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RESEARCH ARTICLE

Impact of Invasive Alien Plant Species and Their Management Implications to Endemic Diseases, Food and Health Security in Africa

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Abstract

Africa is currently invaded by dangerous invasive alien plant species (IAPS) – *Chromolaena odorata*, *Parthenium hysterophorus*, and *P. juliflora* which are directly involved in food and health securities and disrupt the ecosystem. Herein, the current location of these IAPS on the African continent, the interlocking economic and health impact, blueprint reinforcing early surveillance, phytosanitary, and strategic management measures are presented. As a direct consequence of IAPS, the African continent incurs annual losses of over USD 3–5 billion severely impacting food production and the livelihoods of subsistence farmers. We show that out of 54 African countries, 29.63% (n=16), 31.48% (n=17), and 59.25% (n=32) are invaded by *C. odorata*, *P. juliflora*, and *P. hysterophorus*, in endemic regions,respectively. Remarkably, out of the 54 African countries, 84.33% (n=45) are invaded either by *C. odorata*, *P. juliflora*, or *P. hysterophorus*.This study depicts an unparalleled invasion of the African continent which severely threatens food and health securities, notably, promotes malaria. We propose a blueprint management strategy for IAPS which requires more leadership and investment in reinforcing integrated IAPS phytosanitary surveillance, containment, and control.

Keywords: *Malaria, food security, Prosopis invasion, Parthenium infestations, Chromolaena, resistance, surveillance*

1. Introduction

Invasive alien plant species (IAPS) are a direct or indirect consequence of human activities leading to the introduction of new exotic life forms in a biota where they proliferate, spread, and destabilize the ecological dynamics with far-reaching detrimental effects to human interest(1). The International Plant Protection Convention (1952) considers invasive alien species (IAS) as those that cause significant economic, environmental loss, or adversely affect human health(2). By 2001 estimated global cost of damage caused by invasive species was valued at USD 1.4 trillion per year, close to 5% of the global GDP in 2001(3). Currently, it is estimated that economic impacts of IAPS such as *Chilopartellus*, Maize Lethal Necrosis Disease, *Liriomyza* spp., *Tuta absoluta*,and *Parthenium hysterophorus* on economically important crops such as maize in six African countries (e.g. Ethiopia, Kenya, Malawi, Rwanda, Tanzania, and Uganda) amounted to an annual loss of USD 0.9–1.1 billion(4), highlighting the importance to study invasive plant pests in the 21st century. In addition, future annual losses in the next 5–10 years are predicted at USD 1.0–1.2 billion in these African countries(4). The plants *C. odorata*, *P. hysterophorus*, and *P. juliflora* are considered the world's top IAPS(4; 5; 6), but their overall invasion of the African continent is associated with increasing socio-demographic and environmental challenges, adaptations, and rising pesticide resistance. Notwithstanding, the economic impacts of IAPS in developing countries are widely unreported, the losses might exceed USD 10 billion annually based on extrapolation from losses observed in Pratt et al.(4) in six African countries. The paucity and sporadic data on the growing trend, extent, pattern, and nature of IAPS emergence and resistance spread require concerted and urgent attention across the African continent and worldwide. This paper evaluates the growing trend and extent of *Chromolaena odorata* L (Asteraceae), *P. hysterophorus* L(Asteraceae), and *P. juliflora* L (Fabaceae) comprehensive threats, and demonstrate an unprecedented infestation with associated implications on food insecurity and endemic disease burden on the African continent.

2. Materials and Methods

2.1 Ethics Statement

There were no specific permissions required for these studies and did not involve the use of life or protected organisms. In addition, this study was funded by TWAS/DBT for the enrichment of public welfare and promotion awareness of agricultural activities and management of invasive alien plant species in Africa.

