

Full Length Research Paper

Weeds associated with cross border traffic, their approach and infestation rates in Zimbabwe

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Weeds carried by different plant pest-pathways in international cross-border traffic are linked to severe biological and biosecurity threats to plant health, animal health, food safety and environmental safety. Regulated quarantine weeds have zero tolerance in pest pathways across borders. This study employed a simple random survey technique and analysed 1668 human-aided transboundary plant pest-pathways drawn from 14 ports of entry and a non-official crossing points during the period stretching from 2020 to 2024 at the Plant Quarantine Services Institute Central Laboratory as well as the National Herbarium and Botanic Gardens Institute. Three regulated weeds that impact plant trade and seed production systems were identified. The weed approach rate was 182 from a global pest approach rate of 1072. Two weed species (*Datura stramonium* L and *Adenium obesum* (Forssk.) Roem. and Schult.) found in association with human-aided cross-border traffic concerned food and feed safety matters. Analysis of variance revealed highly significant differences in weed approach rates ($P < 0.001$). The Beitbridge and Forbes border ports had the highest volume of human-aided plant pest pathway traffic and they were also associated with high weed approach rates into Zimbabwe. Victoria Falls and Robert Gabriel Mugabe International airports were associated with the hitchhiking of plant propagules in passengers' baggage. It is recommended that weed pests be guarded precisely in grain products and passengers' baggage by employing baggage scanners and sniffer dogs to aid phytosanitary inspections at ports of entry.

Key words: Human aided, pest-pathways, transboundary.

INTRODUCTION

Plant pest transmission across borders is a serious threat to global agriculture, food security and biodiversity (Awasthi et al., 2024; Munhoz et al., 2024). New weeds threaten biodiversity and plant life as well as animal and human life due to the nature biosecurity risks they cause

(Lovett et al., 2016). Regulated quarantine weeds have a zero tolerance in international trade as these weeds pose high economic impacts to state economies (Froese et al., 2024; International Plant Protection Convention [IPPC] Secretariat, 2016).

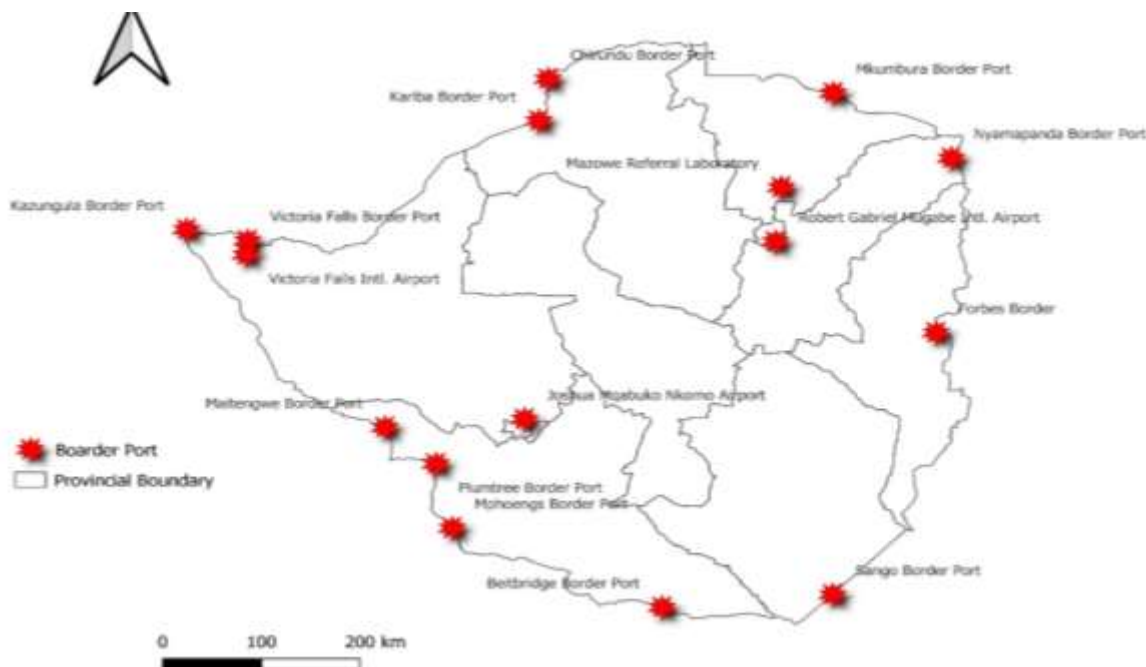


Figure 1. Ports of entry where samples were collected, non-official crossing points were along the Zimbabwean borders for the trapping of trans-boundary plant pests associated with cross-border traffic into Zimbabwe for the period from 2020 to 2024.

