Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Prioritization of absent quarantine pests in Brazil through the Analytical Hierarchy Process

Priorização de pragas quarentenárias ausentes no Brasil por meio do Processo de *Analytical Hierarchy Process*

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Abstract

Introducing an Absent Quarantine Pest (AQP) can cause severe economic, social and environmental impacts, generating food insecurity. The Analytical Hierarchy Process (AHP) method is an excellent tool for prioritizing APQs, allowing countries to better prepare against these threats. This study aimed to determine which AQPs should be prioritized in Brazil. For this, 20 AQPs were selected from the Brazilian official list. The selection was based on pests intercepted by Brazil between 2015 and 2018 and by countries of the European and Mediterranean Plant Protection Organization, in the international movement of plants. It can be concluded that out of the 20 AQPs studied, 17 are the priority and that the AHP method is effective for this purpose. Other countries from different continents can use this methodology to prioritize PQAs and thus create strategic plans to prevent entry into their territories and economic, social, and environmental impacts.

Keywords: crop pathogens, insects, invertebrate crop pests, pest prioritization, weeds.

Resumo

A introdução de uma Praga Ausente Quarentena (PQA) pode causar graves impactos econômicos, sociais e ambientais, gerando insegurança alimentar. O método Processo de Hierarquia Anal Analytical Hierarchy Process (AHP) é uma excelente ferramenta para priorizar APQs, permitindo que os países se preparem melhor contra essas ameaças. Este estudo teve como objetivo determinar quais AQPs devem ser priorizados no Brasil. Para isso, foram selecionados 20 AQPs da lista oficial brasileira. A seleção foi baseada em pragas interceptadas pelo Brasil entre 2015 e 2018 e por países da European and Mediterranean Plant Protection Organization. Pode-se concluir que dos 20 AQPs estudados, 17 são os prioritários e que o método AHP é eficaz para este fim. Outros países de diferentes continentes podem usar essa metodologia para priorizar os PQAs e, assim, criar planos estratégicos para prevenir a entrada em seus territórios e impactos econômicos, sociais e ambientais.

Palavras-chave: fitopatógenos, insetos, invertebrados-pragas, priorização de pragas, plantas daninhas.

1. Introduction

Introducing an Absent Quarantine Pest (AQP) can cause severe economic, social and environmental impacts, generating food insecurity. In some cases, it reaches the level of a trade barrier for the country involved (WTO, 2020). Worldwide costs with invasions reached US$ 1.288 trillion from 1970 to 2017, and the average annual cost was US$ 26.8 billion. In Brazil, the minimum estimated costs for just 16 invasive species were US$ 105.3 billion over the last 35 years (1984–2019), with an average cost of US$ 3.02 (± 9.8) billion per year (Adelino et al., 2021). Brazilian agriculture is the sector most impacted by biological invasions, with an estimated economic cost of US$ 39.61 billion (Adelino et al., 2021). This study is important to reduce production losses to avoid pressure on conserved areas and, consequently, combine sustainable development with environmental protection.

Brazil is responsible for producing food that serves 800 million people from different countries. By 2050, national grain production could exceed 500 million tons, being even more critical for world food security (Canal Rural, 2020). Despite the volumes produced and sold, some obstacles hamper production, especially pests. Among the primary means of spreading pests is the increase in the flow of people around the world (IPPC, 1997), which reached U$ 1.5 billion arrivals (ONU, 2022). Furthermore, the increase in commercial relations contributes to potentially introducing these harmful organisms (IPPC, 1997).

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Received: April 29, 2023 – Accepted: July 27, 2023

Brazil has an extensive history of pest introductions, such as *Ceratitis capitata* Wied. (Diptera: Tephritidae) in 1905, *Xanthomonas citri* (Hasse) Dye (Xanthomonadales: Xanthomonadaceae) in 1957, *Hemileia vastatrix* Berk. et Br. (Uredinales: Pucciniaceae) in 1970, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae) in 1983, *Bactrocera caramboleae* Drew andHancock (Diptera: Tephritidae) in 1996, *Phakopsora pachyrhizi* Sidow (Pucciniales: Phakopsoraceae) in 2001, *Candidatus liberibacter* (Hyphomicrobiales: Rhizobiaceae) in 2004 and *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) in 2012 (Hilman and Goulart, 2015). For example, *H. armigera* has the potential to cause about 40% production losses. Soybean, corn, and cotton represent some crops of choice and are among the main species grown in Brazil (CEPEA, 2019). The most recent pests introduced in the country were *Drosophila suzukii* Matsumura (Diptera: Drosophilidae) in 2014, which spread to Uruguay, Argentina, and Chile (Garcia, 2020; Garcia et al., 2022), and *Sternochetus mangiferae* (Fabricius) (Coleoptera: Curculionidae) in 2017 (Silva and Ricalde, 2017).

I view the damage caused by AQP to food-producing countries, and preventive measures are taken to reduce the risk of introduced pests. Brazil has prevention strategies established in international agreements. Among them are pest risk analysis, phytosanitary certification, global agricultural surveillance, plant quarantine, and specialized laboratory support (IPPC, 1997). The Ministry of Agriculture, Livestock, and Supply - MAPA established as AQPs in about 600 organizations widely distributed worldwide (Brasil, 2018). These pests have biological characteristics and different forms of dissemination that can find conditions for their establishment in the national territory. Brazil has a vast area dedicated to agriculture and marked environmental diversity (IBGE, 2019), which can facilitate this dissemination.

In this context of threats and impacts, it is necessary to establish methodologies on pest prioritization for risk and human and financial resources management. The Analytical Hierarchy Process (AHP) method makes it possible to remove subjectivity from decisions, logically structuring a complex problem and facilitating the determination of priorities (Saaty, 2013).

The Analytical Hierarchy Process (AHP) can be used for several purposes, such as: to evaluate alternative pest-control strategies (Wan et al., 2009), for application in the selection of plant types on the community agroforestry land (Rahmawaty et al., 2022), for selection of agricultural irrigation systems (Veisi et al., 2022), for prioritization of barriers to offshore wind energy (Dhingra et al., 2022), for ecological risk assessment of marine microplastics (Zhang et al., 2022), for hospital site selection (Sahin et al., 2019), selecting strategies for rice stem borer management (Abdollahzadeh et al., 2016), among many other applications.

There are few records in the literature focused on pest prioritization using AHP. Therefore, the present study evaluated which AQP should be prioritized by Brazil using the Analytic Hierarchy Process (AHP) methodology. This study evaluates 20 AQPs considered important for MAPA (Brasil, 2019).

2. Material and Methods

2.1. Selection of AQPs

In this study, we used the AHP method adopted by Laranjeira et al. (2018) to assess 20 AQPs not included in the official list of priorities listed in Ministério da Agricultura e Pecuária (MAPA) Ordinance 131 (Brasil, 2019).

