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Unravelling potential plant health threats for the European Union: application of horizon scanning methodology

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Abstract. The European Food Safety Authority (EFSA) has been conducting horizon scanning (HS) activity in the field of plant health, in collaboration with the EC Joint Research Centre (JRC) and the French Agency for Food, Environmental and Occupational Health and Safety (ANSES), since 2017. As of 2024, this activity has produced 130 reports, named newsletters. The aim of this activity is to capture signals from the web about potential threats caused by plant pests from all around the world and to convey them to European Union risk managers in support of their preparedness and timely reactions. The tool used was the Medical Information System (MedISys), a public health surveillance system that continuously monitors the content of more than 3200 scientific and media sources worldwide. The items selected for inclusion in the monthly newsletters are reviewed and validated by a team of experts, while another team carries out further analysis on specific "not-listed" pests. This analysis, PeMoScoring (short for pest and monitoring scoring), is a fast procedure based on a ranking system that warns risk managers of the potential new threats by unknown or not-listed pests. These signals can then trigger actions by risk managers: requests for more assessments by EFSA or facilitation of preventive measures. Recently, a series of workshops and webinars have been organised to foster collaboration among institutions engaged in horizon scanning activities in the field of plant health and to broaden the applicability of this service to other contexts and areas of focus. This article presents an analysis of the data collected from the newsletters, along with a detailed examination of the PeMoScoring outcomes and potential directions for future development. The results highlight the potential of horizon scanning tools in the prevention of emerging threats for plant health and their capacity to support risk management decisions by anticipating challenges and facilitating timely interventions.

1 Introduction

Plants constitute approximately 80 % of the human diet and are utilised in various industries, including textiles and pharmaceuticals, serving as sources for clothing materials and medicinal compounds (FAO, 2022). In addition, the other ecosystem services provided by plants are an essential support for human wellbeing, such as soil formation and nutrient cycling (Richter et al., 2007; FAO, 2022). Global agricultural production volumes of primary crops recorded a growth rate of 56 % between 2000 and 2022 due to the improvement of production technologies, increased use of irrigation, plant protection products, fertilisers, high-yield crop varieties, and cropland expansion (IPPC, 2021; FAO 2022).

Despite this agricultural intensification, modern farmers continue to experience significant losses in crop production, attributed not only to environmental factors, such as drought and heat, but also to biotic stressors, including plant diseases

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and insect herbivores, which are estimated to cause up to 40 % of global crop production losses (FAO, 2022). Other anthropogenic activities, including global trade and climate change, are exacerbating these challenges, further contributing to the spread of plant pests and pathogens beyond their native regions (Seebens et al., 2017; Hulme 2021; Harvey et al., 2023). Biological invasions may result in serious environmental (Herms and McCullough, 2014; IPBES, 2019; Martín et al., 2019; Cancellario et al., 2023), economic, and social consequences in the novel geographic ranges (Herms and McCullough, 2014; Costa et al., 2021; Fantle-Lepczyk et al., 2022) and are blamed for a loss of 0.4–1.3 trillion euros globally within the last 50 years (1970–2020) (Turbelin et al., 2024). The literature is constantly being expanded to include many examples that illustrate the negative impact of pests on growing crops (Bucci, 2018; De Groote et al., 2020; Hulagappa et al., 2022; Roditakis et al., 2023) and, subsequently, on rural economic sustainability (Schneiker et al., 2016; De Groote et al., 2020; Schneider et al., 2020) and cultural heritage (Herms and McCullough, 2014; Semeraro et al., 2021).

In this context, the ever-increasing impact of global trade on biological invasions is a concern for risk managers (Hulme, 2021). Species never encountered before in geographic ranges are anticipated to emerge with equal or even higher rates than those recorded in the past (Liebhold et al., 2017; Hulme, 2021). In addition, costs of management prior to pest invasions are lower than those after invasions (Cuthbert et al., 2022). It is also possible that sustainable pest management strategies for known native pests could be disrupted as a result of pest invasions (Roditakis et al., 2023). Moreover, resources should be allocated to targeted measures in a timely manner to achieve results efficiently (Ward, 2016). The Euphresco project exemplifies this approach by coordinating research efforts and supporting policy development (Giovani et al., 2019). Hence, risk managers should be informed in a timely manner of the invasive potential of given species as they emerge, which is more pivotal than ever to the protection of natural and managed environments.

So far, a few early warning systems exist that gather and communicate pest information to support decision-making (Noar et al., 2021). An example is PestLens, an early warning system that is operated by USDA-APHIS Plant Protection and Quarantine (PPQ). PestLens identifies plant pests and pathogens that may threaten United States agriculture and natural resources (Meissner et al., 2015). Another example of a real-time cost-efficient monitoring system is provided by the European and Mediterranean Plant Protection Organization (EPPO). Comprising 52 member countries, EPPO publishes a reporting service that uses various methods and criteria to compile lists of species requiring stakeholders' attention (EPPO, 2024d). Similarly, CABI provides global plant pest information through its Plantwise Knowledge Bank, offering early warning and management guidance to support decision-making in agriculture (CABI, 2025). Their resources focus particularly on countries participating in CABI's Plantwise network, including Africa, Asia, and Latin America.