Knowledge of weeds associated with cross-border traffic and their approach rates is key in managing human aided cross-border pest-pathways in plant biosecurity and agriculture (Bhunjun et al., 2021; Dubey et al., 2021). Knowledge of weed pest approach and infestation rates from incoming cross-border traffic pathways bridges the knowledge gap of plant protection organization to avert accidental new weed introductions (Griffin, 2017; Douma et al., 2016).

This study was done to provide new insights into the weeds associated with cross-border traffic, their infestation and approach rate across a variety of pest pathways at various ports of entry into Zimbabwe. According to the best of our knowledge, this is the first study on weeds associated with cross-border traffic; their approach and infestation rate at the Zimbabwean ports of entry.

MATERIALS AND METHODS

A survey approach was used to collect biological materials from human-aided pest pathways found in cross-border traffic at Zimbabwean ports of entries (Figure 1). Samples were drawn from all potential pest pathways (Webber, 2010). The samples were

collected from 14 ports of entries and from non-official crossing points during the period between 2020 and 2024. The pathways were grouped into three classes, which were also sub-divided into two more categories per class (Meurisse et al., 2019). The three classes and the categorization are outlined in Table 1. The singling out of the *Solanaceae* plant pest pathway was ascertained to the claim by Centre for Agriculture and Bioscience International (CABI, 2021), that *Solanaceae* plants from various parts of the world are critical for their roles in hosting pathogens or diseases of the cultivated plants and hence their importance in the studies of trans-boundary movement of pests (International Plant Protection Convention (IPPC) Secretariat, 2019). Multiple cargo pathway segments were collected for pest extraction (Webber, 2010; Webber and Rose, 2008). The sample size varied depending on the pathways sampled. Only anthropogenic aided pathways were sampled. The data collected included the volume of cross-border traffic examined; pests approach rates and pest infestation or infection rate. Sampling was done over the same period across all sampling points for the period from 2020 to 2024. Samples that were collected from non-official crossing points were obtained by purchasing the goods smuggled from the border jumpers.

Trapping and identification of pests from samples

The extraction of weed seeds from consignments followed the process described by Collier (2024) and Wilson et al. (2016). Weeds

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Table 1. Description of the segregated plant pest pathways for the period 1 January 2020 to 31 December 2024.

Pathway type	Purpose of the import	Description of the pathway
<i>Solanaceae</i> species (<i>Juss.</i>)	Other use	<i>Solanaceae</i> plants not imported for propagation
	Propagation (planting – including replanting) (IPPC Secretariat, 2024)	<i>Solanaceae</i> plant species material imported for propagation
Organic materials	Growing media	Any material in which plant roots grow (IPPC Secretariat, 2024, 2023)
	Packaging materials	Imported for carrying a commodity (IPPC Secretariat, 2024, 2023)
Other plant species	Propagation (planting including replanting)	Any other plant species imported for propagation (IPPC Secretariat, 2024)
	Other use	Any plant material not imported for propagation (IPPC Secretariat, 2024)

were extracted by cleaning, winnowing and sieving them from consignment samples. Weeds in soil were trapped by subjecting the intercepted growing media contents to conditions that cause germination and emergence of weeds (Travlos et al., 2020). Weeds were identified up to the genus and species levels using the binomial system of taxonomy. The weeds were identified using methods prescribed by Naidu (2012). Pests, other weeds (pathogens, nematodes and insects) were also observed in order to make comparison of pest free pathways, weeds infested pathways and non-weed pest infested pathways. Analyses of samples were done visually at ports of entries and using laboratory process and procedures at the Mazowe Reference Laboratory of the Zimbabwe National Plant Protection Organisation.

Screening consignments for phytosanitary measures at the port of entry

The intercepted pathways were sampled according to ISPM 32. Phytosanitary inspections were done according to the general inspection procedure at ports of entry standard by the Zimbabwe NPPO (IPPC Secretariat, 2016; Plant Quarantine Services Institute, 2022).