2.2 Database Search and Extraction

A non-structured literature review was performed using the NCBIMESH terms *Chromolaena odorata*, *Parthenium hysterophorus*, and *P. juliflora* in Africa. *C. odorata*, *P. hysterophorus*, *P. juliflora*, *C. odorata* in Africa, *P. hysterophorus* in Africa, and *P. juliflora* available data in peer-reviewed publications were generated from Medline, Scopus, and Google Scholar and standalone index databases- The Centre for Agriculture and Bioscience International (CABI, http://www.cabi.org), Q-bank comprehensive databases on quarantine plant pests and diseases `http://www.q-bank.eu/Plants/BioloMICS.aspx?TargetKey=4917900000000500&Rec=309` and the Southern African Plant Invaders Atlas (SAPIA; `http://www.invasives.org.za/plants/famine-weed` updated reports upto January 2019 on IAPS on the African continent.

2.3 Health Burden Caused by Iaps and Synthetic Assessment

Health implications of *C. odorata*, *P.hysterophorus*, and *P. juliflora* in Africa were re-queried in local and global agencies namely PubMed, FAO, and WHO from June–August 2021 for relevant information about human illness and resistance of the IAPS to herbicides. The abstract and relevant texts were read, then the full articles or documents were reviewed.

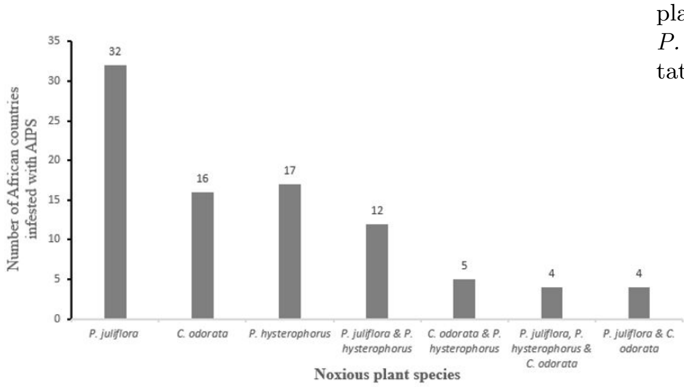

Figure 1: The number of African countries invaded by *P. juliflora*, *P. hysterophorus*, and *C. odorata* as to August 2017

The extent of Africa's invasion by *C. odorata*, *P. hysterophorus*, and P. juliflorawere computed into a graphic map using the Google Global Positioning Satellite Maps tool at default settings.

2.4 Data Analysis

The relevant captured data included sites of IAPS reports in Africa, latitudes, longitudes, date of first reports, authors, and origin of IAPS, and extent of proliferation (S1 Table). All statistical analysis was performed in XLSTAT 2017.4.

3. Results and Discussion

Out of the 54 African countries studied covering a total of 30,370,000 km2 and home to 1.2 billion people, 29.63% (n=16) is invaded by *Chromolaena odorata*, 31.48 % (n=17) is invaded by *P. juliflora*, and 59.25% (n=32) is invaded by *P. hysterophorus*. In some cases, the countries are invaded by more than two IAPS (Figure 1, Table 1).

Figure 2: Current geographical distribution of alien invasive plant species – A) *C. odorata*, B) *P. hysterophorus*, and C) *P. juliflora*, and green tag indicates regions of major infestation

Figure 3: Overview captured of Africa infestation by IAPS–*C. odorata* (orange point marker), *P. hysterophorus*(black point marker), and *P. juliflora* (blue point marker).

