new vegetable cultivars for integrated production), BASF Poland (new chemicals for vegetable production), Horticultural Farm Piotr Florianczyk (introducing new technologies improving plant health in tomato and sweet pepper in greenhouse production), Dary Natury (ecological production of medicinal plants and spices, use of medicinal plants as the source of biologically-active compounds for human and in ecological plant protection), P.U.H. "PUCH" Wojciech Pietron (Modified Atmosphere Packaging in postharvest of perishable crops)). The newly implemented regimes by farmers and distributors on vegetable production, harvesting, packaging and storage are behind the recent rapid growth of vegetable export into international markets in addition to the already well established export of the Polish fruits and their processed products.

The strategy of WP6 leads to the development of realistic and active links with SMEs. Some of their activities are actively involving SMEs as partners in R&D projects, some actions have a realistic application perspective but they are still in the discovery phase.

The project on "Intelligent light systems for industrial plant production" has several business partners, such as "Danko Breeding Company Ltd.", "Poznan Plant Breeding Ltd.", "Kutno Sugarbeet Breeding Ltd." and "Smolice Plant Breeding Ltd.". The WOODTECH project, aiming to biotechnological improvement of mechanical and energetic properties of wood, has a serious application perspective for application in the paper, furniture and bio-fuel industries. Another WP 6 team, in close co-operation with German and Dutch scientists, is working on the development of cyst nematode resistance by screening gene expression perturbations leading to lower susceptibility to nematode attack. The candidate genes are tested and as a result we indicate the targets for molecularly based resistance breeding using new gene editing technologies, for example. The WP 6 is part of the Department of Plant Genetic, Breeding and Biotechnology, where plant breeding activity for improved quality, environmental and disease resistance covers much broader crop species. The "W. Legutko Breeding and Seed Company Ltd." is producing and distributing vegetable varieties of tomatoes, pumpkins, squash and sweet peppers bred in the Department.

(e) direct impact of the WULS academics on end users (extension service and farmers).

Regular participation of the WULS staff in the national meetings with participation of farmers and staff of extension firms and state service were described above. The results of the regularly carried out survey on the knowledge, attitude and practices (KAP survey) gave an impulse to initiating new research projects and/or preparation of literature review on relevant topics and existing recommendations on ICPM, e.g.: (i) demonstration of economic benefits from individual monitoring of pests and diseases in fruit and vegetable production or (ii) identification of infestation symptoms of newly-emerging problems of pests and diseases for a given crop plant. The KAP survey also demonstrated substantial improvement in obeying rules of safe preparation and application of pesticides by fruit producers in central Poland. The changes in the farmers perception of pesticides' potential negative effects during the last ten years were presented during the national meeting on "Safety in fact", organised by Bayer CropScience (approx. 300 participants) at the WULS and following press and video releases.

The Faculty is organising annual "open days" meetings, such as: (i) "Experiment orchard in Wilanów" gathering farmers, advisers, distributors of pesticides and biological control products, publishers and the general public; (ii) "Melon's day" and "Cucurbitaceae – for health". The staff is also engaged in training fruit and vegetable producers, which is organised by the food processing industry and farmers' organisations.

The post-graduate professional activities of well-trained WULS M.Sc. graduates in integrated crop production and protection contributes to the sustainable development of horticulture crops in three ways: (i) by their return to their farms and implementing ICPM; (ii) organising new SMEs or joining staff of existing SME firms specialised in the IPM advising; and (iii) combining farming with the dissemination of practical IPM through technical publication in the professional press or participation in farmers' training. The government policy on obligatory implementation of integrated pest management (IPM) by farmers imposed by Directive 2009/128/EC partly relays on enhancing active role of SME advisory firms.

INTERNATIONAL IMPACTS

International impacts of the WULS PHI project should be evaluated in the perspective of the recommendation listed in the reports prepared by the Science Advisory Council of European Academies, presented by J. Schieman on: "Risk to plant health: European Union strategic priorities for tackling emerging plant pests and diseases" and "Planting the future" during the EC Innovation Convention 2014 (10-11 March 2014, Brussels) (www.easac.eu). The reports included the following main points: (i) challenges for food security and the environment; (ii) risks to plant health; (iii) approaches to tackling risks; (iv) opportunities for science and technology; and (v) recommendations.

The EASAC also recommended undertaking the following innovations and regulations in Europe:

- Improving translation of research findings for practical application.
- New control approaches to overcome current limitations of pesticides and respond to challenges of pesticide legislation.
- Breeding improved plants that are resistant to biotic stresses using the whole portfolio of new innovative crop genetic improvement technologies.
- Using sound scientific, evidence-based approaches to inform proportionate regulatory frameworks.
- Considering opportunities for strategic linkages across plant-animal-human health ("One health").

The WULS PHI, through its mini-symposia and workshops, upgraded research facilities and expansion of international scientific contacts, addressed the majority of the above listed activities, especially the symposium on "Updated policy on plant protection

research in response to new pathogens, pests and weeds emerging in the European Union" with the participation of the Czech Republic, France, Denmark and Poland represented scientists, policymakers and regulators in plant health which critically reviewed available and/or missing options for Integrated Pest Management programmes included in Annex III of Directive 2009/128/EC. Short-term priorities to fill gaps in the IPM recommendations and long-term strategies of using alternative plant protection methods as: semiochemicals modifying pest behaviour, antagonistic micro-organisms and molecular methods in developing resistant plants to abiotic and biotic stimuli were identified.