Among the hundreds of AQPs that make up the official Brazilian list (Brasil, 2018), twenty AQPs were selected according to the following parameters: I - Pests with at least five interceptions recorded between 2015 and 2018 by MAPA and the European and Mediterranean Plant Protection Organization - EPPO. The records of interceptions were made available by the Department of Plant Health - DSV/MAPA, II – Pests with at least five host crops and at least one of these crops with an area implanted in three Brazilian regions, according to the Instituto Brasileiro de Geografia e Estatística (IBGE), III – Pests occurring in at least three countries with commercial relations with Brazil (Table 1).

2.2. Criterion and sub-criteria

The AHP is composed of the *entry*, *establishment, spread, d* and, *estimated impacts* criteria. These criteria have 19 correlated sub-criteria, each with its importance. This importance is characterized by the adoption of different weights between the sub-criteria (Table 2).

It has six sub-criteria referring to the probability of entry of an AQP into the Brazilian territory. Mainly related to the geographic distribution of AQPs and the commercial movements of their hosts (Adaime et al., 2018).

Refers to the potential for establishment and spread of absent quarantine pests after occasional entry into the Brazilian territory. Its seven sub-criteria are directly related to climate, area of cultivation of host plant species, human intervention, and biological characteristics (Fidelis et al., 2018).

The *Estimated impacts* criterion has six sub-criteria related to the possible economic, social, and environmental impacts caused by an eventual introduction of AQP into the Brazilian territory. These impacts can be directly due to the product's unfeasibility and indirect effects caused by the social and environmental issues involved (Lohmann et al., 2018).

After selection, the 20 AQPs were evaluated by the AHP method and subjected to each of the 19 sub-criteria that are part of the entry, establishment, and spread and estimated impacts criteria, reaching scores that ranged from 0 to 1,000 (Hilman et al., 2023).

2.3. Statistical analysis

Data from the 20 AQPs evaluated by the AHP were subjected to basic statistical analysis and the K-Means Clustering algorithm. This method, improved by Hartigan (1975), classifies data sets with similar results, regardless of presets, forming groups or clusters. This method classifies data sets with similar results, independent of presets, forming groups or clusters. The organization analyzes possible clusters using a multivariate data mining technique, automatically homogenizing the data into groups according to their similarities (PUC-RIO, 2020).

Table 1. List of Absent Quarantine Pests (AQP) selected according to the number of interceptions by Brazil and the European and Mediterranean Plant Protection Organization between 2015 and 2018, hosts, and countries in which their occurrence was recorded. NI, Number of interceptions, NH, Number of hosts, NC, number of countries.

Absent Quarantine Pests (AQP)	Order: Family	Common name	Type of pest	NI	NH	NC
Arabis Mosaic Virus Smith and Markham, 1944	Picornavirales, Comoviridae	hop bare-bine	virus	212	20	44
Impatiens necrotic spot ortho-tospovirus	Mononegavirales, Bunyaviridae	Impatiens Necrotic Spot Virus	virus	196	19	23
Rhodococcus fascians (Tilford, 1936)	Actinomycetales, Nocardiaceae	leafy gall	fungus	132	122	27
Scirtothrips dorsalis Hood, 1919	Thysanoptera, Thripidae	Chilli thrips	insect	102	85	66
Spodoptera littoralis Boisduval, 1833	Lepidoptera, Noctuidae	cotton leafworm	insect	64	126	60
Otiorhynchus sulcatus Fabricius, 1775	Coleoptera, Curculionidae	vine weevil	insect	52	67	33
Pratylenchus scribneri Steiner, 1943	Tylenchida, Pratylenchidae	northern root lesion	insect	38	49	15
Tetranychus pacificus McGregor, 1919	Acarina: Tetranychidae	Pacific spider mite	mite	38	54	3
Erwinia rhapontici (Millard 1924)	Enterobacterales, Enterobacteriaceae	rhubarb crown rot	bacteria	32	19	13
Chondrostereum purpureum Pers, 1794.	Agaricales, Cyphellaceae.	The silver blight of stone fruit trees	fungus	30	178	27
Platynota stultana Walsingham, 1884	Lepidoptera, Tortricidae	omnivorous leaf roller	insect	28	89	3
Latheticus oryzae Waterhouse, 1880	Coleoptera, Tenebrionidae	longheaded flour beetle	insect	22	6	21
Acarus siro L. 1758	Sarcoptiformes, Acaridae	Flour mite	mite	21	18	22
Senecio vulgaris L. 1753	Asterales, Asteraceae	Common groundsel	weed	19	78	78
Botrytis fabae Sardiña, 1929	Helotiales, Sclerotiniaceae	chocolate spot	fungus	16	11	39
Sonchus arvensis L. 1753.	Asterales, Asteraceae	perennial sowthistle	weed	14	19	47
Globodera pallida (Stone, 1973)	Tylenchida, Heteroderidae	potato cyst nematode	nematode	11	28	55
Heterodera zeae Koshy, Swarup, andSethi, 1971	Tylenchida, Heteroderidae.	corn cyst nematode	nematode	5	11	10
Phalaris paradoxa L. 1763	Cyperales, Poaceae	awned canary-grass	weed	5	10	50
Asphodelus tenuifolius Cav. 1801	Liliales, Liliacea	onionweed	weed	5	15	28

References: Number of interceptions = interceptions carried out by the Ministry of Agriculture, Livestock, and Supply (MAPA) and by the countries that make up the European and Mediterranean Plant Protection Organization, Number of hosts = several pest hosts, Number of countries a = number of countries with the occurrence of the pest.

Table 2. List of criteria and sub-criteria used to determine the importance of twenty quarantine pests in Brazil.

Criterion	Sub-criteria
Entry	1. Distance between the nearest location and the Brazilian border
	2. Number of continents where the pest occurs
	3. Number of imports of host material or regulated article
	4. Number of countries in which the pest occurs
	5. Number of countries bordering Brazil where the pest occurs
	6. Import volume of host material or regulated article.
Establishment and spread	7. Climate adaptation in Brazil
	8. Total area of host crops
	9. Efficiency of control methods
	10. Annual natural spread distance estimation
	11. Number of hosts
	12. Percentage of microregions with host cultures
	13. Probability of human spread of pest
Estimated impacts	14. Expected percentage of damage
	15. Number of jobs in the host crop production chain
	16. Number of properties with the host crop
	17. Number of countries regulating the pest
	18. Potential for contamination by pesticides
	19. Value of the annual production of the host crop

3. Results

3.1. Entry criterion

The awned canary grass (*Phalaris paradoxa*), Common groundsel (*Senecio vulgaris*), Onionweed (*Asphodelus tenuifolius*), Chilli thrips (*Scirtothrips dorsalis*), and Potato cyst nematode (*Globodera pallida*) presented high risk in the entry criterion (scores more significant than 750). Their prioritization was influenced by the presence in border countries, wide geographic distribution, and considerable import of host material. On the other hand, the corn cyst nematode (*Heterodera zeae*), rhubarb crown rot (*Erwinia rhapontici*), omnivorous leaf roller (*Platynota stultana*), and Pacific spider mite (*Tetranychus pacificus*) had the lowest risk of entry (scores less than 500). These four AQPs have in common that they are absent in South America and have a restricted worldwide distribution. The other pests reached intermediate scores (between 500 and 750), influenced by geographic distribution and their proximity to Brazil (Table 3).