Approach rate

The number of times a particular pest (or pest collection/

category) is associated with a particular volume in a specified pathway (Gilioli et al., 2017; North American Plant Protection Organization [NAPPO], 2017). This was determined by recording the frequencies at which a specific pest was isolated in the pest pathways. The data collected were segregated by port of entry, pathway, and pest category (NAPPO, 2017)

Data analysis

Analysis of variance was used to analyze the variables (volume of phytosanitary traffic rejected due to non-compliance with phytosanitary standards at the port of entry and the weed approach rate). The frequency of contamination was calculated by expressing as a percentage, the infected samples as ratio of the total samples subjected to the pathway visual examination at ports of entry. The data obtained was analyzed using GenStat 14 and SPSS statistical packages. ANOVA and statistical inference were computed, and Fischer's least significant difference was used for mean separation where necessary (Gomez and Gomez, 1984; Little and Hills, 1978).

RESULTS

A total of 1668 samples collected from cross border human aided pest-pathways were examined at the

Mazowe Plant Quarantine services Laboratory, and 31 of the analyzed samples were obtained from unofficial crossing points. The remainders of the samples were obtained from the 14 ports of entry as referred to in Figure 1.

Weed species diversity in pest pathways intercepted at Zimbabwe ports of entries

Trapped weeds or plants comprised of eleven species in eight orders (Table 2). Two potentially new weed threats, *Convolvulus arvensis* (L) (Figure 3A) and *Adenium obesum* (Forssk) were found trapped from the human-aided pest-pathways into Zimbabwe. One weed that was intercepted was *Datura stramonium* L., a weed associated with feed and food poisoning (Figure 3B). *D. stramonium* is a regulated weed for seeds in Zimbabwe. A weed not known to exist in Zimbabwe (*C. arvensis*) was intercepted in wheat grain destined for consumption. *Helianthus annuus* and *D. stramonium* weeds were intercepted in maize consignments destined for animal feed and food. Three weeds were smuggled for planting as flowers and ornamentals (*A. obesum*; Lilac Chaste

Table 2. Nomenclature of plants/weeds found in association with cross-border pest pathways during the 2020-2024 periods at Zimbabwe ports of entries.

Common name	Order	Species	Pathways	Purpose of Importation	Pest Status In Zimbabwe
European bindweed	Solanales	<i>C. arvensis</i> L.	Wheat grain	Consumption	Absent (Intercepted only)
Common Sunflower	Asterales	<i>Helianthus annuus</i> L.	Maize grain and soya beans	Consumption	Present
Thorn apple, and jimsonweed	Solanales	<i>D. stramonium</i> L.	Maize grain.	Consumption	Present
Common duckweed	Alismatales	<i>L. minor</i> L.	Passenger baggage	Feed production	Present. In national parks (Mapaura and Timberlake, 2004)
Lesser duckweed	Alismatales	<i>L. aequinoctialis</i> Welw.	Passenger baggage	Feed production	Present in national parks (Mikulyuk, 2009; Mapaura and Timberlake, 2004)
Desert rose	Gentianales	<i>A. obesum</i> ((Forssk.) Roem. and Schult.)	Passenger baggage	Unknown (suspected ornamental)	Absent (intercepted and destroyed) (Plant Quarantine Services Institute, 2023)
Lilac Chaste Tree	Lamiales	<i>V. agnus-castus</i> L.	Passenger baggage	Unknown (suspected ornamental)	Absent (intercepted only) (Plant Quarantine Services Institute, 2023; Rojas-Sandoval, 2020)
Apples	Rosales	<i>Malus domestica</i>	Passenger baggage	Planting	Present
Grapes	Vitales	<i>Vitis vinifera</i> L.	Passenger baggage	Planting	Present
Oranges	Sapindales	<i>Citrus × sinensis</i>	Passenger baggage	Planting	Present
Sweet potatoes	Solanales	<i>Ipomea batatas</i>	Passenger baggage	Planting	Present

Tree (*Vitex agnus-castus*) tree seeds, *L. minor* (Welw) (Figure 4) and *Lemna aequinoctialis* (Welw)). *L. minor* (Welw) and *L. aequinoctialis* were also smuggled for planted as animal feeds.

Two weeds (*D. stramonium* and *A. obesum*) that were intercepted were a threat to food and feed safety as potential feed and food poisons. One weed which was found in passenger baggage *Vitex agnuscastus* was known for its medicinal properties in Asia and Middle East, where it also behaved as a weed. *V. agnuscastus* has potential to grow in a wide range of climates and soil types with high seed production rates. Figures 2, 3, 4 and 5 show some of the weeds or plants that were found in association with human aided cross-border traffic into Zimbabwe during 2020 to 2024.