Major countries invaded simultaneously by *C. odorata*, *P. hysterophorus* and *P. juliflora* are Mauritius, Mozambique, South Africa, and Zimbabwe (Fig 2). By superimposing the distribution pattern of *C. odorata* (Fig2A), *P. hysterophorus* (Fig 2B),and *P. juliflora* (Figure 2C), we captured an overview distribution of the studied IAPS on the African continent (Figure 3). From the analyzed data set generated in this study (S1 Table), it is worth noting that Namibia, Angola, Congo, Gabon, Equatorial Guinea,Central Africa, and Cameroon have rare cases of invasive *C. odorata*, *P. hysterophorus*,and *P. juliflora* (Figure 2, 3). Importantly, we inferred three important overwhelming spreadspatterns of invasive *C. odorata*, *P. hysterophorus*,and *P. juliflora* on the African continent as thus: i) The plant *C. odorata* (Figure 2A) invasion appears to have occurred following the trajectory of the trans-African highway 8, a principal route linking West Africa and East Africa, and covering a total distance of 6,259 km. Given that this route transit from Accra (Ghana), Lomé (Togo), Lagos (Nigeria), Bamenda-Yaoundé (Cameroon), Bangui (Central Africa Republic), Kisangani (Democratic Republic of Congo), Kampala (Uganda) to Nairobi-Mombasa (Kenya), and the parallel distribution pattern of *C. odorata* is not surprising (Figure 2A). Consequently, it is tempting to suggest that *C. odorata* has been disseminated in the African continent by opened trade routes linking major trade blocks such as the ECOWAS (Economic Community of West Africa), Economic Community of Central African States (ECCAS), and Common Market for Eastern and Southern Africa (COMESA).Given that *C. odorata* can invade water bodies and the fact that some of the African major rivers such as the Senegal River, Volta River, Niger River, Benue River, and Congo River could be interconnected with other minor rivers, there is a strong likelihood that the continent was invaded via these routes. ii) The plant *P. hysterophorus* invasion appears to have been restrained to Mediterranean, Eastern, and Southern African countries (Figure 2B). Given the strong linkage between countries of the Great Lake region,dependence on river Nile and trade among COMESA countries, inter/trans country roads and water bodies may have facilitated the dissemination of *P. hysterophorus.* While South Africa remains highly infested with *P. hysterophorus*, Climax algorithmic analysis and route surveys led to the conclusion that the main sources of spread were probably from public minibus vehicles, car-wash facilities, earth moving equipment for road maintenance on gravel roads, or building operations related to poor sanitation and management cycle(7). iii) The plant *P. juliflora*invasion could probably be from strong wind currents across the African continent such as the Aejejwhirl wind of Morocco, the Sirocco of Northern Africa, Etesian, Gregale, and Borasco of the Mediterranean, and Harmattan in the Sahelian regions that might carry mature seeds during the flowering booms. This thesis is based on the uneven distribution pattern of *P. juliflora* in Northern Africa and part of Southern Africa (Figure 2C).

3.1 The need for phytosanitary surveillance and programs initiatives implementation

Considerable variations in climate change affecting the existing and emerging global cohort of pests and diseases impact food security and health quality(8). Advisably, it is not always appropriate to impose the same phytosanitary measures and requirements on food safety and food crops production access coming from different countries. Foreign food crops often bear invasive alien species (IAS) that go undetected due to weak or poor detection facilities(or weak workforce capacity) as well as porous international trade roads and border quarantine checks in Africa.It is now recognized that developing countries are the most threatened by invasive pest species(9).Thus, the direct and indirect introduction of alien food crops into the agricultural farmland in most countries continue to exert selective pressure on crop production, with consequential harmful effects on plant and human health, hallmarked in persistent and rampant famine and vicious poverty cycle in the Sahel and other parts of sub-Saharan Africa(10). To ensure that animal and plant protection against IAPS is maintained,producers of foodstuff should provide consumers with a guaranteed label stating IAPS-free of the greatest quality. Furthermore, governmental bio economy policies and regulations on IAPS-free areas may not always correspond to appropriate political and socio-economic boundaries and integration for sustainable and resilient agricultural production and food auto-sufficiency. The usefulness of invasive risk assessment in food safety, animal and plant health, and strategic invasive species management measures are essential for safeguarding the African continent's quest for food and health securities. Contextual IAPS strategic plan should provide appropriate scientific evidence-based sustainable and effective local, national and global standards on sanitary and phytosanitary programs. For example, the impact of IAPS in developing countries cannot be overemphasized such as in India, where invasive alien microbes have been identified as a major drawback for Indian agricultural production and loss of human lives(2). Rice farming was the worst affected during The Great Bengal famine of 1943, caused by the invasive fungus *Cochliobolus miyabeanus*, resulting in nearly 2 million deaths(11). Moreover, it is documented that the aggressive weed *P. hysterophorus* caused a 40% agricultural yield decrease in India(12), and 40–97% sorghum (*Sorghum bicolor* L) grain loss in Ethiopia in seasons when *P. hysterophorus* was uncontrolled(13).

