Measuring the general phytosanitary situation: development of a plant health barometer

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Abstract

The development of a plant health barometer, an instrument to measure the general phytosanitary situation on a national level (Belgium) and on a yearly basis and to monitor its evolution over time, is described. The elaboration of a set of 13 plant health indicators (PHI's) as the basis for the plant health barometer is discussed. These indicators were weighted by experts - including scientists, policy makers and agro-industrial representatives - to determine their relative impact in the barometer. The result of the barometer is expressed as a comparison with the previous year. Based on the results of the 13 PHI's, it is concluded that the general plant health in Belgium shows a positive evolution from 2007 until 2010 and a negative evolution from 2010 until 2012. The plant health barometer provides a overview of the phytosanitary situation of plants and plant products in Belgium and is a tool to communicate in an intelligible, comprehensible manner on aspects of plant health to consumers and professional stakeholders in the plant production chain. Together with the food safety barometer and the animal health barometer, the plant health barometer is one of the three instruments to provide a overview on the general status of the safety of the food chain in Belgium.

Keywords
Barometer – plant health – phytosanitary situation – Belgium

1. Introduction

There is an increase in exposure of plants and plant products to pests and diseases (harmful organisms) in particular due to globalisation and climate change (Bezirtzoglou *et al*. 2011; Pautasso *et al*. 2010). If present, these harmful organisms can have a significant negative economic impact on the plant production chain (yield losses, plant consignments/batches to be destroyed, closed export markets…). Furthermore the EU is a contracting party to the International Plant Protection Convention (IPPC) and has thus to satisfy a series of obligations, including the implementation of a phytosanitary legislation. This is why, within the EU, a Community Plant Health Regime (CPHR) was already established as soon as 1977 (Council Directive 77/93/EEC). This CPHR aims to protect crops, fruit, vegetables, flowers, ornamentals and forests from these harmful organisms by preventing their introduction into the EU or their spread within the EU. The basic legal framework of this CPHR is the Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. This CPHR was subject to an in-depth evaluation (FCEC 2010). Following this evaluation, specific recommendations were formulated to further develop prevention, risks targeting (prioritisation) and solidarity between Member States. Based on this evaluation, the European Commission has submitted a proposal for a new EU plant health regulation in May 2013 to the European Parliament and Council for co-decision, which may take several years before final adoption. This future new CPHR might have implications on the plant health barometer discussed in this paper. In Belgium, the phytosanitary policy is modelled on the European legislation on these matters (Royal Decree of 10 August 2005 on the control of organisms harmful to plants and plant products).

In addition, the safety of the food chain has been reinforced by the general implementation of procedures based on the 'Hazard Analysis and Critical Control Points' (HACCP) principles treated by the General Food Law (Regulation (EC) 178/2002) and the European Hygiene legislation (Regulation (EC) 852/2004). In the various EU Member States competent authorities inspect and audit the

implementation of 'Good Agricultural Practices' (GAP) and HACCP based procedures. These procedures are also applicable in the plant production chain and have an indirect effect on plant health as such.

In 2000, the Belgian Federal Agency for the Safety of the Food Chain (FASFC) was created (Law of 4 February 2000) as a response of the government to the dioxin crisis, which had revealed the lack of coordination between different inspection services of the food chain. The expectations regarding the organisation of the food chain control system were clearly defined and were meant to cover the entire food supply chain from farm to fork (starting from the raw materials and the feed to the rearing of food production animals up to their transformation into food), with the objective to protect public health, animal health and plant health.

All respective segments within the food chain bear their own responsibility to ensure that safe food is offered to the consumer, without the hazardous presence of biological, chemical or physical agents. Controls and inspections concerning the sanitary status, hygiene and infrastructure, animal health and plant health, and the safety of animal and plant products are important tasks performed by the Belgian FASFC. The results are published in annual activity reports, which can be consulted on the FASFC website (http://www.favv-afsca.fgov.be/rapportsannuels/). However, these results do not provide a simple general picture of the evolution of the safety of the food chain. Therefore, the 2009 FASFC business plan mentioned the need to identify a set of indicators to measure and follow-up the safety within the food chain (Houins 2009). This task was dedicated to the Scientific Committee of the FASFC (Scientific Committee 2010). The idea to develop a barometer to measure the safety of the food chain fits within the context of the prevailing trend towards measurable objectives, performance indicators, assessments, score systems and the like. This idea was also inspired by the introduction of similar notions in other sectors, such as the Belgian inter-federal poverty barometer (2011) and the Belgian sustainability barometer (Sustainable Development Task Force 2009).

The concept of the measurement of the safety of the food chain and the illustration of the case study of the food safety barometer has been described in detail by Baert *et al*. 2011 and 2012. The present paper discusses the development of a plant health barometer as a practical tool for measuring and monitoring the general (national) phytosanitary situation of plants and plant products.