The WULS PHC international impact can be summarised as follows:

(a) meeting EC standards on food safety via the contribution to pro-ecological plant protection methods implementation in Poland. The WULS PHC impact on the Polish horticulture sector implemented pro-ecological methods of production and protection has a direct effect on the quality of products offered on international markets. Poland, as a leading European exporter of fresh and processed fruits and vegetables (apples, soft fruits, high-bush blueberries, tomatoes, etc., totalling EUR 1,990M in 2013), has to meet European consumer requirements for safe foods, with a minimal approval level of pesticide residues, mycotoxins and human pathogenic microorganisms. Some countries accept only certified products grown under Integrated Production systems, with the restriction of using of pesticides with negative effects on pest natural enemies and environment.

(b) increased knowledge, visibility and intensity of collaboration within Europe through: Twenty-three (23) young staff exchange visits lasting 4–12 weeks (12 took place in the Partner institutions) and 111 out-going national and international consultations by both senior and junior participants. Promotion of WPHC accomplishments and competitive advantages implemented through participation of 123 junior and senior staff in international and national conferences, meetings, and workshop (with 32 oral and 67 poster presentations); 188 in-coming visits, including participation in the WULS PHI symposia and workshops.

(c) active participation in the seven COST programmes and three working groups of International Organization of Biological Control, co-organising (outside REGPOT budget) two international conferences in Poland in 2014 (WP2 and WP6).

(d) creation of new and challenging opportunities for better integration of the selected WULS PHC research teams in the European Research Area and developing joint research projects with European partners. Potential contribution of the WULS PHC teams in the Horizon 2020 joint project covers areas recommended by the European Academies on plant health and presented by Prof. J. Schieman during the EC 2014 Innovation Convention. - cit. "Pest and disease diagnosis and characterisation, and relationships with hosts and vectors; ecology and epidemiology; mechanisms of plant diseases resistance; biological and cultural strategies for sustainable pest and disease management".

The WPHI teams participating in the project are likely to be recognised as partners worth co-operating with interesting for researchers both national and within ERA. Members of the WPHI, beyond the project lifetime, declare to continue and enhance the collaborative, cross-disciplinary interactions among Cluster research teams and are open to co-operation with experts from other departments and faculties of WULS-SGGW, national scientific institutions but most of all within ERA. They are also open to **join new avenues of research to the extent that they are experts**. Areas of expertise of WPHI members are as follows:

- Ecological, behavioural and physiological aspects of phytophagous and predatory Acari (especially Eriophyoidea).
- Persistent vs. temporal effects of enhancers of natural and chemical plant defence against arthropod herbivores.
- Effect of ecological infrastructures on regulation of herbivorous pest populations, their natural enemies and pollinators.
- Stochastic modelling of on-farm pest behaviour and IPM with complex spatiotemporal mosaic of farming ecosystem.
- Field production of various vegetable species and greenhouse production of leafy and Solanaceous vegetables and cucumber.
- Bioactive compounds in raw plant material and factors affecting biological value of vegetable, aromatic and medicinal plants.
- New fertilizers and biostimulants in plant production.
- Postharvest physiology and technology of vegetable, aromatic and medicinal plants.
- Soil management, plant nutrition, mode of action of biostimulants and physiological diseases in horticultural plants.
- Weeds' resistance to herbicides: appearance, biology of reproduction and prevention: determination from field to genome level.
- Functional biological infrastructure in humanosphere.
- Plants with its microbiome - key element in successful phytoremediation.
- Plant viruses and modern methods of their detection and characterisation.
- Mycology – various aspects of fungal biology, taxonomy, biodiversity, and biotechnology/agricultural application as a biocontrol agent.
- Modern plant disease diagnostics methods, isolation and characteristics of causing factors.
- Flow cytometry analysis in microbiology.
- Nematology.
- Precision plant phenomics.
- Transcriptomics of biotic and abiotic stress.
- Bioinformatic analysis of *cis* and *trans* gene regulatory elements.
- Regulation of plant development by light quality and quantity,
- Small RNA transcriptomics.
- Genetic modifications of crop and model plants.

Members of the WULS Plant Health Cluster are in the process of grant proposal applications, inter alia, for Horizon 2020 program. Researchers from the area of plant-microorganism interactions submitted a project entitled, **Phylloshere microbe synergy: An innovative, eco-friendly, solar powered tool for better Air Quality,** and are planning to submit a project entitled, **An innovative strategy of exploiting plants and their associated microbiomes for improving air quality and reducing ecological footprints in cities** with 28 other participants from 11 countries (9 European, USA and China). Researchers from the area of crop production, are preparing to apply for funds in **Marie Skłodowska-Curie actions** together with 8 other European research teams. Also, members of WPHI teams are actively participating in several COST Actions.

Apart from those mentioned, over a dozen project proposals were submitted to national funding agencies in all five areas of plant health research.

Along with the progress of the WPHI project, an effort will be undertaken to apply for a project or projects that will provide a basis for further collaborative and enhanced co-operation between research teams in the Warsaw Plant Health Cluster. The programme of WPHI project, from a long-term perspective, will also play an important role, as it provides a start point for preparing highly-qualified specialists that should continue and enhance the

achievements of WPHI. For this, a decision was taken to enhance education programmes via creating a new field of a study for a BSc. (engineering) course called **Plant Health Protection** starting October 2015.

In the medium term, the result of studies on plant resistance to pest, semiochemicals, manipulating pests' and natural enemies' behaviour and functional biodiversity will be integrated into the "push and pull strategy" of crop protection against pests and diseases under various agriculture systems (ecological and integrated crop production). This concept has been proposed by British scientists and already tested on a maize cropping system in Kenya. In the long term, we expect to use molecular techniques not only to identify plant-pest interactions but also to develop new cultivars that are resistant to biotic and abiotic factors. Expanding plant health to the healthy environment for healthy people, the internationally joint project with the role and potential application of plant microbiomes in phyto-remediation, was prepared with partners from the EU, USA and China.

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