3.2 Profiles of *C. odorata*, *P. hysterophorus*,and *P. juliflora*, and Impact on Food and Health Securities in Africa

Overwhelmingly, invasive *C. odorata* has successfully invaded the coast of West Africa (Figure 2A), severely affecting cash crop production notably in Congo, Cote d'Ivoire, Democratic Republic of Congo, Benin, Central African Republic, Liberia, Mauritius, Nigeria, Senegal, South Africa, Swaziland and Togo(14; 15; 16). *C. odorata* severely threatens the population of Nile crocodiles(15) as well as invade plantations of cocoa, rubber, palmoil, cassava, banana, and plantain(17). Contemporary, it has been suggested that *C. odorata* provides a varied degree of protection to certain pests and vectors of diseases associated with acute diarrhea in cattle and other grazing animals; but also, reportedly cause human skin irritation and rashes to allergens populations. Invasive weeds *P. hysterophorus* and *P. juliflora* flowers attract malaria vector, the female Anopheles mosquitoes that feed on nectar, a major setback in the control of malaria in Africa(18). Remarkably, it was shown that Parthenium could sustain *Anopheles gambiae* life span even in the absence of blood meal(18). Given the ability of *P. hysterophorus* and *P. juliflora* to actively grow,boom for a longer period,and provide an obscure energy source, these alone ensures the continent remains a reservoir for Anopheles species. Additionally, the presence or absence of *P. juliflora* in regions has been shown to significantly influence the population size of mosquito population in general, composition of mosquito species, sugar feeding status, and age structure of female mosquitoes population(19). While a large portion of the African landmasses have been colonized by invasive *P. hysterophorus* and *P. juliflora* (Figure 3) that often sustain malaria-spreading mosquitoes(18), by implication, the use of outdoor or indoor insecticide spray and fumigation against Anopheles malaria vector is impeded indirectly in a large portion of Africa. Regardless of the implication of climate change and insecticide resistance linked to malaria vector transmission dynamics and the changing vectorial capacity, *P. hysterophorus* is associated with dermatitis, asthma, and bronchitis in humans and animals because of its active toxic compound called parthenin(20). It was previously shown that *P. hysterophorus* extracts gave a positive immune reaction to skin mAb2 and were also involved in TH-type cytokines mediated dermatitis(21).Food security is severely threatened alone in the Lake Chad basin because of the overwhelming invasion of *J. juliflora*. It is estimated that 300,000 hectares of Prosopis forest alone the Lake chad not only affect farmers but fisher folk since this has hindered boat navigation and increase the shallowness of the water and thus, decrease fishing output(22). The current IAPS threats and burden status-quo on the Africa continent highlight the importance of sanitary and phytosanitary surveillance and management gaps and operational crops approaches at all levels. Timeously enhanced IAPS surveillance and mitigation strategies are critical to avert or reduce human lives and agricultural production losses. In this light, increase early detection and diagnostic susceptibility of *C. odorata*, *P. hysterophorus* and *P. juliflora* towards IAPS-linked human or animal life threats, effects on early warning, risk factors mitigation, and appropriate management should be of interest to African consumers and partners from hidden protectionism and trade technical necessities. Core components in the blueprint reinforcing early surveillance of invasive alien plant species infestation on the African continent include:

3.2.1 Phytosanitary Risk Assessments of Gaps in Infestation Trends and Patterns

We documented that plant pest sanitary and phytosanitary-linked diseases, IAPS knowledge gaps, and challenges remain poorly diagnosed and documented across world trade organization (WTO) members countries in Africa. Understanding the risk factors and determinants of agricultural pest-linked zoonotic diseases surveillance and monitoring across WTO member countries is crucial. Our findings reported limited data on IAPS geographic distribution and associated food insecurity and diseases threats and burden on agricultural commodities in Africa. Investing in agricultural pest and disease surveillance integration in national priorities is critical due to the growing impact of climate change and greenhouse gas emission on crop diversity. The establishment of an identification and mitigation program to determine, address and develop risk assessments of the potential threat to the agricultural industry is important in scaling agriculture produce and wellbeing.

3.2.2 Strengthening Legal Framework and Intergovernmental Responsibilities on Early Surveillance Activities

There is a need for building inter-governmental cooperative agreements on agriculture to conduct early plant pest detection and surveillance based on sound scientific data. Thorough risk assessments are necessary to enable growers to identify and prioritize nursery plant pests and diseases of regulatory significance to mitigate herbicidal burden for the control of IAPS on the African continent. Resources mobilization including direct and indirect cooperative financial allocation costs, and leadership investment in funds to carry out early IAPS detection, their proliferation, and mechanism of their spread is required. Strategic IAPS funding mobilization supported by technical assistance, and implementation of strategic capacity building and legislation on innovative technologies is crucial on specialty crop growers and related livestock and agricultural landscape.

3.2.3 Averting Iaps Resistance and the Interlocking Relationship That Causes Spreading of Animal and Human Diseases

Global invasive weed Parthenium is toxic to animals, causes dermatitis characterized by skin lesions in humans, including horses and cattle's(5). In invaded grazing land, significant ingestion (10–50%) of Parthenium weed kills cattle23 Also, it has been shown that alopecia, diarrhea, anorexia, pruritus, and eye irritation are associated with dogs–Parthenium interactions. Because of the interlocking relationship between invasive weeds colonization of farmlands, and human surroundings that served as a habitat of malaria female anopheles mosquitoes, and the use of chemical pesticides, the likelihood of resistance emergence is high. It has been shown that invasive weed *P. hysterophorus* sustain malaria-spreading mosquitoes associated with intense use of insecticide (e.g., DDT, pyrethroids) in control and elimination programs in China, East Asia. Exposure of weeds biotypes to normal doses of herbicides often drive herbicide resistance(24) and the resistance phenomenon is favored by intensive usage of the same active herbicide ingredient(25). Herbicides such as trifluralin, diphenamid, paraquat (gramoxone), and glyphosate are widely advocated for the control of invasive plant pests. Glyphosate gained prominence worldwide because of its ability to kill Parthenium by application of less than 10 µg per plant(26). Recently, glyphosate-resistant *P. hysterophorus* has been detected in the Caribbean Islands(27). Hypothetically, the spread of *P. hysterophorus* resistance worldwide will severely impact negatively on human, human diseases such as malaria, animal health, and crop production.

3.2.4 Building National and Regional "one-health" Initiative To Counter Invasive Plant Pests

Owing to the interface of human-animal and environment, investing in the development and implementation of national and regional 'One health' approach provides an integrated and comprehensive framework and action plans on plant–animal–human research and development. Fostering one-health resource capacity building is imperative and calls for proactive joint operational research in IAPS surveillance in guiding context-specific decision-making agricultural policies and best management practices. This is vital in engaging communities and other stakeholders for concerted commitment, participatory mitigation, and adaptation strategies in reducing IAPS, rising pesticide resistance,and malaria burden in Africa.