2. Materials and methods

To identify the indicators suitable to determine plant health in a well-substantiated manner, the following approach was developed.

2.1. Scope of the barometer, key activities and definition of an indicator

The scope of the plant health barometer is restricted to the presence/absence of only quarantine harmful organisms, i.e. those regulated under the Law of 2 April 1971 on the control of organisms harmful to plants and plant products. The presence/absence of these quarantine organisms defines the phytosanitary situation. The term "plant health" does not therefore cover the presence/absence of non-regulated harmful organisms, namely the agents responsible for endemic diseases such as late blight. This term neither covers abiotic diseases such as those caused by the lack or excess of water, of trace elements, of herbicide residues or caused by the excess of salt or by frost.

The term "food chain" encompasses all possible stages of the food supply chain from farm to fork. Plant health indicators (PHI's) are therefore also chosen to cover the entire plant production chain, that is to say at the suppliers level (seeds/propagating materials, soil conditioners...), at the primary production level (farm, plant nursery...), at the distribution level (including imports), at the processing level (wood packaging materials, cut flowers...) and at the level of green spaces/forests.

Numerous controls and inspections are routinely conducted by the FASFC in order to monitor plant health (phytosanitary situation) and the related activities by the operators. An overview of most of these measurement data is publicly available in the annual reports of the FASFC.

PHI's have been selected covering key activities along all the stages of the plant production chain. These activities encompass a considerable production volume, and/or may have a significant impact

on the safety of the plant production chain in general and on plant health more precisely. Key activities are for example the seeds or propagating materials production or the field crops production.

An indicator synthesises or simplifies relevant data about the status or evolution of a number of phenomena or symptoms. An indicator can assume either a quantitative (cardinal) or a qualitative (nominal or ordinal) form, in accordance with Sustainable Development Task Force (2009).

The PHI's as used in the plant health barometer are not performance indicators, in the sense that it is not being used for evaluating the performance level of a certain set of activities neither of the performance of the Phytosanitary Services, as is often done in a management context where the goals have been clearly set. The PHI's are basically descriptive in nature. The ultimate goal is to introduce a systematic operating procedure based on this barometer in order to enable the monitoring of the phytosanitary situation, in an accessible way to a broader public and to observe or analyse trends over the longer term.

The barometer's outcome is a measure for the level of plant health of the national 'plant population' at the end of a determined period (e.g. one year) compared to a previous year. In the present study this figure basically relates to the presence of hazards (pests and diseases) within the plant production chain and the existence of preventive systems for controlling and reporting such phytosanitary hazards. Information about the state is collected yearly via the core activities of the FASFC and external partners.

2.2. Selection of indicators

Earlier work on the development of a barometer for the safety of the food chain (Baert *et al*. 2011) has determined a number of criteria have been established for the selection of indicators. As far as plant health is considered, indicators should respond to the following characteristics: be measurable, independent, reliable, easily available, representative for plant health, representative for the plant production chain, unambiguous and sustainable.

Based on the above-mentioned criteria, a set of 13 different indicators was composed (Table 1). A detailed technical sheet for each PHI is available on http://www.favv-afsca.fgov.be/scientificcommittee/advices/_documents/ADVICE10-2011_EN_DOSSIER2009-09ter_appendix1.pdf.

Table 1: Overview of the plant health indicators.

Title	Description	Interpretation
PHI1: Mandatory notification of plant diseases and harmful organisms	The number of notifications received by the FASFC each year with regard to the detection of plant diseases and harmful organisms.	Given that mandatory notification is an inherent part of the preventive approach, and is crucial for the authorities to establish timely control measures for preventing the spread of plant pests and diseases, an increase of the indicator is therefore considered as an indication of vigilance and alertness with regard to the safeguarding of plant health and is therefore interpreted as positive.
PHI2: Self-checking for plant production	The percentage of annual key activities performed with a validated/certified self-checking system in the plant production sector.	An increase of the percentage of key activities with a validated/certified self-checking system indirectly leads to a higher confidence level with regard to adequate preventive actions taken in order to ensure general plant health. An increase of the indicator is therefore interpreted as positive.
PHI3: Phytosanitary inspections (physical checks)	The percentage of annual phytosanitary inspections (physical checks) that were deemed to be favourable or favourable, subject to remarks.	The indicator measures the extent to which the operators have met the legal requirements concerning plant health. An increase of the indicator is therefore interpreted as positive.
PHI4: Phytosanitary inspections (traceability)	The percentage of annual phytosanitary inspections related to traceability that were deemed to be favourable or favourable, subject to remarks.	The indicator measures the extent to which the operators have met the legal requirements concerning traceability with regards to plant health. An increase of the indicator indicates a better functioning of the ability to trace and monitor plants and plant products through the various production, processing and distribution phases and is therefore interpreted as positive.
PHI5: Harmful organisms regulated and detected in Belgium	The percentage of regulated harmful organisms for which at least one sample is tested positive per year in Belgium in relation to the total number of regulated harmful organisms.	The indicator measures the extent to which plants and plant products are subject to the pressure of harmful quarantine organisms. An increase of the indicator is therefore interpreted as negative.
PHI6: Phytosanitary import controls	The percentage of samples of plant and plant product consignments, imported into the EU via the Belgian border inspection posts, which are compliant with the phytosanitary requirements.	The indicator demonstrates that the active plant and plant product import operators comply with the legal requirements with respect to plant health. An increase of the indicator is therefore interpreted as positive.
PHI7: *Bursaphelenchus xylophilus* (Pine wood nematode)	The annual percentage of compliant results in relation to the control of pine wood nematode (*Bursaphelenchus xylophilus)* within the framework of the FASFC control plan.	The indicator measures the presence of pine wood nematode within the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.
PHI8: *Meloidogyne chitwoodi*	The annual percentage of compliant results with respect to the	The indicator measures the presence of root-knot nematodes within