3.2. Establishment and spread criterion

The AQP *Spodoptera littoralis* (Boisduval), African cotton leafworm, *Senecio vulgaris* L. groundsel, and *Tetranychus pacificus*, Pacific spider mite, achieved scores greater than 750, that is, very high potential for establishment and spread. The pests *Acarus siro*¸ Flour mite, and *Latheticus oryzae*, longheaded flour beetle, achieved the lowest scores in this criterion, as they are stored grain pests and do not directly attack crops. All AQPs studied had a high capacity for climatic adaptation, however, the sub-criteria *efficiency of control methods* and *annual natural spread distance estimation* had wide variation in scores (Table 4).

3.3. Estimated impacts criterion

Most AQPs achieved high or very high scores. The exceptions were *Acarus siro* and *Latheticus oryzae*, due to their characteristics of causing low impacts. *Scirtothrips dorsalis* and *Spodoptera littoralis* stood out, which reached the maximum scores in all sub-criteria (Table 5).

3.4. General result of the prioritization

The prioritization of pests according to the AHP methodology signals the importance of the AQP selected in the present study, especially *Scirtothrips dorsalis*, *Spodoptera littoralis*, *Senecio vulgaris*, *Globodera pallida*, and *Platynota stultana*. However, all the pests studied reached expressive results (above 600). The exceptions are the stored grain pests, *Latheticus oryzae*, and *Acarus siro*, due to their characteristics already reported in the present study (Table 6). The clustering result (Table 7).

Table 3. Ranking of absent quarantine pests (AQP), their prioritization (P), and score (S), according to the sub-criteria of the ***entry*** criterion and sub-criteria: 1, th distance between the nearest location and the border, 2, number of bordering countries in which it occurs, 3, number of countries in which it occurs, 4, number of continents where the pest occurs, 5, the Import volume of the host material, 6, host material import numbers.

AQP	P	S	SUB-CRITERIA/WEIGHT					
			1	2	3	4	5	6
			0.1727	0.2498	0.1398	0.0755	0.2029	0.1593
Phalaris paradoxa	1	797	750	500	750	1,000	1,000	1,000
Senecio vulgaris	1	797	750	500	750	1,000	1,000	1,000
Scirtothrips dorsalis	3	778	750	500	750	750	1,000	1,000
Asphodelus tenuifolius	4	762	750	500	500	1,000	1,000	1,000
Globodera pallida	5	757	750	500	750	1,000	1,000	750
Botrytis fabae	6	700	750	250	500	1,000	1,000	1,000
Latheticus oryzae	7	662	750	250	500	500	1,000	1,000
Acarus siro	8	594	500	0	500	1,000	1,000	1,000
Chondrostereum purpureum	8	594	500	0	500	1,000	1,000	1,000
Otiorhynchus sulcatus	8	594	500	0	500	1,000	1,000	1,000
Sonchus arvensis	8	594	500	0	500	1,000	1,000	1,000
Arabis Mosaic Virus	8	594	500	0	500	1,000	1,000	1,000
Spodoptera littoralis	13	591	500	0	750	500	1,000	1,000
Impatiens Necrotic Spot Virus	14	535	500	0	500	750	1,000	750
Rhodococcus fascians	15	532	250	0	500	750	1,000	1,000
Pratylenchus scribneri	16	516	250	0	250	1,000	1,000	1,000
Heterodera zeae	17	497	250	0	250	750	1,000	1,000
Erwinia rhapontici	18	478	250	0	250	500	1,000	1,000
Platynota stultana	19	459	250	0	250	250	1,000	1,000
Tetranychus pacificus	20	440	250	0	250	0	1,000	1,000

Table 4. Ranking of absent quarantine pests (AQP), their prioritization (P), and score (S), according to the sub-criteria of the *ESTABLISHMENT AND SPREAD* criterion and subcriteria: 7, climate adaptation, 8, number of hosts, 9, the total area of host crops, 10, percentage of microregions with host crops, 11, efficiency of control methods, 12 annual natural spread distance estimation, 13, probability of human spread of the pest.

AQP	P	S	SUB-CRITERIA/WEIGHT						
			7	8	9	10	11	12	13
			0.159	0.1762	0.1752	0.1174	0.096	0.131	0.1452
Spodoptera littoralis	**1**	**855**	1,000	1,000	1,000	1,000	250	1,000	500
Senecio vulgaris	**2**	**773**	1,000	1,000	1,000	1,000	0	0	1,000
Tetranychus pacificus	**3**	**757**	1,000	1,000	1,000	1,000	250	250	500
Globodera pallida	**4**	**709**	1,000	750	750	1,000	250	0	1,000
Arabis Mosaic Virus	**5**	**708**	1,000	500	1,000	1,000	1,000	0	500
Scirtothrips dorsalis	**6**	**700**	1,000	1,000	1,000	1,000	0	0	500
Platynota stultana	**7**	**697**	1,000	1,000	1,000	1,000	0	250	250
Chondrostereum purpureum	**8**	**677**	1,000	1,000	750	750	250	750	0
Rhodococcus fascians	**9**	**664**	1,000	1,000	1,000	1,000	0	0	250
Sonchus arvensis	**10**	**645**	1,000	500	1,000	1,000	0	250	500
Impatiens Necrotic Spot Virus	**11**	**628**	1,000	750	500	1,000	1,000	0	250
Pratylenchus scribneri	**12**	**620**	1,000	750	1,000	1,000	0	0	250
Heterodera zeae	**13**	**612**	1,000	500	1,000	1,000	0	0	500
Asphodelus tenuifolius	**13**	**612**	1,000	500	1,000	1,000	0	0	500
Botrytis fabae	**15**	**609**	1,000	500	1,000	1,000	0	250	250
Erwinia rhapontici	**16**	**602**	1,000	500	1,000	500	500	0	500
Phalaris paradoxa	**17**	**583**	1,000	500	1,000	750	0	0	500
Otiorhynchus sulcatus	**18**	**562**	1,000	1,000	750	500	0	0	250
Acarus siro	**19**	**356**	1,000	500	0	0	0	0	750
Latheticus oryzae	**20**	**316**	1,000	500	0	0	0	250	250

Table 5. Ranking of absent quarantine pests (AQP), their prioritization (P), and score (S), according to the sub-criteria of the *Estimated impacts* criterion. 14, the expected percentage of damage, 15, the value of the annual production of the host crop, 16, number of countries regulating the pest, 17, number of properties with the host crthe op, 18, number of jobs in the host crop production chain, the 19, potential of contamination by pesticides.