4. Conclusion and Future Directions

The paper demonstrated the increasing food and public health threats and burden of invasive alien invasive plant species – *C. odorata*, *P. hysterophorus*, and *P. juliflora* across the African continent. Authors call for robust and concerted leadership commitment and investment to implement the integration of IAPS phytosanitary surveillance and control approaches and action plans. Furthermore, strengthening public participatory awareness and border

Table 1: Distribution of invasive alien plant species (IAPS) infestation of Africa

		Invasive alien plant species		
No	African countries	*C. odorata*	*P. hysterophorus*	*P. juliflora*
1	Benin	yes	-	-
2	Cameroon	yes	-	-
3	Central African Republic	yes	-	-
4	Congo	yes	-	-
5	Congo Democratic Republic	yes	-	-
6	Côte d'Ivoire	yes	-	-
7	Ghana	yes	-	yes
8	Guinea	yes	-	-
9	Liberia	yes	-	yes
10	Mauritius	yes	yes	yes
11	Mozambique	yes	yes	yes
12	Nigeria	yes	-	yes
13	South Africa	yes	yes	yes
14	Swaziland	yes	yes	-
15	Togo	yes	-	-
16	Zimbabwe	yes	yes	yes
17	Comoros	-	yes	-
18	Egypt	-	yes	yes
19	Eritrea	-	yes	yes
20	Ethiopia	-	yes	yes
21	Kenya	-	yes	yes
22	Madagascar	-	yes	yes
23	Mayotte	-	yes	-
24	Réunion	-	yes	-
25	Seychelles	-	yes	-
26	Somalia	-	yes	yes
27	Tanzania	-	yes	yes
28	Uganda	-	yes	yes
29	Algeria	-	-	yes
30	Botswana	-	-	yes
31	Burkina Faso	-	-	yes
32	Cape Verde	-	-	yes
33	Chad	-	-	yes
34	Djibouti	-	-	yes
35	Gambia	-	-	yes
36	Guinea-Bissau	-	-	yes
37	Libya	-	-	yes
38	Mali	-	-	yes
39	Mauritania	-	-	yes
40	Morocco	-	-	yes
41	Namibia	-	-	yes
42	Niger	-	-	yes
43	Senegal	-	-	yes
44	Sudan	-	-	yes
45	Tunisia	-	-	yes

security checks along with the trans-African trade networks, and quarantine measures are imperative to curb IAPS on the African continent. a) Strengthening local and cross borders phytosanitary legislation, regulatory capacities towards reliable and sustainable plant pest quarantine, pest risk analyses, surveillance activities, diagnosis, and covered market access, import and export standards in line with The Agreement on the Application of Sanitary and Phytosanitary Measures of World Trade Organization, 1995 on food safety and animal and plant health regulations and International Health Regulations (IHR), 2005 and Sustainable Development Goals (SDGs). b) Development and implementation of improved integrated pest management methods, operationally based on pest risk analysis associated with the importation of exotic plant species not yet established in the country of import. The operation of such

a program should tie-up with policies aimed at promoting community-based support activities for the control of IAPS. c) Increase in research funding aimed at improving knowledge on the biology of IAPS focusing on favorable biological factors which allow them to flourish rapidly, and outpace indigenous plants. The generated knowledge should be shared, integrated into core courses in schools, colleges and make available to laymen to raise awareness on the impact of IAPS. d) Conducting integrated and contextual evolutionary studies geared at understanding the phenomenon of herbicide-resistant plant pests distributed worldwide paying attention to the ecological factors driving herbicide resistance. Alternatives such as mycoherbicides should be encouraged for the control of Parthenium.
e)Understanding and determining the environmental and climate change impacts on the potential distribution and disruption of IAPS life cycle. f) Ensuring the promotion of all signatories of The International Agreements concerning IAPS, Article 8(h) of the Convention on Biological Diversity (CBD) to implement key clauses such as 1) prevent and control the introduction of IAPS, and 2) eradicate preexist IAPS which pose threats to the ecosystem and other beneficial species. Unfortunately, many signatories to the agreement in developing countries have not implemented them [30].