and/or *M. fallax* (Root-knot nematodes)	control of root-knot nematodes (*Meloidogyne chitwoodi* and/or *M. fallax*) within the framework of the FASFC control plan.	the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.
PHI9: *Globodera rostochiensis* and/or *G. pallida* (Cyst nematodes)	The annual percentage of compliant results with respect to the control of cyst nematodes (*Globodera rostochiensis* and/or *G. pallida*) within the framework of the FASFC control plan.	The indicator measures the presence of cyst nematodes within the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.
PHI10: *Ralstonia solanacearum* and/or *Clavibacter michiganensis* subsp. *sepedonicus* (Potato brown rot and/or ring rot)	The annual percentage of compliant results with respect to the control of potato brown rot and/or ring rot (*Ralstonia solanacearum* and/or *Clavibacter michiganensis* subsp. *sepedonicus*) within the framework of the FASFC control plan.	The indicator measures the presence of potato brown rot and/or ring rot within the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.
PHI11: *Pospiviroidae*	The annual percentage of compliant results in relation to the control of *Pospiviroidae* within the framework of the FASFC control plan.	The indicator measures the presence of *Pospiviroidae* within the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.
PHI12: *Diabrotica virgifera* Le Conte (Corn rootworm)	The annual percentage of traps found to be free from corn rootworm (*Diabrotica virgifera* Le Conte) within the framework of the FASFC control plan.	The indicator measures the presence of corn rootworm within the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.
PHI13: *Phytophthora ramorum*	The annual percentage of compliant samples tested for *Phytophthora ramorum* within the framework of the FASFC control plan.	The indicator measures the presence of *Phytophthora ramorum* within the Belgian plant production chain. An increase of the indicator, i.e. an increase in the percentage of compliant samples, is therefore interpreted as positive.

This set of indicators covers all stages of the entire plant production chain (suppliers, primary production, distribution/trade, propagating of plants, processing of plants (e.g. wood packaging materials, cut flowers etc.), forests and green spaces) and the various types of plants and plant products (fruit, vegetables, potatoes, cereals, ornamental plants (including trees), plants/seeds, cut flowers, wood packaging).

Some indicators (PHI1, PHI2, PHI4) are related to the preventive approach of the phytosanitary policy (mandatory notification of plant diseases and harmful organisms, self-checking for the primary plant production sector and traceability). Prompt notification of regulated plant pests and diseases is crucial for the authority to establish effective control measures without delay in order to prevent the early spread of these harmful organisms. Self-checking refers to the whole range of measures taken by business operators to make sure that the products for which they are responsible meet the requirements laid down in the regulations on the safety and the quality of products under the authority of the FASFC, and on traceability. In the primary production sector, the setting up of a self-checking system is not mandatory. Business operators at primary production must, however, comply with good hygiene/agricultural practices and keep records of certain operations. Several incentives have been put in place in order to encourage primary production operators to have their self-checking system validated. For food business operators (including primary production) with an externally validated/certified self-checking system, FASFC inspection frequencies are lowered and their annual contribution due to the FASFC is reduced.

Some indicators (PHI3, PHI4, PHI6) are related to the production process control (inspection and audits). Other indicators (PHI7-13) target specific pests and diseases associated with defined plants or plant products.

On the other hand, taking into account the definition of plant health mentioned above, as being restricted to the phytosanitary aspects, it was decided not to use data from agricultural pest warning systems in place in Belgium or statistics on the use of pesticides on crops as indicators. Both of these data sources are focussed mainly on endemic diseases, i.e. those caused by the presence of harmful non-quarantine organisms, and can be influenced to a large extent by uncontrollable factors such as local weather conditions.

The plant health indicator matrix (Table 2) shows the relationship of the different PHI's with the respective stages of the plant production chain or with the types of plant production indicating that the whole plant production chain and each type of plant production are covered.