These early detection systems use horizon scanning (HS) methodology for their production. HS functions as a foresight process, serving as an initial step in uncovering and assessing emerging issues during the surveillance of pathogens and pests (Sutherland and Woodroof, 2009; Antoniou et al., 2024). The types of activities involved in the HS process can be clustered among three main categories of actions: monitoring, where data are gathered from various sources and are continuously reviewed; analysing/synthesising, where retrospective and forward-looking analysis identifies emerging trends and patterns in the environment and estimates future events; and communicating the delivery of results to risk managers and/or other final users.

The European Union (EU) plant health regime was updated in 2019 with the entry into force of the Regulation (EU) 2016/2031 of the European Parliament and of the Council concerning protective measures against pests of plants. The latest consolidated text of Commission Implementing Regulation (EU) 2019/2072 (dated 15 August 2024) counts 187 taxonomic entities, which in some cases cover genera (e.g. *Gymnosporangium* spp.) or families (e.g. Margarodidae), bringing the total number of species to over 400 (European Commission, 2019). Within this context, the EFSA HS activities are used to capture and identify signals about the very large number of regulated pests but, even more importantly, about unknown, non-regulated ones (Sutherland and Woodroof, 2009).

The HS approach varies according to data availability and the intended output. This HS activity, which operates within the framework of EU legislation, focuses on gathering and compiling global information on plant health risks and delivering it to EU risk managers to support preparedness and timely responses. Since 2017, monthly reports have been issued featuring news articles on both regulated and non-regulated pests. In parallel, a rapid screening is conducted to identify pest species affecting agriculture and forestry that are most likely to enter, establish, and spread within the EU. This screening uses a dedicated tool, PeMoScoring (short for pest and monitoring scoring) (EFSA et al., 2022b). PeMoScoring highlights plant pests with the greatest potential impact in a given territory. The overall objective of these monthly reports is to provide an early warning on quarantine pests and on new and emerging plant health threats for the EU.

Here, all the information published from 2017 to 2024 in this HS activity was compiled into a database and analysed by the sources reported, the regulatory status, the biology of the pests, and the outcome of the PeMoScoring. As a result of this analysis, we obtained patterns about (i) the monitoring phase of the HS activity, (ii) its outcomes, and (iii) the way such outputs are communicated. These results show how effective the methodology has been in detecting "not-listed" pests as emerging pests over the period and in strengthening collaboration between risk assessors and risk managers. These findings help to provide insight into the HS activity applied to invasion processes and may prove useful in the future for designing a driver detection approach able to detect future events at an earlier stage.

2 Methods

2.1 Newsletter production

In 2017, the HS report was named Media Newsletter. In 2019, a second report was produced, simultaneously collecting information from scientific publications (i.e. peer-reviewed), the Scientific Newsletter. In February 2022, they were combined to become the HS Newsletter (EFSA, 2025a) (Fig. S1).

For the scanning of media and scientific sources, EFSA used the IT platform of the Medical Information System (MedISys) developed by the EC Joint Research Centre (JRC) (Rortais et al., 2010; Linge et al., 2012). This is a fully automatic event-based surveillance system that was initially developed for public health surveillance (Linge et al., 2009) and later expanded to cover plant health threats. In 2024, MedISys collected thousands of articles daily from multiple sources (3221) based on different categories. The categories, which have been manually created, correspond to the scientific name and the multilingual common names for a given pest as keywords. The system includes 3366 categories grouped in terms of their status in the legislation: ANNEX II Part A of the Commission Implementing Regulation (EU) 2019/2072 and ANNEX II Part B of the Commission Implementing Regulation (EU) 2019/2072 (European Commission, 2019). Complementary to this regulation is the Priority pest list and the Emergency measure pests (European Commission, 2024), other EU legal acts, EPPO lists (A1, A2, and Alert List) (EPPO, 2024a, b, c), and pests non-listed in EU legal acts or in EPPO lists. In addition to the categories corresponding to already known pests for EFSA, generic keywords (e.g. "pest", "plant disease", "crop", "yield losses") have been added to enable the retrieval of articles regarding the discovery of new and emerging pests of plants. In the database, two regulatory status levels were established: regulated (under EU regulation and EPPO lists) and not-listed (emerging pests not covered under EU regulation or EPPO lists).

A manual selection of these automatically retrieved articles is performed and is included in the monthly HS report, published in the EFSA Journal (Wiley) and presented to the Plant Health section of the Plants, Animals, Food and Feed (PAFF) Committee (EU Commission) following a request from the European Commission (European Commission, 2017). Considering PAFF to be the main end-user, the manual selection prioritises news of relevance for EU risk managers (EFSA, 2025a).