Conflict of Interest The authors declare no conflict of Interest in this reported communication.

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References

[1] C. Kueffer, P. Pyšek, and D. M. Richardson, "Integrative invasion science: model systems, multi-site studies, focused meta-analysis and invasion syndromes," *New Phytologist*, vol. 200, no. 3, pp. 615–633, 2013, publisher: Wiley Online Library.

[2] S. Singh, A. K. Pandey, B. K. Singh, and D. Rajak, "Impact of Exotic Pests on Agro-biodiversity and their Management: A," 2016.

[3] D. Pimentel, S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'connell, E. Wong, L. Russel, J. Zern, and T. Aquino, "Economic and environmental threats of alien plant, animal, and microbe invasions," *Agriculture, ecosystems & environment*, vol. 84, no. 1, pp. 1–20, 2001, publisher: Elsevier.

[4] C. F. Pratt, K. L. Constantine, and S. T. Murphy, "Economic impacts of invasive alien species on African smallholder livelihoods," *Global Food Security*, vol. 14, pp. 31–37, 2017, publisher: Elsevier.

[5] M. Kaur, N. K. Aggarwal, V. Kumar, and R. Dhiman, "Effects and management of Parthenium hysterophorus: A weed of global significance," *International scholarly research notices*, vol. 2014, 2014, publisher: Hindawi.

[6] R. T. Shackleton, D. C. Le Maitre, N. M. Pasiecznik, and D. M. Richardson, "Prosopis: a global assessment of the biogeography, benefits, impacts and management of one of the world's worst woody invasive plant taxa," *AoB plants*, vol. 6, 2014, publisher: Oxford Academic.

[7] A. McConnachie, L. Strathie, W. Mersie, L. Gebrehiwot, K. Zewdie, A. Abdurehim, B. Abrha, T. Araya, F. Asaregew, and F. Assefa, "Current and potential geographical distribution of the invasive plant Parthenium hysterophorus (Asteraceae) in eastern and southern Africa," *Weed research*, vol. 51, no. 1, pp. 71–84, 2011, publisher: Wiley Online Library.

[8] S. Savary, A. Ficke, J.-N. Aubertot, and C. Hollier, "Crop losses due to diseases and their implications for global food production losses and food security," pp. 519–537, 2012.

[9] D. R. Paini, A. W. Sheppard, D. C. Cook, P. J. De Barro, S. P. Worner, and M. B. Thomas, "Global threat to agriculture from invasive species," *Proceedings of the National Academy of Sciences*, vol. 113, no. 27, pp. 7575–7579, 2016, publisher: National Acad Sciences.

[10] D. Rangi, "Invasive species and poverty: The missing link," *Environment matters*, pp. 12–13, 2009.

[11] R. P. Scheffer, *The nature of disease in plants.* Cambridge University Press, 1997.

[12] S. Khosla, "Effective control of parthenium hysterophorus linn," 1981.

[13] T. Tamado, L. Ohlander, and P. Milberg, "Interference by the weed Parthenium hysterophorus L. with grain sorghum: influence of weed density and duration of competition," *International Journal of Pest Management*, vol. 48, no. 3, pp. 183–188, 2002, publisher: Taylor & Francis.

[14] S. Lowe, M. Browne, S. Boudjelas, and M. De Poorter, *100 of the world's worst invasive alien species: a selection from the global invasive species database.* Invasive Species Specialist Group Auckland, 2000, vol. 12.

[15] A. Leslie and J. Spotila, "Alien plant threatens Nile crocodile (Crocodylus niloticus) breeding in Lake St. Lucia, South Africa," *Biological Conservation*, vol. 98, no. 3, pp. 347–355, 2001, publisher: Elsevier.