AQP	P	S	SUB-CRITERIA/WEIGHT					
			14	15	16	17	18	19
			0.2708	0.2493	0.1636	0.1198	0.13	0.0664
Scirtothrips dorsalis	**1**	**1,000**	1,000	1,000	1,000	1,000	1,000	1,000
Spodoptera littoralis	**1**	**1,000**	1,000	1,000	1,000	1,000	1,000	1,000
Platynota stultana	**3**	**959**	1,000	1,000	750	1,000	1,000	1,000
Heterodera zeae	**3**	**959**	1,000	1,000	750	1,000	1,000	1,000
Pratylenchus scribneri	**5**	**918**	1,000	1,000	500	1,000	1,000	1,000
Impatiens Necrotic Spot Virus	**6**	**871**	1,000	750	1,000	1,000	1,000	0
Tetranychus pacificus	**7**	**865**	500	1,000	1,000	1,000	1,000	1,000
Globodera pallida	**8**	**853**	750	750	1,000	1,000	1,000	750
Rhodococcus fascians	**9**	**852**	1,000	1,000	500	1,000	1,000	0
Asphodelus tenuifolius	**10**	**850**	750	1,000	500	1,000	1,000	1,000
Senecio vulgaris	**10**	**850**	750	1,000	500	1,000	1,000	1,000
Sonchus arvensis	**10**	**850**	750	1,000	500	1,000	1,000	1,000
Arabis Mosaic Virus	**13**	**833**	750	1,000	1,000	1,000	750	0
Botrytis fabae	**14**	**784**	750	1,000	500	1,000	1,000	0
Otiorhynchus sulcatus	**15**	**753**	1,000	500	750	1,000	500	750
Erwinia rhapontici	**16**	**722**	750	750	500	1,000	1,000	0
Chondrostereum purpureum	**17**	**711**	750	1,000	250	1,000	750	0
Phalaris paradoxa	**18**	**661**	750	500	500	1,000	500	1,000
Acarus siro	**19**	**467**	500	1,000	500	0	0	0
Latheticus oryzae	**19**	**467**	500	1,000	500	0	0	0

Table 6. Ranking of absent quarantine pests (AQP), their prioritization (P), and score (S), according to the Entry (E), Establishment and spread (ES,) and estimated impacts (EI) criteria.

AQP	S	P	CRITERIA/WEIGHT		
			E	ES	EI
			0.2465	0.2068	0.5466
Scirtothrips dorsalis	1	883	778	700	1,000
Spodoptera littoralis	2	875	591	885	1,000
Senecio vulgaris	3	821	797	773	850
Globodera pallida	4	799	757	709	853
Platynota stultana	5	781	459	697	959
Asphodelus tenuifolius	6	779	762	612	850
Heterodera zeae	7	773	497	612	959
Pratylenchus scribneri	8	757	516	620	918
Arabis Mosaic Virus	9	748	594	708	833
Sonchus arvensis	10	744	594	645	850
Impatiens Necrotic Spot Virus	11	738	535	628	871
Tetranychus pacificus	11	738	440	757	865
Rhodococcus fascians	13	734	532	664	852
Botrytis fabae	14	727	700	609	784
Phalaris paradoxa	15	678	797	583	661
Chondrostereum purpureum	16	675	594	677	711
Otiorhynchus sulcatus	17	674	594	562	753
Erwinia rhapontici	18	637	478	602	722
Latheticus oryzae	19	484	662	316	467
Acarus siro	20	475	594	356	467

Table 7. Clustering of absent quarantine pests (AQP), according to the K-means algorithm.

AQP	Type of pest	K-means cluster
Acarus siro	Mite	G1
Latheticus oryzae	Insect	G1
Tetranychus pacificus	Mite	G2
Erwinia rhapontici	Bacterium	G2
Rhodococcus fascians	Bacterium	G2
Platynota stultana	Insect	G2
Spodoptera littoralis	Insect	G2
Heterodera zeae	Nematode	G2
Pratylenchus scribneri	Nematode	G2
Sonchus arvensis	Weed	G2
Arabis Mosaic Virus	Virus	G2
Impatiens Necrotic Spot Virus	Virus	G2
Botrytis fabae	Fungus	G3
Chondrostereum purpureum	Fungus	G3
Otiorhynchus sulcatus	Insect	G3
Scirtothrips dorsalis	Insect	G3
Globodera pallida	Nematode	G3
Phalaris paradoxa	Weed	G3
Asphodelus tenuifolius	Weed	G3
Senecio vulgaris	Weed	G3

The final data from the prioritization of pests were subjected to statistical analysis (mean, standard deviation, standard error, and variance) as a prerequisite for applying the K-means algorithm, as there was a similarity in scores of most AQPs. Statistical clustering was necessary to remove subjectivity from data analysis.

The prioritization of pests according to the AHP methodology [adapted by Laranjeira et al. (2018)] signals the importance of the AQP selected in the present study, especially *Scirtothrips dorsalis*, *Spodoptera littoralis*, *Senecio vulgaris*, *Globodera pallida,* and *Platynota stultana*. However, all the pests studied reached expressive results (above 600). The exceptions are the stored grain pests, *Latheticus oryza,* and *Acarus siro*, due to their characteristics already reported in the present study.

The final data from the prioritization of pests were subjected to statistical analysis (mean, standard deviation, standard error, and variance) as a prerequisite for applying the K-means algorithm, as there was a similarity in scores of most AQPs. Statistical clustering was necessary to remove subjectivity from data analysis (Table 7).

The K-means algorithm included two, ten, and eight pests in groups 1, 2, and 3, respectively. Group 1 scored close to 600 on the entry criterion, 350 on the establishment and spread criterion, and 480 on the estimated impacts criterion. Group 2 scored approximately 500 on the entry criterion, 700 on the establishment and spread criterion, and 900 on the estimated impacts criterion. Group 3 achieved a score close to 700 in the entry criterion, 700 in the establishment and spread criterion, and 800 in the estimated impacts criterion (Figure 1).

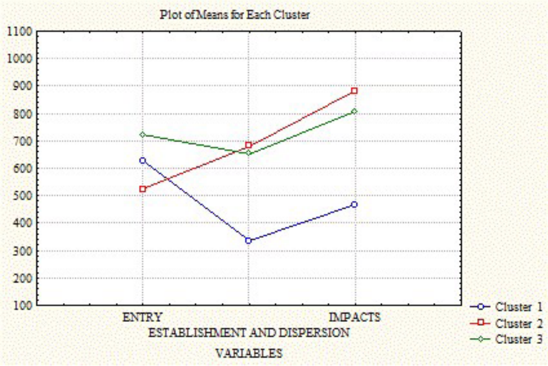

Figure 1. Clustering of Absent Quarantine Pests (AQP) by the K-means algorithm, in the criteria of entry, establishment, and spread, and estimated impacts.