To highlight the main focus of each article, a specific topic label is assigned that reflects its most relevant content (e.g. distribution, detection method, new host plant). For the analysis, topics were grouped together in three thematic sections: assessment, management, and new observations (Table S1). For the new observations group, scientific names of host plants affected by pests were annotated and assigned to a single class based on the following hierarchical order: crop > forest > ornamental > wild (Table S1). For example, *Citrus* species were classified under "crop" while also being found in ornamental plantings.

The selection of the articles and their inclusion in the report is the first step of the HS process, identifying early signals of potential invasive pests. The next step is the screening of the some of those pests in terms of their potential threat to the EU, the PeMo.

2.2 PeMoScoring (PeMo)

The PeMoScoring or "PeMo" is a fast scrutiny by a group of experts based on a ranking system that provides information on the potential risks represented by those unknown or not-listed pests generating an early warning signal. The pests eligible to PeMoScoring, in the EU HS context, have to fulfil the following conditions: (a) they can cause damages to plant species of economic relevance to the EU, (b) they should be able to enter the EU territory by at least one commodity not banned for import into the EU or by natural spread from non-EU territories, (c) they are not newly described pests.

PeMoScoring evaluates 15 criteria classified into five items (i.e. host range, entry, establishment, spread, and impact) and retrieves a negative or positive result: a positive PeMo means a potential threat for plants in the EU territory (EFSA et al., 2022b). These criteria are presented as questions and are described in a scheme in Fig. S2. Each question provides a set of predefined response options, to which scores have been assigned based on the evaluation of reference pests. This approach ensures consistency across assessments and facilitates comparison between responses (Schrader et al., 2010). Uncertainty is addressed by selecting the most plausible intermediate outcome for questions with more than two possible answers to avoid extreme assumptions, even though this does not eliminate uncertainty; therefore, PeMoScoring results are accompanied with a descriptive expression of the uncertainty (EFSA Scientific Committee et al., 2018). For each answer there is a respective rate, with the aim to acquire the final score from the 15 answers, called the net phi value (Phi). This final score is defined by the combination of all rates and ranges from -1 to $+1$, representing the minimum and maximum levels of expected risk, respectively. A threshold has been defined distinguishing between negative PeMo (Phi lower than the threshold), meaning insufficient evidence of risk (therefore no action), and positive PeMo (Phi higher than or equal to the threshold) pests, meaning sufficient evidence of risk, supporting the possibility of further action. This methodology allows the set of reference pests to be updated, which automatically determines the corresponding threshold. Density functions used to determine the threshold are provided by EFSA et al. (2022b).

Both steps (Newsletter Production and PeMoScoring) are currently implemented in Pest Horizon and Risk Scanning (PHoRiS) (Junius et al., 2023), and PeMo results are included in the newsletter (EFSA, 2025b).

2.3 Data analysis

Data from all HS reports (media, scientific, and HS newsletters) from between 2017 and 2024 were manually compiled into a database containing the following information: pest biological category, scientific name, alternative names, report date, PeMo result, PeMo date, article topic, source name, source type (scientific or media), and, when applicable, country of detection and host plant. Data visualisations were generated using R (version 4.3.1) (Wickham, 2016).

3 Results

3.1 Biological categories and sources

A total of 130 HS reports were produced from 2017–2024: 58 Media, 37 Scientific, and 35 HS newsletters. They included articles about 1153 pests, of which 836 are not-listed and 317 are regulated. Considering that there are more than 400 regulated pests in EU regulation and EPPO lists, not all regulated pests have been covered in this exercise (Fig. S1). Pests were first analysed by biological categories, considering the number of pest species and the total number of articles per category included in the HS reports (Fig. 1a). Most of the cited species across all categories were not-listed (Fig. 1a, left panel). The category insects and mites included the highest number of regulated species cited. On the other hand, in terms of the number of articles, HS reports included more articles about regulated species, except for the category fungi and oomycetes, where not-listed species were more frequently reported (Fig. 1a, right panel). For viruses, viroids, and phytoplasmas, the distribution was nearly equal.

To further explore reporting patterns across biological categories, we analysed the sources of the articles, distinguishing between media and scientific sources (Fig. 1b). The predominant source for regulated pests varied by biological category: the insects and mites category was more frequently covered in media articles, whereas viruses, viroids, and phytoplasmas appeared more often in the scientific literature (Fig. 1b, left panel). In general, the scientific literature covered more articles for not-listed pests, particularly for fungi and oomycetes and for viruses, viroids, and phytoplasmas (Fig. 1b, right panel).

Among the sources that have been included in the HS reports, the majority corresponded to media, having 617 unique sources and 301 scientific sources (Fig. 2, left panel). However, when analysing the number of articles reported, 1380 were gathered from media sources and 1978 were gathered from scientific journals. Specifically, there were 617 articles coming from sources used only once, from which 443 were media and 174 were scientific (Fig. 2, right panel). On the other hand, 490 articles came from only two sources: 420 from a scientific source and 50 from a media source (Table S1).