Table 2: Overview of the Plant Health Indicators that are related to the different stages of the plant production chain and different types of plant production.

Plant production chain stage	Number of Plant Health Indicators	PHI
Suppliers	5	1-5
Primary plant production	12	1-5, 7-13
Processing	6	1-5, 7
Distribution	11	1-5, 7-11, 13
Green spaces/forests	5	1, 3, 5, 7, 13
Imports	10	1-7, 9, 11, 13
Plant production type	**Number of Plant Health Indicators**	**PHI**
Agricultural supply (fertilisers, soil conditioners etc.)	6	1-6
Cereals	8	1-6, 8, 12
Forage crops, industrial crops, corn	8	1-6, 8, 12
Potatoes	10	1-6, 8-11
Market gardening	9	1-6, 8-9, 11
Fruit crops	6	1-6
Horticulture, Nurseries, Green spaces	10	1-7, 9, 11, 13

2.3. Assigning a weight to each indicator

The definition of the concept of 'Plant Health' is not as unambiguous as it seems. The impact of the various indicators on plant health may be perceived in a different way by different individuals or professional stakeholders. In order to get a proper insight into the degree of importance attributed to defined indicators by the various stakeholders and experts, a weighting of the indicators was performed. This weight is taken into account when the overall value for plant health is calculated. Therefore, a method similar to the one described by Baert *et al.* (2011) during the development of the food safety barometer was used.

Each of the 13 PHI's was scored by representatives originating from the stakeholders of the Belgian food chain (FASFC risk managers, the FASFC Advisory Committee - including representatives from the industry associations, as well as from other competent authorities and consumer organizations in Belgium - and the FASFC Scientific Committee) by means of a survey. In this survey (Las Vegas method - Gore 1987), responders had to assign 10 points to the PHI's according to their judged importance to plant health. Several points could be assigned to one PHI and several PHI's could receive points, however the total sum of all assigned points had to be equal to 10. Finally, the mean weight of each PHI was calculated (Table 3) and validated by the Scientific Committee in its advice 11-2012 (Scientific Committee, 2012).

2.4. Calculation of the plant health barometer

For all 13 PHI's, data are gathered for the years 2007, 2008, 2009, 2010, 2011 and 2012 and the proportional changes between two consecutive years were calculated. The majority of the PHI's (PHI3 to 4 and PHI6 to 13) are expressed as a percentage of compliant samples or as a percentage of inspections that were given a 'favourable' opinion or 'favourable, subject to remarks'. These indicators show the extent to which the operators or plant or plant products have met the legal requirements. The other PHI's (PHI 1, PHI 2 and PHI5) are expressed respectively as an absolute number of notifications received by the FASFC each year with regards to the detection of plant diseases and harmful organisms, as a percentage of annual key activities performed with a validated/certified self-checking system in the plant production sector and as a percentage of regulated harmful organisms for which at least one sample is tested positive per year in Belgium in relation to the total number of regulated harmful organisms.

For most indicators an increase was interpreted as an amelioration of the situation. Only for PHI5 (percentage of regulated harmful organisms for which at least one sample is tested positive per year in Belgium in relation to the total number of regulated harmful organisms), a decrease of the indicator reflects an improvement of plant health.

In order to calculate the value that reflects the change of the state of plant health, the weighting factor is multiplied with the annual proportional change (two consecutive years) of each PHI and the mean of all these values is calculated. Next, observed changes of the indicator values from one year to the previous year are tested by means of a Poisson regression (StataCorp 2011). Values of $p<0.05$ are considered significant.

The overall results of the plant health barometer measures the sum percentage-change across all indicators, thus in 13 dimensions.

3. Results

The individual values for each indicator for a single year as well as the proportional change between two consecutive years are shown in Table 3. This analysis indicates that the general plant health in Belgium has improved from 2007 until 2010 and decreased from 2010 until 2012.

Table 3: Overview of the results between 2007 and 2012 of the respective Plant Health Indicators and significance level (*=p<0.05, **=p<0.01, ***p<0.001) when comparing between two consecutive years.