4. Discussion

The AQP list prioritized has scored above 500 (Brasil, 2019). In the present study, 17 out of the 20 AQP evaluated reached scores between 687 and 883, affirming that these pests should be officially incorporated into this list. This statement is based on the K-means algorithm for forming groups, from which it was possible to observe that groups 2 and 3 have similar, high, and very high scores, distinguishing in the entry criterion. Pests in group 1 had significantly lower scores and were not considered a priority. The greatest uniformity was found in group 3, formed by *Scirtothrips dorsalis*, *Senecio vulgaris*, *Globodera pallida*, *Botrytis fabae*, *Chondrostereum purpureum*, *Otiorhynchus sulcatus*, *Phalaris paradoxa*, and *Asphodelus tenuifolius*.

Scirtothrips dorsalis reached the highest score among the 20 AQPs. Its performance was significant across all criteria, with a maximum score in *estimated impacts*. In addition to direct impacts, the pest is a virus vector for mango trees and other important host plants (Paula and Oliveira, 2001). The occurrence this pest was found in *Anacardium occidentale* in a greenhouse in the Ceará state. For this reason, this crop was eliminated (Dias-Pini et al., 2018). Another evidence of the importance of this AQP is its high number of hosts, especially citrus. The impacts of this pest can range from 61 to 74% of host production (Kumar et al., 2013). Brazil is the world's largest producer, with approximately 18 million tons, generating about U$ 2.2 billion (IBGE, 2020). These facts confirm the effectiveness of the method that prioritized *S. dorsalis* with the highest score because it causes high damage and has a high risk of introduction into the Brazilian territory.

Senecio vulgaris had the third-highest score among the 20 AQPs. It achieved expressive results in the three criteria, evidencing its high capacity for entry, establishment, and spread and impact. Brazilian Normative Instruction in 2020 excludes this species from the official Brazilian AQP list due to the recognition of its presence in Brazil (Brasil, 2020). This situation allows affirming that the method is effective since it determined a high probability of entry of this pest.

Globodera pallida had the fourth-highest prioritization score. This nematode, together with *G. rondachiensis*, initially evaluated by experts (Laranjeira et al., 2018), can impact the potato and tomato production chains, which have 171,220 hectares of cultivated and about U$ 2.2 billion (IBGE, 2020). These pests can cause approximately 26% damage with an impact of U$ 2.88 billion (Van Oijen et al., 1995). It has records of occurrence in Argentina, Chile, Ecuador, Colombia, and Bolivia (CABI, 2020). MAPA conducts inspections of buses, passenger vehicles, and pedestrians from Bolivia and Peru on the border between Brazil and Bolivia. In these actions, potato tubers (chuños) are frequently intercepted and transported mainly to São Paulo, with a high risk to national agriculture (MAPA, unpublished data).

Botrytis fabae is registered in Colombia, Argentina, and Uruguay, countries bordering Brazil (CABI, 2020). Its wind spread capacity can reach 26 meters per day (Fitt et al., 1985). The importance of this pest suggests the need to design survey and surveillance programs in border areas that have reported its presence. The damage potential in their hosts can reach 50% production (Emeran et al., 2006). Its impacts are also recorded in beans, one of its main hosts, with 2,769,934 hectares cultivated in Brazil. The production value is U$ 1.49 billion (IBGE, 2020). Although the method assigned this pest the 14th highest average in the three criteria, its importance is justified by the high and homogeneous scores.

Chondrostereum purpureum also has an important wind spread capacity, reaching up to 400 km per year (France and Grinberg, 2014). It is present in Argentina, Chile, Paraguay, and Uruguay, with more than 150 hosts, particularly peach, apple, and grape (CABI, 2020). Apples are among its preferred hosts, with a cultivated area of 32,433 ha and U$ 362 million in production value (IBGE, 2020). Its impact can compromise 50% of production (France and Grinberg, 2014). These losses could amount to U$ 181 million.

The AHP prioritized *Otiorhynchus sulcatus* F. (vine weevil) in the 17th, mainly justified by its high scores with an emphasis on the estimated impacts criterion. This pest has dozens of hosts, such as grapes, strawberries, hops, and *Taraxacum officinale* Wiggers, and mainly ornamental species, such as violets, roses, primrose, camellia, and begonia (CABI, 2020). This AQP can cause about a 60% reduction in the biomass of the host species (Clark et al., 2012). Larvae attack the lower portion of the stem and roots, making it difficult to control them. Adults feed on leaves and flowers (Fernandez, 2020). It is estimated that the violet production chain encompasses approximately 5,000 producers in Brazil, and losses are estimated at U$ 150 million (Fernandez, 2020).

Concerning *Phalaris paradoxa* (awned canary grass), the AHP assigned high scores, especially in the entry criterion. This was contextualized with the interception of this pest during an inspection by the International Agricultural Surveillance Service of Foz do Iguaçu, Paraná state (SVA FOZ-VIGIAGRO - MAPA) in a shipment of birdseed from Argentina and confirmed by a laboratory report issued on 16/11/2021, by an accredited laboratory (MAPA, unpublished data). The risk of the probability of entry is based, among other aspects, on the fact that it is present on all continents, especially bordering countries, such as Argentina, Bolivia, Chile, and Uruguay (CABI, 2020).

The borders with these countries are recognized as having a high phytosanitary risk because they have numerous crossing points (Spadotto et al., 2014). This species has high seed production, with characteristics of dormancy and emergence periodicity (Taylor et al., 1999). The main impact of this pest occurs in the cultivation of wheat, whose production value in Brazil is U$ 1.06 billion (IBGE, 2020). Losses from this AQP can reach U$ 698 million, equivalent to 86% of production (Taye and Tanner, 1997).

Asphodelus tenuifolius (onionweed) reached the sixth-highest score according to the AHP methodology. It stood out in the three criteria since it is widely distributed across the five continents (CABI, 2020), emphasizing its registration in Bolivia, which has 3,400 km of border with Brazil (IBGE, 2020). It stands out for producing up to 2,300 seeds per plant (Baber et al., 2009). It affects sugar cane, corn, wheat, cotton, and tobacco (Holm et al., 1997). Chickpea production can decrease by 80% and mustard by 56% due to infestation by this pest (Tewari et al., 2001). Losses in sugarcane can be significant due to the 10,109,413 hectares cultivated in Brazil. The production value is U$ 4.6 billion, and losses are estimated at U$ 4.5 billion (IBGE, 2020).

Group 2 is formed by *Tetranychus pacificus*, *Erwinia rhapontici*, *Rhodococcus fascians, Heterodera zeae*, *Pratylenchus scribneri*, *Sonchus arvensis*, Arabis Mosaic Virus, Impatiens Necrotic Spot Virus, *Spodoptera littoralis,* and *Platynota stultana*, the last two stand out. These AQPs had the second and fifth-highest scores on the AHP, evidencing the effectiveness of the method since these pests are widely discussed in the literature due to the high impact caused on their hosts (Van der Gaag and Van der Straten, 2017; Lázaro-Berenguer et al., 2022).