3.2 Topics

The topics for each article in the HS reports were classified in three main groups: assessment, management, and new observations (Table S1). Among them, assessment was the least represented group, followed by management (Fig. 3). The distribution of topic groups varied with the regulatory status of the pests. Articles under assessment and management groups were predominantly associated with regulated pests, while the most common group across all pests was new observations (Fig. 3a, left panel). Conversely, the distribution of media and scientific sources was nearly uniform across the three topic groups (Fig. 3a, right panel).

Given that most of the articles correspond to the new observations group, a more detailed analysis was performed on this group. New observation topics were subdivided into absence, entry, eradication, first finding, interception, new finding, new host plant, new pest, and new vector (Table S1). Due to the relevance of first findings and new findings, being the two most cited subtopics, their patterns across the biological categories were analysed. As expected, most first findings were mainly reported in scientific publications, whereas new findings – defined as the detection or observation of a pest in a different region within the same country – were primarily reported in media articles (Fig. 3b). This pattern appeared to be independent of the pest regulatory status. In particular, the insects and mites category presented more media articles reporting first and new findings compared to other biological categories (Fig. 3b). In this case, the trend was strengthened for regulated pests, for which 97 % of articles reporting new findings of insects and mites were originated from a media source (Fig. 3b).

New pest was the third most frequently cited topic under the new observations group (Table S1). Out of 392 new pests reported in the HS exercise, only 27 were mentioned again in subsequent articles. New host plant was the fourth most cited topic. Analysis of host plant citation frequencies revealed that crops accounted for 67.5 %, forests accounted for 10.1 %, ornamentals accounted for 10.5 %, and wild plants accounted for 4.9 % of mentions, with 7 % classified as non-EU (Table S1). Only 10 % of the articles reporting a first finding included the report of a new host plant.

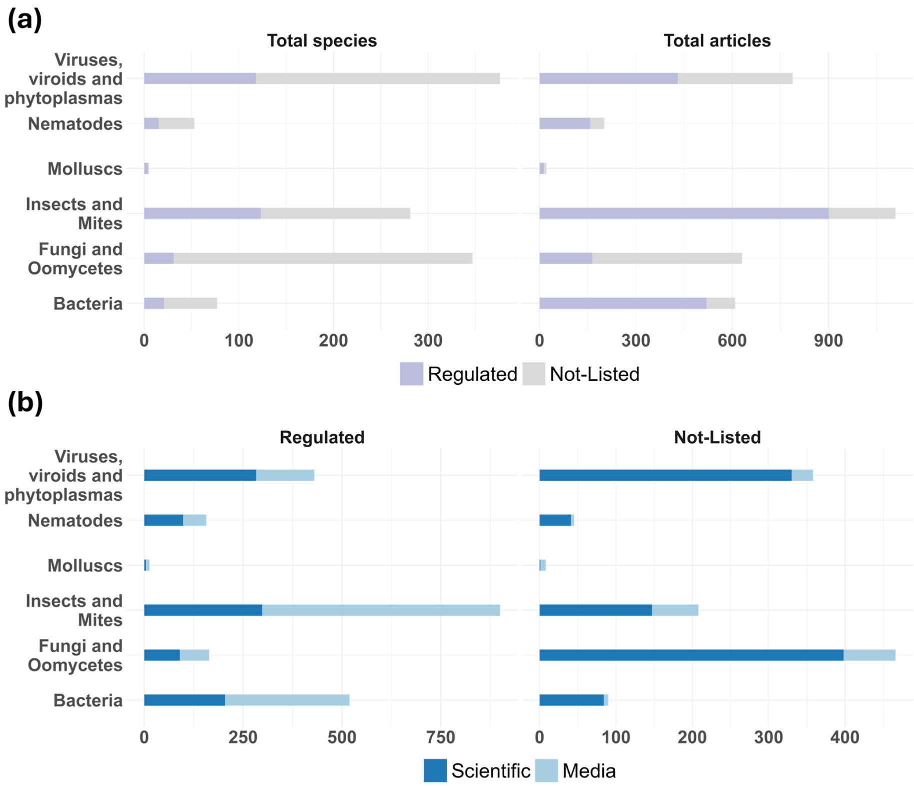

Figure 1. Distribution of biological categories in horizon scanning (HS) reports from 2017 to 2024. **(a)** Number of species (left) and articles (right) reported for each biological category. Bar colours indicate the regulatory status (purple: regulated; grey: not-listed). **(b)** Number of articles captured for each biological category separated by regulatory status (left: regulated; right: not-listed). Bar colours indicate the source type (dark blue: scientific; clear blue: media).