PHI	2007	2008	2009	2010	2011	2012	% Change (2008/ 2007)[1]	% Change (2009/ 2008)[2]	% Change (2010/ 2009)[3]	% Change (2011/ 2010)[4]	% Change (2012/ 2011)[5]	Weight factor	Weighted result 2008/ 2007	Weighted result 2009/ 2008	Weighted result 2010/ 2009	Weighted result 2011/ 2010	Weighted result 2012/ 2011
1	12	43	23	25	15	13	258.3%[11]	-46.5%[11]	8.7%[11]	-40.0%[11]	-13.3%[11]	1.47	381%	-68.5%	12.8%	-58.9%	-19.6%
2	12.1%	19.0%	31.0%	42.8%	47.4%	43.4%	56.4%***	63.3%***	38.1%***	10.9%***	-8.6%***	1.43	80.7%	90.6%	54.4%	15.6%	-12.3%
3	94.6%	95.2%	95.3%	96.4%	95.0%	94.0%	0.6%	0.1%	1.2%*	-1.5%**	-1.1%	1.91	1.2%	0.2%	2.2%	-2.8%	-2.0%
4	94.0%	96.2%	95.6%	98.0%	98.1%	97.5%	2.3%*	-0.6%	2.5%**	0.1%	-0.6%	1.08	2.5%	-0.7%	2.7%	0.1%	-0.7%
5	5.5%	6.4%	6.6%	6.6%	7.1%	8.6%	-17.3%[7]	-3.9%[7]	0.0%[7]	-6.6%[7]	-21.8%[7]	1.34	-23.2%[7]	-5.3%[7]	0.0%[7]	-8.9%[7]	-29.2%[7]
6	83.8%	77.5%	8.6%	87.2%	94.9%	84.8%	-7.6%*	10.4%**	1.9%	8.8%**	-10.6%***	1.91	-14.4%	19.8%	3.6%	16.8%	-20.3%
7	100%	100%	100%	100%	100%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.48	0.0%	0.0%	0.0%	0.0%	0.0%
8	-[6]	99.5%	100%	100%	100%	100%	-	0.5%	0.0%	0.0%	0.0%	0.48	-	0.3%	0.0%	0.0%	0.0%
9	99.9%[8]	99.4%	99.2%	99.1%	98.8%	98.2%	-0.5%*	-0.2%	-0.1%	-0.3%	-0.7%*	0.52	-0.2%	-0.1%	-0.1%	-0.1%	-0.3%
10	100%	100%	100%	100%	100%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.78	0.0%	0.0%	0.0%	0.0%	0.0%
11	73.0%	97.1%	99.3%	67.0%	78.2%	88.0%	33.0%***	2.3%	-32.5%***	16.7%*	12.5%**	0.69	22.9%	1.6%	-22.6%	11.6%	8.7%
12	100%	100%	100%	100%	100%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.39	0.0%	0.0%	0.0%	0.0%	0.0%
13	81.0%	78.3%	75.8%	91.6%	93.2%	94.3%	-3.3%	-3.2%	20.8%***	1.8%	1.2%	0.52	-1.7%	-1.7%	10.8%	0.9%	0.6%
Global							**26.9%[8]**	**1.7%[9]**	**3.1%[9]**	**-0.8%[9]**	**-3.3%[9]**		**37.4%[9]**	**2.8%[10]**	**4.9%[10]**	**-2.0%[10]**	**-5.8%[10]**

[1] % Change = (2008 result – 2007 result)/2007 result x 100%. Significant changes are indicated with * (*=p<0.05, **=p<0.01, ***=p<0.001).
[2] % Change = (2009 result – 2008 result)/2008 result x 100%. Significant changes are indicated with * (*=p<0.05, **=p<0.01, ***=p<0.001).
[3] % Change = (2010 result – 2009 result)/2009 result x 100%. Significant changes are indicated with * (*=p<0.05, **=p<0.01, ***=p<0.001).
[4] % Change = (2011 result – 2010 result)/2010 result x 100%. Significant changes are indicated with * (*=p<0.05, **=p<0.01, ***=p<0.001).
[5] % Change = (2012 result – 2011 result)/2011 result x 100%. Significant changes are indicated with * (*=p<0.05, **=p<0.01, ***=p<0.001).
[6] Result not available.
[7] The sign of this indicator is changed since a decrease of this indicator actually shows an improvement in plant health.
[8] Based solely on statistics of the Belgian Regions, i.e. without statistics from the National Autorithy.
[9] Average of 12 indicators (= PHI8 excluded, cf. [5]).
[10] Average of 13 indicators.
[11] The significance level is undeterminable using the Poisson regression model.

As described earlier, a survey was organised amongst stakeholders to obtain a weighting factor for each PHI. In total 30 responses were obtained of which 7 (23%), 7 (23%) and 16 (53%) were filled in by FASFC risk managers, FASFC stakeholders and risk assessors respectively. Each PHI received a score, meaning that the stakeholders were convinced that every PHI was important for the measurement of plant health. Based on the answers the mean weight of each PHI was calculated (cf. Table 3) indicating their importance assigned by the experts with regard to their contribution in measuring plant health. As such, the six 'generic' (cf. below) indicators, related notably to inspections and controls, were given more importance than the seven 'specific' (cf. below) indicators.

For the general plant health (phytosanitary situation) barometer, taking into account the weighing factors assigned to each indicator by expert opinion, changes of +37.4%, +2.8%, +4.9%, -2.0% and -5.8% are observed respectively for 2008 compared to 2007, for 2009 compared to 2008, for 2010 compared to 2009, for 2011 compared to 2010 and for 2012 compared to 2011 (cf. Table 3).