Although the countries of occurrence of *Spodoptera littoralis* and *Platynota stultana* are far from Brazil, which determined a lower score in the *entry* criterion, these pests are important due to their ability to spread. The main spread is through the transit of plants, which can be transported from one continent to another (Korycinska and Eyre, 2013). The pest *S. littoralis* has a flight capacity of approximately 50 km day-1 (Nasr et al., 1984), and the young larvae of *P. stultana* have the habit of ballooning in the wind on silk threads allowing floating in air currents.

Another point in common between *S. littoralis* and *P stultana* is the important impacts they can cause. *S. littoralis* is capable of reducing around 75% of cotton production (Espinosa and Hodges, 2009). Since Brazil has a cultivated area of 1,626,445 ha and a production value of U$ 5.33 billion (IBGE, 2020), losses can amount to U$ 2.4 billion. This result corroborates the description that *S. littoralis* is a polyphagous lepidopteran that is one of the most destructive crops in tropical and subtropical regions of the world (EPPO, 1997). Damage caused by *P. stultana* corresponds to approximately 50% production value of the attacked hosts. In grapes growing in Brazil, losses can reach U$ 334 million (Korycinska and Eyre, 2013).

The classification determined the low prioritization assigned by the method for *Latheticus oryzae* and *Acarus siro* composed group 1 and had lower results than the others, according to the AHP. Their final scores were low, mainly in the establishment and spread and estimated impacts criteria, because they are pests associated with stored grains, not affecting the hosts in the field (CABI, 2020).

The probability of entry of these pests, according to the AHP, is important. The occurrence of *L. oryzae* in Argentina (CABI, 2020) can facilitate its entry into the country due to the many border points considered vulnerable (Spadotto et al., 2014). Regarding *A. siro*, the method contains a high probability of entry. This entry potential was confirmed with its recent detection in Brazil (Barbosa et al., 2022). The economic impacts of *A. siro* are cited in stored grains of rice, corn, soybeans, wheat, and sorghum, in which it can reach 25% damage (Işikber et al., 2016; Clemmons and Taylor, 2016). Moreover, this species affects human health by causing allergies (Marques et al., 2022).

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The results obtained in the present study contain fundamental information for government decision-making in the development of public policies on absent quarantine pests.

5. Conclusions

The results obtained in the present study contain essential information for government decision-making in the development of public policies on absent quarantine pests.

The AHP method is effective for AQP prioritization for organisms of different biological groups since out of the 20 AQPs studied, 17 are the priority. This method provides substantial subsidies for developing research and phytosanitary defense strategies to prevent the introduction of AQPs in Brazil.

Other countries from different continents can use this methodology to prioritize AQPs and thus create strategic plans to prevent entry into their territories and economic, social, and environmental impacts.

Acknowledgements

We thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for Research Productivity Grant to FRMG.

References

ABDOLLAHZADEH, G., DAMALAS, C.A., SHARIFZADEH, M.S. and AHMADI-GORGI, H., 2016. Selecting strategies for rice stem borer management using the Analytic Hierarchy Process (AHP). *Crop Protection*, vol. 84, pp. 27-36. http://dx.doi.org/10.1016/j.cropro.2016.02.004.

ADAIME, R., PARIZZI, P., ASSIS FILHO, F.M., LOVATO, F.A. and FILIPUTTI, M.T., 2018. Análise de resultado para Entrada. In: E.G. FIDELIS, T. LOHMANN, M. LOPES-DA-SILVA, P. PARIZZI and F.F. LARANJEIRA, eds. *Priorização de pragas quarentenárias ausentes no Brasil*. Brasília: Embrapa, pp. 57-73.

ADELINO, J.R.P., HERINGER, G., DIAGNE, C., COURCHAMP, F., FARIA, L.D.B. and ZENNI, R.D., 2021. The economic costs of biological invasions in Brazil: a first assessment. *NeoBiota*, vol. 67, pp. 349-374. http://dx.doi.org/10.3897/neobiota.67.59185.

BABER, B.H., TANVEER, A., AZIZ, A., JAVAID, M.M., TAHIR, M., SIBTAIN, M., KHALIQ, A. and PACANOSKI, Z., 2009. Phytotoxic influences of *Asphodelus tenuifolius* Cav (wild onion) on germination and seedling growth of wheat. *Allelopathy Journal*, vol. 24, pp. 341-350.

BARBOSA, M.F.C., CORRÊA, A.S. and MORAES, G.J., 2022. *Acarus siro* L. (Astigmatina: Acaridae): first confirmed record for Brazil based on morphological and molecular characterization. *Journal of Stored Products Research*, vol. 97, p. 101958. http://dx.doi.org/10.1016/j.jspr.2022.101958.

BRASIL. MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO, 2018. *Instrução Normativa nº 39, de 01 de outubro de 2018. Estabelece a lista de Pragas Quarentenárias Ausentes (PQA) para o Brasil*. Diário Oficial da República Federativa do Brasil, Brasília, 2 Oct. Seção 1, pp. 11-14.

BRASIL. MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO, 2019. *Portaria nº 131, de 27 de junho de 2019. Institui o Programa Nacional de Prevenção e Vigilância de Pragas Quarentenárias Ausentes*. Diário Oficial da República Federativa do Brasil, Brasília, 3 Jul. Seção 1, p. 8.

BRASIL. MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO, 2020. *Instrução Normativa nº 117, de 28 de dezembro de 2020. Exclui o Senecio vulgaris da Lista de Pragas Quarentenárias Ausentes para o Brasil*. Diário Oficial da República Federativa do Brasil, Brasília, 30 Dec. Seção 1, p. 35.

CABI, 2020 [viewed 13 June 2022]. *Invasive species compendium* [online]. CABI Digital Library. Available from: www.cabi.org/isc

CANAL RURAL, 2020 [viewed 27 July 2023]. *O Brasil na produção global de alimentos* [online]. Canal Rural. Available from: https://blogs.canalrural.com.br/embrapasoja/2020/09/21/o-brasil-na-producao-global-de-alimentos/

CENTRO DE ESTUDOS AVANÇADOS EM ECONOMIA APLICADA – CEPEA, 2019. *Mensuração econômica da incidência de pragas e doenças no Brasil: uma aplicação para as culturas de soja, milho e algodão - Parte 1*. Piracicaba: CEPEA.

CLARK, K.E., HARTLEY, S.E., BRENNAN, R.M., JENNINGS, S.N., MCMENEMY, L.S., MCNICOL, J.W., MITCHELL, C. and JOHNSON, S.N., 2012. Effects of cultivar and egg density on a colonizing vine weevil (*Otiorhynchus sulcatus*) population and its impacts on red raspberry growth and yield. *Crop Protection*, vol. 32, pp. 76-82. http://dx.doi.org/10.1016/j.cropro.2011.10.008.

CLEMMONS, E.A. and TAYLOR, D.K., 2016. Booklice (Liposcelis spp.), grain mites (Acarus siro), and flour beetles (Tribolium spp.): 'other pests' occasionally found in laboratory animal facilities. *Journal of the American Association for Laboratory Animal Science*, vol. 55, no. 6, pp. 737-743. PMid:27931310.