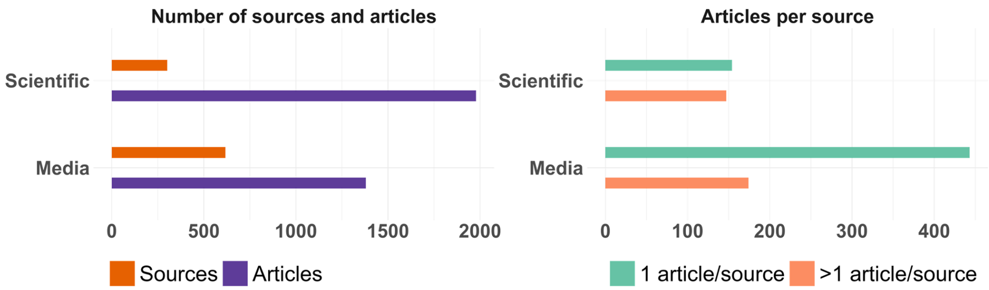

Figure 2. Distribution of sources and articles in horizon scanning (HS) reports from 2017 to 2024. Left: total number of sources (orange) and articles (purple), categorised by source type (scientific and media). Right: number of sources capturing only one article (green) versus those capturing more than one article (red), for both scientific and media sources.

3.3 PeMoScoring

PeMoScoring is a tool designed to provide an indication of the potential risk of a plant pest. From 2017 to 2024, a total of 233 pests were scored by PeMo, with 114 pests scoring negative and 119 scoring positive (Fig. 4a). Among the pests that scored positive, 27 were proposed for further analysis, named pest categorisation. The pest categorisation outcome indicates whether regulatory measures in the EU territory may be required for a given pest. Of the 27 pests subjected to pest categorisation, 20 resulted in a positive outcome, 3 resulted in a negative outcome, and 4 resulted in an inconclusive outcome (Figs. 4a, S3). Among the 835 total not-listed pests, 392 were collected under the topic new pest, thereby excluding them from the PeMoScoring analysis (see Methods). From the remaining 443 not-listed pests, 233 were assessed for PeMoScoring, with 119 pests scoring positively – about 15 % of the 835 not-listed pests identified through the scanning activity (Fig. 4a).

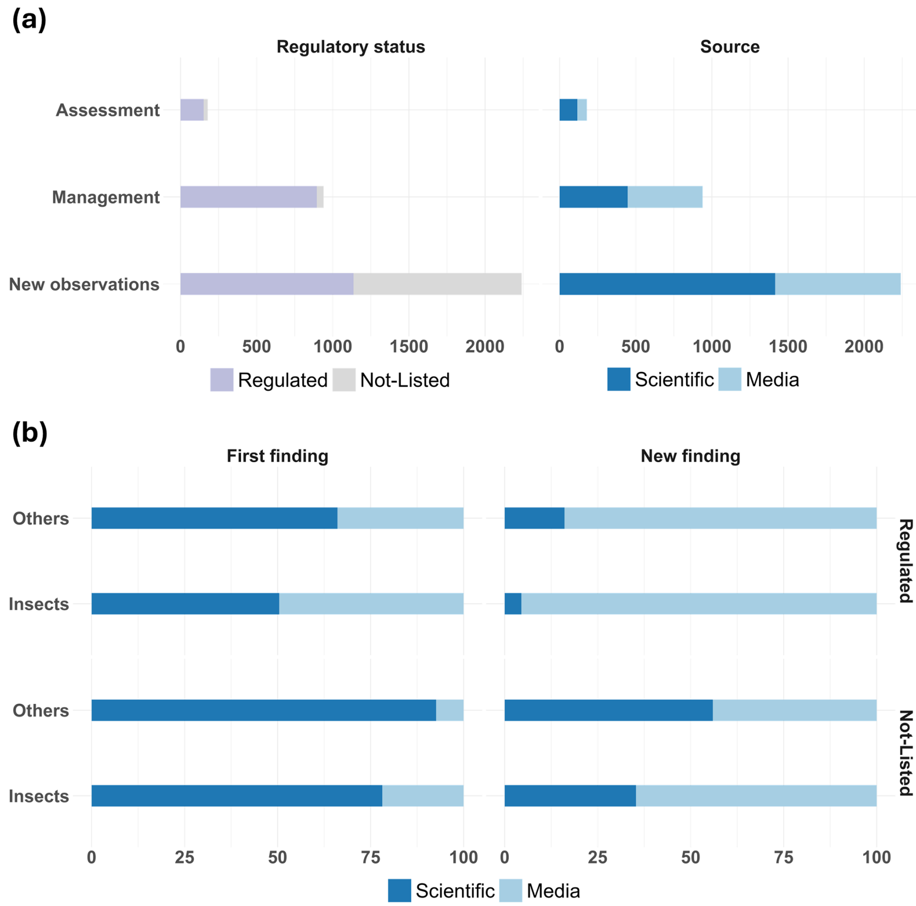

Figure 3. Distribution of articles by topic class in horizon scanning (HS) reports from 2017 to 2024. **(a)** Total number of articles in topic classes (assessment, management, and new observations). Left: bar colours indicate the regulatory status (purple: regulated; grey: not-listed). Right: bar colours indicate the source type (dark blue: scientific; clear blue: media). **(b)** Percentage of articles within the insect and mites category and all other biological categories, classified by first and new findings, regulatory status (y axis, regulated and Not-Listed), and source type (dark blue: scientific; light blue: media).