The overall value of +37.4% for the 2008 plant health barometer (2008 *versus* 2007) is mainly the result of the increase of the number of mandatory notifications of plant diseases and harmful organisms to the FASFC (PHI1) and of the significant improvement ($p<0.001$) of the situation in relation to self-checking at plant production level (PHI2) and to the detection of *Pospiviroidae* (PHI11). Concerning the evolution of the PHI1, it can be noted that this increase is due to a higher number of fireblight (*Erwinia amylovora*) notifications. This could be explained, on one hand, by an increased vigilance after an intensive information campaign in the province of West Flanders on fireblight and, on the other hand, by a higher number of outbreaks resulting from favourable weather conditions. Both elements could have led to an increase in notifications. As discussed below, we consider an increase of this indicator as a positive evolution as it is a measure of vigilance of operators in the field and it allows the FASFC to take promptly appropriate mitigation actions. Given that this indicator is not expressed in relation to other variables, it is not possible to carry out a statistical analysis of the results for the various years using the Poisson regression model. In the same time, a significant improvement ($p=0.044$) is observed for the PHI4 (Phytosanitary inspections (traceability)) and significant deteriorations ($p=0.022$ and $p=0.010$) are observed respectively for the PHI6 (Phytosanitary import controls) and the PHI9 (*Globodera rostochiensis* and/or *G. pallida* (Cyst nematodes)). This last result must however be put into perspective, bearing in mind that this indicator, only for 2007, is calculated solely on the basis of statistics from the Belgian Regions, i.e. without statistics from the National Autorithy. It can also be noted that there is an important, even if non-significant, deterioration of the situation concerning the harmful organisms regulated and detected in Belgium (PHI5).

The overall value of +2.8% for the 2009 plant health barometer (2009 *versus* 2008) is mainly the result of significant improvements ($p<0.001$ and $p=0.007$) of the situation in relation to respectively self-checking at plant production level (PHI2) and the phytosanitary import controls (PHI6). In the same time, the number of mandatory notifications of plant diseases and harmful organisms to the FASFC (PHI1) decreases. It can also be noted that there is a deterioration, even if non-significant, of the situation concerning the harmful organisms regulated and detected in Belgium (PHI5).

The overall value of +4.9% for the 2010 plant health barometer (2010 *versus* 2009) is mainly the result of significant improvements ($p<0.001$) of the situation in relation to self-checking at plant production level (PHI2) and to the detection of *Phytophthora ramorum* (Sudden oak death) (PHI13). In the same time, significant improvements ($p=0.030$ and $p=0.002$) are observed respectively for the PHI3 (Phytosanitary inspections (physical checks)) and the PHI4 (Phytosanitary inspections (traceability)) and a significant deterioration ($p<0.001$) is observed for the PHI11 (*Pospiviroidae*). This last result must however be put into perspective bearing in mind that until 2009, the results are increasingly favourable but related solely to the *Potato spindle tuber viroid* (PSTVd), whereas from 2010 they related to all *Pospiviroidae*.

The overall value of -2.0% for the 2011 plant health barometer (2011 *versus* 2010) is mainly the result of the decrease of the number of mandatory notifications of plant diseases and harmful organisms to the FASFC (PHI1). Since 2010, operators registered to the FASFC, which take appropriate control measures and which mention it in their register of presence of harmful organisms, do not have to notify anymore the presence of fireblight (*Erwinia amylovora*). In the same time, significant improvements ($p<0.001$, $p=0.001$ and $p=0.019$) are observed respectively for the PHI2 (Self-checking for plant production), the PHI6 (Phytosanitary import controls) and the PHI11 (*Pospiviroidae*) and a significant deterioration ($p=0.009$) is observed for the PHI3 (Phytosanitary inspections (physical

checks)). It can also be noted that there is a deterioration, even if non-significant, of the situation concerning the harmful organisms regulated and detected in Belgium (PHI5). Maybe this could be explained by the weather conditions of the year 2011, which were 'very exceptionally hot' according to the Royal Meteorological Institute of Belgium.

The overall value of -5.8% for the 2012 plant health barometer (2012 *versus* 2011) is mainly the result of an important, even if non-significant, deterioration of the situation concerning the harmful organisms regulated and detected in Belgium (PHI5). Maybe this could be explained by the weather conditions of the year 2012, which were 'very exceptionally stormy' and 'abnormally humid' according to the Royal Meteorological Institute of Belgium. But this last result could however be put into perspective bearing in mind that in 2012 the total number of regulated harmful organisms in Belgium increased (232 *versus* 226). In the same time, significant deteriorations ($p<0.001$, $p<0.001$ and $p=0.021$) are observed respectively for the PHI2 (Self-checking for plant production), the PHI6 (Phytosanitary import controls) and the PHI9 (*Globodera rostochiensis* and/or *G. pallida* (Cyst nematodes)) and a significant improvement ($p=0.001$) is observed for the PHI11 (*Pospiviroidae*). Those last results for the PHI2, the PHI6 and the PHI11 could however be put into perspective bearing in mind that in 2012 the FASFC respectively reorganized its activities tree (= list of all activities that can be performed within the food chain), took 146 extra samples and took also 93 extra samples specifically for the detection of the *Chrysanthemum stunt viroid*, which were in this case, in contrary to those taken for the PHI6, all negative. It can also be noted that the number of mandatory notifications of plant diseases and harmful organisms to the FASFC (PHI1) decreases.