DHINGRA, T., SENGAR, A. and SAJITH, S., 2022. A fuzzy analytic hierarchy process-based analysis for prioritization of barriers to offshore wind energy. *Journal of Cleaner Production*, vol. 345, p. 131111. http://dx.doi.org/10.1016/j.jclepro.2022.131111.

DIAS-PINI, N.S., LIMA, M.G.A., LIMA, E.F.B., MACIEL, G.P.S. and DUARTE, P.M., 2018. *Scirtothrips dorsalis* (Thysanoptera: Thripidae): a newly introduced polyphagous pest in northeastern Brazil. *Neotropical Entomology*, vol. 47, no. 5, pp. 725-728. http://dx.doi.org/10.1007/s13744-018-0618-3. PMid:29982977.

EMERAN, A.A., BELAL, E.B. and EL-ZAHABY, H.M., 2006. Biological control of faba bean chocolate spot disease caused by *Botrytis fabae*. *Journal of Agricultural Research*, vol. 32, no. 2, pp. 243-258.

EPPO, 1997. *Spodoptera littoralis and Spodoptera litura. Datasheets on quarantine pests*. Paris: EPPO, 7 p.

ESPINOSA, A. and HODGES, A.C., 2009 [viewed 13 May 2022]. *Spodoptera littoralis* [online]. BugwoodWiki. Available from: https://wiki.bugwood.org/Spodoptera_littoralis

FERNANDEZ, P.S.C., 2020. Ácaros e insetos associados a diferentes variedades de lúpulo em quatro municípios do estado do Rio de Janeiro. Seropédica: Universidade Federal Rural do Rio de Janeiro, 120 p. Dissertação de Mestrado.

FIDELIS, E.G., LARANJEIRA, F.F., LOPES-DA-SILVA, M., PESSOA, M.C.P.Y., RASKI, R.K., MICHEREFF FILHO, M., HIROSE, E., SANCHES, M.M., MELLO, A.F.S., XAUD, M.R. and NOGUEIRA-DE-SÁ, L.A., 2018. Análise de resultado para Estabelecimento e Dispersão. In: E.G. FIDELIS, T. LOHMANN, M. LOPES-DA-SILVA, P. PARIZZI and F.F. LARANJEIRA, eds. *Priorização de pragas quarentenárias ausentes no Brasil*. Brasília: Embrapa, pp.75-96.

FITT, B.D.L., CREIGHTON, N.F. and BAINBRIDGE, A., 1985. A. Role of wind and rain in the dispersal of *Botrytis fabae* conidia. *Transactions of the British Mycological Society*, vol. 85, no. 2, pp. 307-312. http://dx.doi.org/10.1016/S0007-1536(85)80193-5.

FRANCE, A. and GRINBERG, D., 2014. *El plateado del manzano: biología e importancia de una enfermedad subvalorada*. Talca: Universidad de Talca.

GARCIA, F.R.M., 2020. *Drosophila suzukii management*. Cham: Springer. Basis for area-wide management of *Drosophila suzukii* in Latin America, pp. 93-110. http://dx.doi.org/10.1007/978-3-030-62692-1_5.

GARCIA, F.R.M., LASA, R., FUNES, C.F. and BUZZETTI, K., 2022. *Drosophila suzukii* management in Latin America: current status and perspectives. *Journal of Economic Entomology*, vol. 115, no. 4, pp. 1008-1023. http://dx.doi.org/10.1093/jee/toac052. PMid:35595171.

HARTIGAN, J.A., 1975. *Clustering algorithms*. New York: John Wiley and Sons.

HILMAN, R. and GOULART, C., 2015. O controle do trânsito interestadual e sua importância na prevenção de disseminação de pragas. In: R.L. SUGAYAMA, M. LOPES-DA-SILVA, S.X.B. SILVA, L.C. RIBEIRO and L.E.P. RANGEL, eds. *Defesa vegetal. Fundamentos, ferramentas, políticas e perspectivas*. Belo Horizonte: SBDA, pp. 319-332.

HILMAN, R., ABOT, A.R. and GARCIA, F.R.M., 2023. A metodologia Analytic Hierarchy Process (AHP) e sua adaptação para priorização de Pragas Quarentenárias Ausentes (PQAs). *Revista Científica Rural*, vol. 25, no. 1, pp. 80-102. http://dx.doi.org/10.29327/246831.25.1-5.

HOLM, L., DOLL, J., HOLM, E., PANCHO, J. and HERBERGER, J., 1997. *World weeds: natural histories and distribution*. New York: John Wiley and Sons, 1129 p.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE, 2019 [viewed 13 May 2022]. *Clima* [online]. IBGE. Availale from: https://atlasescolar.ibge.gov.br/images/atlas/mapas_brasil/brasil_clima.pdf

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE, 2020 [viewed 13 May 2022]. *Produção agrícola municipal* [online]. SIDRA. Available from: https://sidra.ibge.gov.br/pesquisa/pam/tabelas

INTERNATIONAL PLANT PROTECTION CONVENTION – IPPC, 1997 [viewed 13 May 2022]. *Convención internacional de protección fitosanitaria* [online]. IPPC. Available from: https://www.ippc.int/es/

IŞIKBER, A.A., TUNAZ, H., DOĞANAY, İ. and ER, M.K., 2016. The infestation rate and abundance of insect pests on stored corn in different climatic zones of Turkey. *Turkish Bulletin of Entomology*, vol. 6, no. 4, pp. 349-356. http://dx.doi.org/10.16969/teb.13658.

KORYCINSKA, A. and EYRE, D., 2013. *Plant pest factsheet: omnivorous leafroller Platynota stultana*. London: Department for Environment Food and Rural Affairs, 4 p.

KUMAR, V., KAKKAR, G., MCKENZIE, C.L., SEAL, D.R. and OSBORNE, L.S., 2013. An overview of chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) biology, distribution, and management. In: S. SOLONESKI and M. LARRAMENDY, eds. *Weed and pest control - conventional and new challenges*. USA: IntechOpen, pp. 1-20. http://dx.doi.org/10.5772/55045.

LARANJEIRA, F.F., ALEXANDRE, J.B., FIDELIS, E.G., LOHMANN, T.R., LOPES-DA-SILVA, M., PARIZZI, P. and MICHEREFF FILHO, M., 2018. Processo de priorização de pragas quarentenárias ausentes: hierarquia, critérios e lista final. In: E.G. FIDELIS, T. LOHMANN, M. LOPES-DA-SILVA, P. PARIZZI and F.F. LARANJEIRA, eds. *Priorização de pragas quarentenárias ausentes no Brasil*. Brasília: Embrapa, pp. 48-56.