[16] T. I. Borokini and F. D. Babalola, "Management of invasive plant species in Nigeria through economic exploitation: lessons from other countries," *Management of Biological Invasions*, vol. 3, no. 1, p. 45, 2012, publisher: Regional Euro-Asian Biological Invasions Centre.

[17] A. Ogundola and M. Liasu, "Herbicidal effects of effluent from processed cassava on growth performances of Chromolaena odorata weeds population," *African Journal of Biotechnology*, vol. 6, no. 6, 2007.

[18] V. O. Nyasembe, X. Cheseto, F. Kaplan, W. A. Foster, P. E. Teal, J. H. Tumlinson, C. Borgemeister, and B. Torto, "The invasive American weed Parthenium hysterophorus can negatively impact malaria control in Africa," *PLoS One*, vol. 10, no. 9, p. e0137836, 2015, publisher: Public Library of Science San Francisco, CA USA.

[19] G. C. Muller, A. Junnila, M. M. Traore, S. F. Traore, S. Doumbia, F. Sissoko, S. M. Dembele, Y. Schlein, K. L. Arheart, and E. E. Revay, "The invasive shrub Prosopis juliflora enhances the malaria parasite transmission capacity of Anopheles mosquitoes: a habitat manipulation experiment," *Malaria journal*, vol. 16, no. 1, pp. 1–9, 2017, publisher: BioMed Central.

[20] R. Jayaramiah, B. Krishnaprasad, S. Kumar, G. Pramodh, C. Ramkumar, and T. Sheshadri, "Harmful effects of Parthenium hysterophorus and management through different approaches—A review," *Annals of Plant Sciences*, vol. 6, no. 05, pp. 1614–1621, 2017.

[21] N. Akhtar, A. Satyam, V. Anand, K. Verma, R. Khatri, and A. Sharma, "Dysregulation of TH type cytokines in the patients of Parthenium induced contact dermatitis," *Clinica Chimica Acta*, vol. 411, no. 23-24, pp. 2024–2028, 2010, publisher: Elsevier.

[22] D. Geesing, P. Felker, and R. L. Bingham, "Influence of mesquite (Prosopis glandulosa) on soil nitrogen and carbon development: Implications for global carbon sequestration," *Journal of arid environments*, vol. 46, no. 2, pp. 157–180, 2000, publisher: Elsevier.

[23] T. Narasimhan, M. Ananth, M. N. Swamy, M. R. Babu, A. Mangala, and P. S. Rao, "Toxicity of Parthenium hysterophorus L. to cattle and buffaloes," *Experientia*, vol. 33, no. 10, pp. 1358–1359, 1977, publisher: Springer.

[24] P. Fernández, R. Alcántara, M. D. Osuna, M. M. Vila-Aiub, and R. D. Prado, "Forward selection for multiple resistance across the non-selective glyphosate, glufosinate and oxyfluorfen herbicides in Lolium weed species," *Pest management science*, vol. 73, no. 5, pp. 936–944, 2017, publisher: Wiley Online Library.

[25] J. A. Evans, P. J. Tranel, A. G. Hager, B. Schutte, C. Wu, L. A. Chatham, and A. S. Davis, "Managing the evolution of herbicide resistance," *Pest management science*, vol. 72, no. 1, pp. 74–80, 2016, publisher: Wiley Online Library.

[26] S. Singh, A. Yadav, R. S. Balyan, R. K. Malik, and M. Singh, "Control of ragweed parthenium (Parthenium hysterophorus) and associated weeds," *Weed Technology*, vol. 18, no. 3, pp. 658–664, 2004, publisher: Cambridge University Press.

[27] E. Bracamonte, P. T. Fernández-Moreno, F. Barro, and R. De Prado, "Glyphosate-resistant Parthenium hysterophorus in the Caribbean Islands: Non target site resistance and target site resistance in relation to resistance levels," *Frontiers in plant science*, vol. 7, p. 1845, 2016, publisher: Frontiers.