Over the five plant health barometers it can be noted that there are four times a significant increase ($p<0.001$) of the percentage of annual key activities performed with a validated/certified self-checking system in the plant production sector (PHI2, self-checking for plant production).

It can also be noted that a high number of indicators (7 indicators out of 11 (PH1 and PHI5 excluded because they are other type indicator) in 2010 and in 2011, and even 8 indicators out of 11 in 2008 and in 2009) score very high results in regard to compliance (≥95%), which suggests that there is a high level of plant health (phytosanitary situation) in Belgium.

The yearly result of the barometer is communicated to the public via the annual report and the FASFC website (http://www.favv-afsca.fgov.be/scientificcommittee/barometer/) by means of a simplified visual representation using a spider diagram, which gives a more informative picture of the fluctuations of the individual indicators. An example is given in Figure 1. The spider diagrams of the different years are available on the FASFC website (cf. above).

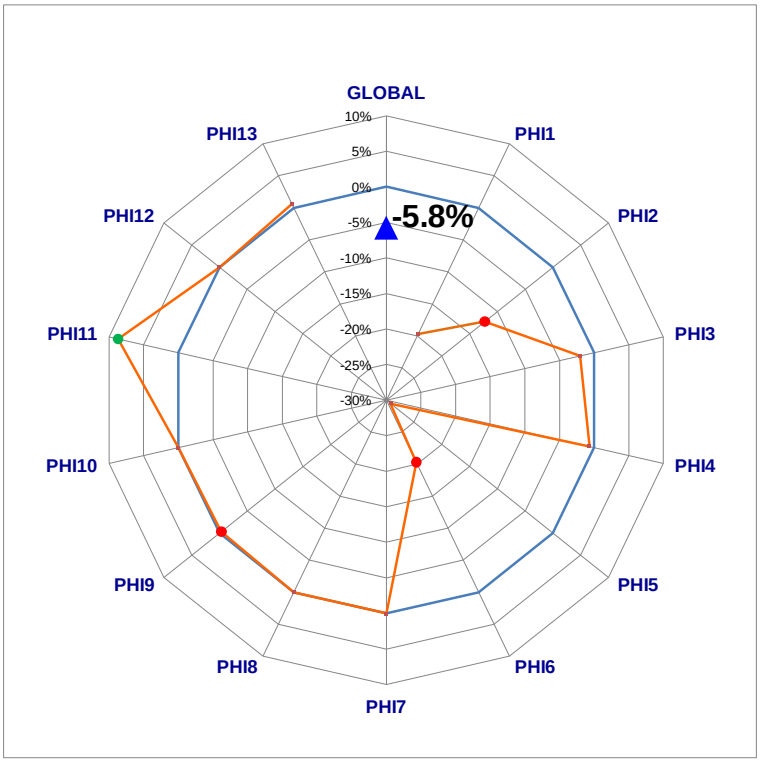

Figure 1: Example of a spider diagram representation of the plant health (phytosanitary situation) barometer: difference between the years 2011 and 2012 expressed as a percentage. ▲: general plant health; ●: significant improvement of the plant health indicator; ●: significant deterioration of the plant health indicator; blue line: status quo baseline.

4. Discussion

The primary objective of the plant health barometer is to conduct a measurement of the national phytosanitary situation on the basis of a set of key indicators that are directly or indirectly related to the monitoring of pests and diseases and to phytosanitary control measures throughout the entire plant production chain.

This barometer aimed at providing a reflection of possible hazards and risks within the plant production chain during a given period. It serves as an instrument for communication, reflection and trend observation with regard to the plant health state, intended both for a broader public and for professional stakeholders in the plant production chain. Therefore, it is not intended to draw up a comprehensive scientific report giving an exact image of the presence and status of all potential hazards within the plant production chain, nor is it intended to carry out any form of risk assessment. Together with the food safety barometer (Baert *et al*. 2011) and the animal health barometer (Depoorter *et al*. submitted for publication), those three instruments provide a overview on the general status of the food chain in Belgium.

The composition of the set of indicators and the context within which they were defined is of major importance. Each indicator has its own strengths and weaknesses, as explained in the technical sheets in Appendix 1 of the advice 10-2011 of the Scientific Committee (Scientific Committee 2011). The composition of this set of indicators may be modified periodically, for instance when it is likely that some indicators are no longer relevant, or when other indicators may better reflect the actual situation as a result of new developments.