LÁZARO-BERENGUER, M., QUAN, Y., HERNÁNDEZ-MARTÍNEZ, P. and FERRÉ, J., 2022. In vivo competition assays between Vip3 proteins confirm the occurrence of shared binding sites in *Spodoptera littoralis. Scientific Reports*, vol. 12, no. 1, p. 4578. http://dx.doi.org/10.1038/s41598-022-08633-y. PMid:35301405.

LOHMANN, T.R., LOPES-DA-SILVA, M., VALENTE, C.M.W., BAGOLIN, D.J., RASKI, R.K. and MICHEREFF FILHO, M., 2018. Análise de resultado para Impactos Estimados. In: E.G. FIDELIS, T. LOHMANN, M. LOPES-DA-SILVA, P. PARIZZI and F.F. LARANJEIRA, eds. *Priorização de pragas quarentenárias ausentes no Brasil*. Brasília: Embrapa, pp.97-114.

MARQUES, M.L., REZENDE, I., CUNHA, I., GOUVEIA, J., SANTOS, F.R., FALCÃO, I., CUNHA, L. and FALCÃO, H., 2022. Allergic sensitization to Storage Dust Mites: a prospective study of patients with respiratory allergy. *European Annals of Allergy and Clinical Immunology*, vol. 54, no. 1, pp. 43-47. http://dx.doi.org/10.23822/EurAnnACI.1764-1489.178. PMid:33191715.

NASR, E.A., TUCKER, M.R. and CAMPION, D.G., 1984. Distribution of moths of the Egyptian cotton leafworm, *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae), in the Nile Delta interpreted from catches in a pheromone trap network in relation to meteorological factors. *Bulletin of Entomological Research*, vol. 74, no. 3, pp. 487-494. http://dx.doi.org/10.1017/S0007485300015753.

ORGANIZAÇÃO DAS NAÇÕES UNIDAS – ONU, 2022 [viewed 13 May 2022]. *Rever totalmente o turismo global pode representar uma oportunidade no pós-pandemia* [online]. ONU News. Available from: https://news.un.org/pt/story/2022/01/1775802

PAULA, S.V. and OLIVEIRA, M.R.V., 2001. *Análise de risco de Scirtothrips dorsalis (Thysanoptera: Thripidae) para a cultura da manga no Brasil*. Brasília: Embrapa Recursos Genéticos e Biotecnologia.

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO DE JANEIRO – PUC-RIO, 2020 [viewed 13 May 2022]. *Clusterização de dados* [online]. PUC-RIO. Availale from: https://www.maxwell.vrac.puc-rio.br/24787/24787_5.PDF

RAHMAWATY, MARPAUNG, R.M.E., BATUBARA, R. and RAUF, Z., 2022. Analytical hierarchy process (AHP) application in the selection of plant types on the community's agroforestry land. *IOP Conference Series. Earth and Environmental Science*, vol. 959, no. 1, p. 012008. http://dx.doi.org/10.1088/1755-1315/959/1/012008.

SAATY, T.L., 2013. *Decision making for leaders: the analytic hierarchy process for decisions in a complex world*. 3rd ed. Pittsburgh: RWS Publications.

ŞAHIN, T., OCAK, S. and TOP, M., 2019. Analytic hierarchy process for hospital site selection. *Health Policy and Technology*, vol. 8, no. 1, pp. 42-50. http://dx.doi.org/10.1016/j.hlpt.2019.02.005.

SILVA, A.C. and RICALDE, M.P., 2017. The first occurrence of Sternochetus mangiferae (Fabricius) (Coleoptera: Curculionidae) in Brazil. *Neotropical Entomology*, vol. 46, no. 5, pp. 587-590. http://dx.doi.org/10.1007/s13744-017-0523-1. PMid:28540532.

SPADOTTO, C.A., MINGOTI, R. and HOLLER, W.A., 2014. *Priorização de locais para implantação ou intensificação da vigilância fitossanitária no Brasil*. Campinas: Embrapa Gestão Territorial.

TAYE, T. and TANNER, D.G., 1997. A comparison of two models for relating wheat yield loss to weed density: differences in calculated economic weed control thresholds. In: *Proceedings of the Eighth Conference of the Crop Science Society of Ethiopia*, 26-27 February 1997, Addis Ababa, Ethiopia. Addis Ababa: Ethiopian Agricultural Research Organization, pp. 26-27.

TAYLOR, I., WALKER, S., ADKINS, S., BULLEN, K. and PETERS, N., 1999. Dynamics of paradoxa grass (*Phalaris paradoxa* L.) soil seed bank. In: *Twelfth Australian Weeds Conference*, 12-16 September 1999, Hobart, Australia. Hobart: Tasmanian Weed Society, pp. 71-74.

TEWARI, A.N., TIWARI, S.N., RATHI, J.P.S., VERMA, R.N. and TRIPATHI, A.K., 2001. Crop-weed competition studies in chickpeas having *Asphodelus tenuifolius* dominated weed community under rainfed conditions. *Indian Journal of Weed Science*, vol. 33, pp. 198-199.

VAN DER GAAG, D.J. and VAN DER STRATEN, M., 2017. *Short pest risk analysis for Platynota rostrana and Platynota stultana*. Utrecht: Netherlands Food and Consumer Product Safety Authority/ Ministry of Economic Affairs.

VAN OIJEN, M., DE RUIJTER, F.J. and VAN HAREN, R.J.F., 1995. Analyses of the effects of potato cyst nematodes *(Globodera pallida)* on growth, physiology, and yield of potato cultivars in field plots at three levels of soil compaction. *Annals of Applied Biology*, vol. 127, no. 3, pp. 499-520. http://dx.doi.org/10.1111/j.1744-7348.1995.tb07608.x.

VEISI, H., DEIHIMFARD, R., SHAHMOHAMMADI, A. and HYDARZADEH, Y., 2022. Application of the analytic hierarchy process (AHP) in a multi-criteria selection of agricultural irrigation systems. *Agricultural Water Management*, vol. 267, no. 1, p. 107619. http://dx.doi.org/10.1016/j.agwat.2022.107619.

WAN, N., JIANG, J., JI, X. and DENG, J., 2009. Application of analytic hierarchy process-based model of Ratio of Comprehensive Cost to Comprehensive Profit (RCCCP) in pest management. *Ecological Economics*, vol. 68, no. 3, pp. 888-895. http://dx.doi.org/10.1016/j.ecolecon.2008.07.021.

WORLD TRADE ORGANIZATION – WTO, 2020 [viewed 13 May 2022]. *Sanitary and phytosanitary measures* [online]. WTO. Available from: https://www.wto.org/english/tratop_e/sps_e/sps_e.htm

ZHANG, F., PENG, G., XU, P., ZHU, L., LI, C., WEI, N. and LI, D., 2022. Ecological risk assessment of marine microplastics using the analytic hierarchy process: a case study in the Yangtze River Estuary and adjacent marine areas. *Journal of Hazardous Materials*, vol. 425, no. 5, p. 127960. http://dx.doi.org/10.1016/j.jhazmat.2021.127960. PMid:34896726.