Over the years, the number of pests submitted for PeMoScoring has fluctuated, peaking at 26 positive identifications in 2019 (Fig. 4b). After 2021, the trend reversed, with more pests scoring negative, reaching a total of 28 out of the 47 scored in 2023 and 25 out of the 40 scored in 2024.

To evaluate the performance of the sources used for the HS exercise in relation to the PeMo tool, we analysed the sources associated with the PeMoScored pests. Sources cited only once in the HS reports were predominantly media sources, regardless of whether the PeMo score was positive or negative (Fig. 4c). In contrast, scientific sources reporting on pests evaluated by the PeMo tool were used more than once across the HS reports.

4 Discussion

In recent years, HS has emerged as a key tool for anticipating threats and taking actions in plant health. However, despite its importance, the application of HS in plant health has received comparatively little attention alongside other foresight tools (Hulme, 2024). Event-based surveillance systems can accelerate the retrieval of relevant pest information (Balajee et al., 2021) by monitoring and collecting events from information sources such as media and scientific publications (Ferilli et al., 2019). These systems play a crucial role in the early identification of new pests and serve as a valuable complement to the National Plant Protection Organization (NPPO) monitoring efforts (Thomas et al., 2011). Indeed, through this HS exercise, 392 new pests (i.e. not-listed) were identified (Fig. 1a). Although a higher number of included articles focused on regulated pests, this information was selected, as it remains relevant for the main end-user: in this case, EU risk managers. For this reason, the insects and mites category was expected to be most frequently cited, as it also includes the highest number of regulated species. Besides, the fact that media sources were predominant for regulated pests reflects that these sources are more reliable or describe data about pests when they are known (Fig. 1b).

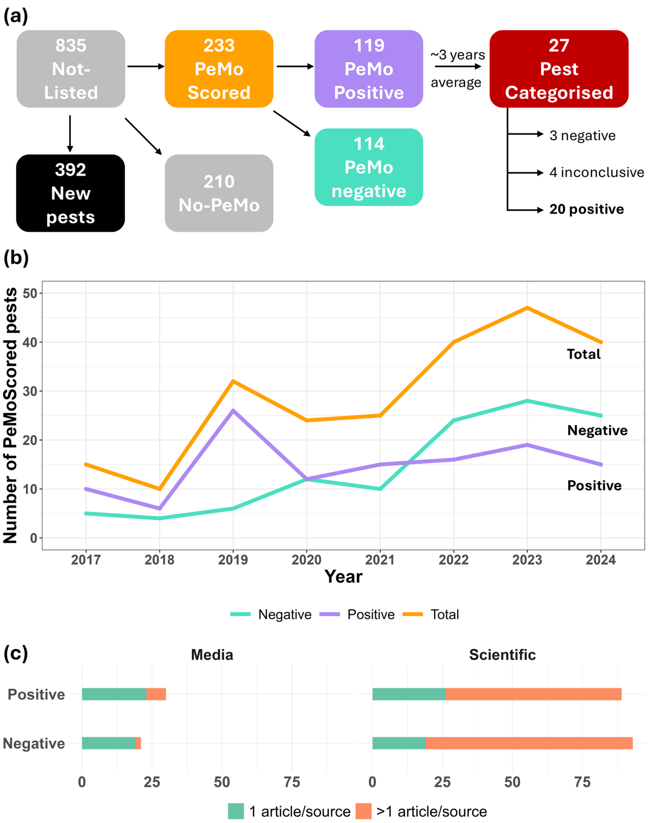

Figure 4. Results of the PeMoScoring process in the horizon scanning exercise from 2017 to 2024. **(a)** Distribution of not-listed pests considering PeMo requirements. Not-listed pests are shown in grey, 392 new pests are shown in black, pests without a PeMo are shown in grey, PeMoScored pests are shown in orange, those with a positive score are shown in purple, and those with a negative score are shown in green. On average, it took approximately 3 years for PeMo-positive cases to undergo pest categorisation. Of the 27 pest categorisation cases, 20 were confirmed as positive, 4 were inconclusive, and 3 were negative. **(b)** Progression of PeMoScoring results over time. Orange indicates the total number of pests, while purple and green indicate positive and negative scores, respectively. **(c)** Number of PeMoScored pests, positive and negative, Bar colours indicate the sources capturing only one article (green) versus those capturing more than one article (red) for both scientific and media sources.

This pattern may also reflect source credibility, with media news seen as more reliable when reporting on established or regulated pests (Takahashi and Tandoc, 2016).