It should be noted that the first six identified indicators (PHI1 to PHI6) are generic as each of them relate to almost any plant or plant product, whereas the seven other indicators (PHI7 to PHI13 inclusive) are more specific, as they apply to a number of specific plants or plant products (e.g. potatoes, corn crops etc.).

With regard to the mandatory notification of plant diseases and harmful organisms (PHI1), it is clear that an increase in the number of reports may possibly be due to the introduction of infectious diseases or pests, which can be interpreted as a deterioration of the phytosanitary situation. Or it may be the result of a higher degree of alertness (whether or not stimulated by information campaigns initiated by the FASFC), leading to a greater degree of vigilance and thus to an increase of the response, which can be interpreted as positive for the evolution of the phytosanitary situation. In the concept of this barometer, the second option has been chosen. Given that mandatory notification is, indeed, an inherent part of the preventive approach, and is also essential for preventing the spread of plant pests and diseases, an increase of the number of reported cases therefore indicates in this context a substantial degree of vigilance and alertness with regard to the safeguarding of plant health. This indicator therefore contains a high degree of interpretation bias.

As for the presence of a validated/certified self-checking system (PHI2), it should be noted that the operators may freely choose whether or not they want to have their self-checking system validated. Attention should however be drawn here to the fact that in case of absence of a validated self-checking system for a key activity, it does not mean that the self-checking system is absent or malfunctioning. The point is that an independently validated self-checking system provides added value and adds to the confidence as to the foundations and functioning of such system. An increase of the percentage of key activities with a validated self-checking system thus indirectly leads to a higher confidence level with regard to adequate preventive actions taken in order to ensure general plant health.

As regards the results of the inspections (PH3 and PHI4), any changes that may be made to the evaluation system from time to time (e.g. new checklists) must be taken into account. This may result in year-to-year differences with regard to the detection of non-conformities. It is however recommended that, in the event of significant changes to the evaluation system, both the sector and the authorities make great efforts in raising awareness, informing and assisting the concerned operators, with a view to applying and limiting the non-conformities to a new evaluation system. This is why, for some indicators, one must also take into account the fact that some inspections may have been aimed at high-risk production sites, products or countries of origin as a result of which some degree of bias is likely. This is however a systematic bias that is inherent to the development of a control system based on risk, which is within the mandate of the FASFC.

As regards PHI5 (Harmful organisms regulated and detected in Belgium), it is worth noting that the composition of the list of harmful regulated organisms varies according to changes in the Belgian and European legislation on this matter. Moreover, this indicator does not cover the detection of regulated harmful organisms at import level given that these statistics are included under PHI6 (phytosanitary import controls). In PHI5, harmful organisms that are exclusively regulated for the protected areas within the EU are not covered (namely those listed under parts B of the Royal Decree of 10 August 2005). Moreover, the harmful organisms listed in the Royal Decree of 19 November 1987 for which no active control policy has been conducted are not covered either.

Concerning the phytosanitary import controls (PHI6), it should be clarified that certain samples are taken at random, whereas others are taken solely on the basis of the visual observation of symptoms or systematically (e.g. as a requirement of European legislation).

The seven specific indicators (PHI7 to PHI13 inclusive) are selected to cover the maximum segments of the plant and plant product production sector (e.g. trees and wood products, potatoes, cereals, vegetables, ornamental plants) and to cover the various types of harmful organisms (e.g. bacteria, insects, nematodes, viroids, moulds). The aim of some of these indicators is to identify the possible emergence of a risk (e.g. *Bursaphelenchus xylophilus*) or the possible reemergence of a risk (e.g. *Diabrotica virgifera*). It should be noted that, although production of in particular apples and pears represent large production volumes in Belgium, there is no specific indicator for fruit production. This could be explained by the fact that there is no quarantine organisms monitoring program specific for the apples and pears production, the two most important fruit productions in Belgium. The organisms harmful to this type of production are indeed covered by the generic indicators. It should also be noted that there are several specific indicators for the potato sector, on the same principle that this sector is targeted by the European phytosanitary regime. The potato sector is also both in production volumes and trade value a very important production sector in Belgium.

It should be noted that several indicators show high level of conformity (PHI4, PHI7, PHI8, PHI9, PHI10, PHI12), leaving less space for improvement. This could mean that the general phytosanitary situation in Belgium is rather good.

Based on the present barometer, the general plant health in Belgium appears to show a positive evolution between 2007 and 2010 followed by a negative evolution between 2010 and 2012. Globally, the evolution between 2007 and 2012 is however still positive. The real meaning of these evolutions has to be assessed over the long term. Given the limited number of calculated barometers up till now, a thorough trend analysis has not yet been executed but should be highly informative in a future evaluation process of the concept of the plant health barometer.

This instrument or a similar concept thereof can also be developed in other countries provided that results of a plant health control plan are available.

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