HS systems rely on the monitoring phase, where capturing information becomes the first key step. Therefore, the data sources are a relevant characteristic of the tool. Certain sources are known to drive abundant information, with the most frequently used scientific source capturing 420 articles, and 50 articles were captured from the most used media source from all HS reports (Table S1). Despite having fewer scientific sources, a higher number of articles was captured from them (Fig. 2). However, the primary objective is to identify key information irrespective of its origin. Expanding the range of sources increases the overall data volume while maintaining the quality of the output. This is represented by the fact that there were 597 articles coming from sources used only once, from which 443 were media and 154 were scientific (Fig. 2).

Regarding the articles' topics, the assessment and management groups were predominately associated with regulated pests, reflecting our selection criteria (Fig. 3a). Such topics typically arise when pests are well characterised, allowing the development of appropriate management strategies. Genome-wide studies have been suggested as a valuable tool for managing invasive species, although they are limited for the moment (Kołodziejczyk et al., 2025). Data on new observations were usually prioritised, as they provide highly valuable insights into new pest biology and discovery information. For instance, the HS newsletter from February 2022 included articles that reported the first observation of *Neofusicoccum mediterraneum* in Italy (Brunetti et al., 2022), a new report of *Citrus concave gum-associated virus* in the US (Diaz-Lara et al., 2022), and evidence for *Hordeum vulgare* as a new host plant of *Chinese wheat mosaic virus* (Kondo et al., 2022). The HS procedure triggered a request from the Swedish Board of Agriculture for a further Swedish-tailored risk assessment analysis for the abovementioned pests (Björklund and Boberg, 2022), none of which were listed in the EU Plant Health Regulation.

For specific biological categories, such as insects and mites, social media sources have proven especially influential, underscoring the value of integrating citizen science (Fig. 3b). For instance, media signals about the *Solenopsis invicta* outbreak in Sicily surfaced well before the formal scientific publication (Menchetti et al., 2023). Also, the collection of environmental DNA by citizen scientists could significantly enhance monitoring efforts and connect data from large geographical areas (Lawson Handley, 2015; Friedrich et al., 2024).

Host plants affected by pests predominantly belong to the crop classification, underscoring the economic importance of these species (Table S1). However, attention to other host plant types, such as forests and wild plants, is crucial, as they may serve as reservoirs for pests that could later impact crops and are also vital for ecosystem services (Brockerhoff et al., 2017; Gentili et al., 2021). Ornamental plants, meanwhile, are of particular interest due to their high potential for introducing invasive species through trade. There is a link between insect invasions and the proliferation of non-native plants (Bertelsmeier et al., 2024). For instance, *Lycorma delicatula*, the invasive spotted lanternfly, spread in the US in a non-native host, *Ailanthus altissima*. Once established, it also inflicted damage on native trees, such as *Juglans nigra*, and cultivated crops like *Vitis vinifera* (Murman et al., 2020). Additionally, many ornamentals are ubiquitous in urban areas, which may have an impact on the cultural ecosystem services and the quality of urban environments (Bertelsmeier et al., 2024).

The high number of non-listed species identifiable each month by the HS exercise necessitates a fast classification without replacing a full pest risk analysis (PRA) outcome. As mentioned, new pests were not subjected to PeMoScoring due to a lack of information. Although most of the new pests identified in this HS activity have not been reported again, it remains important to note them for detection purposes (e.g. distinguishing them from other more common pests) and for tracking in case they reappear (Fig. 4a). This highlights the usefulness of the PeMo tool, as it facilitates alerts for reported pests.

The PeMoScoring is a reference for a further risk assessment also provided by EFSA, named pest categorisation. The pest categorisation report provides a more elaborate result on the possibility of the pest to be a threat for European territory (EFSA, 2024). PeMo has become a useful tool for rapidly assessing and prioritising pest regulation needs, as demonstrated by 20 out of 27 pests with positive PeMo scores aligning with positive pest categorisation outcomes (Fig. 4a). The reduction of PeMo-positive pests along the time may be a sign of improvement of the protective measures, as diagnosis and control measures are taken into consideration for the PeMoScoring evaluation (Figs. 4b, S3).

Efforts to identify and monitor specific pests and the preventive measures taken by risk managers may have helped in preventing the introduction of some of these pests into EU territory. For instance, *Fusarium oxysporum* f. sp. *cubense tropical race 4* (TR4) is a soil-borne fungus responsible for causing Panama disease in bananas (Chen et al., 2024). Initially identified in tropical regions of eastern Asia and Australia (Bai et al., 2013), TR4 infects nearly all banana species and exhibits enhanced transmission routes and pathogenicity (Acuña et al., 2022; Mejías et al., 2023). Considering these characteristics, this fungus was one of the first pests to be used in the PeMo exercise, although bananas are not widely cultivated in the EU. It scored positive in PeMoScoring in July 2017, at which time its distribution was limited to eastern Asia (Taiwan, where it was first identified, and Japan) and the Middle East (Jordan and Lebanon). Since that time, it has also spread to Türkiye, Oceania, and notably Latin America, including Colombia (first detected in 2019), Peru (2021), and Venezuela (2023), where the cultivation of banana is more established. After the PeMo analysis in 2017, a pest categorisation in 2022 was performed, and the pathogen met the criteria for consideration as a potential Union quarantine pest (EFSA et al., 2022a). In 2024, a crisis emerged in the banana sector due to the impact of this pest, and it was included in the EPPO A2 list, meaning it became of quarantine concern to EPPO member countries (EPPO, 2024b). The IPPC set new guidelines on TR4 prevention and preparedness, including measurements for e-commerce (IPPC, 2023). TR4 has emerged as a concerning pest in other HS activities, such as those reported by CABI (Mulema et al., 2025). The development of a resistant banana variety has offered a promising solution to save the banana crop which has been approved for its use in several countries, such as the Philippines, Indonesia, and New Zealand (WUR, 2024).

As previously discussed, having a large number of sources enabled the identification of relevant information, even when individual sources were consulted only once. This is more pronounced for media sources, where most of the pests submitted to PeMoScoring came from sources that were used only once in the HS activity (Fig. 4c).

Given the current potential of the system in detecting relevant literature, not only about pest biology but also environmental interactions, a driver-based strategy could be advantageous. While many biological invasions occur through human-mediated pathways, the underlying ecological processes are the same as in natural colonisations, making it essential to identify and understand the specific dispersal routes involved (Hoffmann and Courchamp, 2016). This approach would prioritise factors such as the evolution of global trade, changes in agricultural practices, and the biology of pests, as well as climate change, supporting the One Health perspective that connects environmental and biological drivers. These drivers could be identified using the data that have already been collected over the years through the HS process. A preliminary study was conducted by screening media and scientific articles from the EFSA monthly HS Newsletters published between June 2021 and September 2022 (Sarakatsani et al., 2022). This article's screening confirmed that global trade is the main driver for pest emergence. Other studies have shown the same trend for global trade as one of the main risks for plant pest introduction, emphasising the volume or the interaction partners (Fenn-Moltu et al., 2023; Nardi et al., 2025). Interestingly, studies regarding possible future changes in biodiversity show that specific traits of different taxonomic groups may mediate an increased abundance of species in a given environment (Gossner et al., 2023), which might be accompanied by new plant health threats. Increased species abundance may be anticipated in the case of polyphagous insect species, adapted to warm climates and/or tolerant to heat, and in the can of anthropogenic disturbances, such as changes in land use and pesticide application. High dispersal capacity can also be a trait that could be favoured by climate change. Overall, genetic diversity could favour pest emergence, since it is related to a higher capacity for the pests to adapt in the new conditions which can be formed by multiple drivers interacting with one another in a given environment (Corrêa et al., 2019). An example of plant pests with high genetic diversity is the fungal family Botryosphaeriaceae; recently, the EFSA HS process identified *Neofusicoccum* fungi among the species to be assessed as quarantine pests for the EU Plant Health regulation, such as *N. mediterraneum* (EFSA et al., 2022a; EFSA, 2025b).

Overall, HS plays a crucial role in the early identification of new pests and serves as a valuable complement to monitoring efforts. For this purpose, the collection of data from the HS newsletter is available in an interactive dashboard (EFSA et al., 2025a). Combining information from different countries will help to identify patterns and anticipate to possible introductions. Therefore, in parallel with the HS reports, several workshops are being organised to improve the tool, guide it towards a driven approach strategy, and build a Plant Health community using HS (Tramontini et al., 2024, 2025).

5 Conclusions

To date, the implementation of this HS tool for plant health has significantly strengthened risk managers' capacity for preventative action, a benefit also reflected in the complementary PeMoScoring.

However, limitations in data publication and web scraping can delay event detection. Improved methods could shift from consequence-to-event to event-to-consequence tracking. Besides, the extensive data collected over the years are a valuable resource for developing artificial-intelligence-based systems that can identify critical information for risk managers in plant health. Overall, preparedness against pest emergence can be reinforced by identifying and monitoring the factors that lead to pest emergence or drivers of pest emergence. Once key drivers are established, such as pathways of introduction (e.g. trade in specific commodities), environmental changes (e.g. climate shifts enabling pest establishment), or agronomic practices, risk managers can use these findings to propose measures that directly mitigate these factors. Defining global plant health threats will help clarify the horizon that needs to be scanned. Investing in coordinated and resource-efficient information-scanning tools could significantly advance plant health surveillance.

Data availability. Horizon scanning reports are available in the EFSA Journal https://efsa.onlinelibrary.wiley.com/journal/23978325 (last access: 17 October 2025). Data are accessible through an interactive dashboard (https://www.efsa.europa.eu/en/powerbi/plant-health-horizon-scanning-dashboard, last access: 17 October 2025).

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