Occurrence and distribution of the weed threats found associated with cross border traffic at Zimbabwean ports of entries

Approach rates for the weeds found in association with cross-border traffic in Zimbabwe

Table 3 shows the weed pest approach rate to Zimbabwean ports. The weeds approach rate was 182 from the 1668 sampled human-aided plant pest pathways that were examined at the Mazowe central laboratory. There were highly significant differences in the mean weed approach rates across the border ports ($P < 0.001$) (Table 4). The highest mean weed approach rate to Zimbabwe's

port of entry was encountered at the Beitbridge (6.76) port of entry, followed by Forbes (0.83) and lastly, Victoria Falls (0.04) and RGMIA airports (0.04).

Infestation frequencies for weeds found in association with cross-border traffic into Zimbabwe

The overall weed infestation frequency was 10.91% of all the pest pathways that were examined at the Mazowe central laboratory (Table 3). The overall pest infestation/infection rate was 53.60% from all the 1668 pathways examined, and 35.49% of the pathway samples examined were



Figure 2. Intercepted maize with Sunflower weeds (A) and *Datura* sp. weeds (B) and organic debris (C) at the Beitbridge border port during the period 2020-2024.

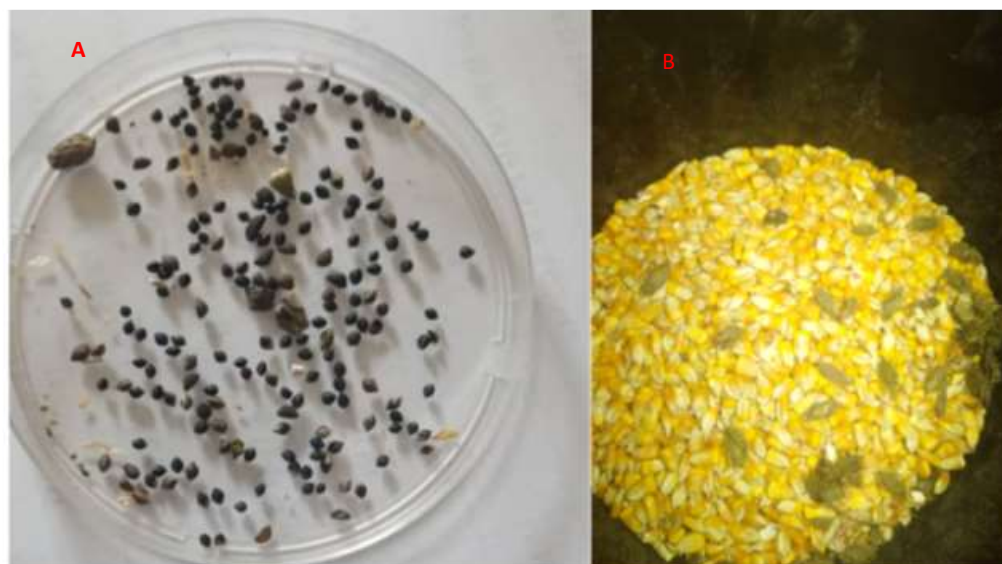


Figure 3. *C. arvensis* L. (A) and *D. stramonium* L. (B) Weed seeds isolated from wheat and in association with maize grain intercepted at the Forbes and the Beitbridge border ports respectively, during the period 2020-2024.

pest-free. The weed infestation frequency was significant across the ports of entries with a mean infestation frequency of 1.41% (Table 4). The Beitbridge port of entry had the highest weed infestation frequency of 10.09% (Table 4). As indicated in Table 4, only four sites had weed infestation frequencies above zero and these ports were Beitbridge with 10.09%; Forbes with 4.05%, RGMIA with 4.18% and lastly Victoria Falls airport which had a weed

infestation frequency of 2.78%. The Beitbridge port had the highest weed infestation frequency of 10.09%, followed by Forbes port, which had a weed infestation frequency of 4.05%. The Victoria Falls and Robert Gabriel Mugabe International Airport (RGMIA) had weed infestation frequencies of 2.78 and 4.18%, respectively. Unofficial crossing points had a weed infestation frequency of 0% as depicted at the other 10 ports of entries (Table 4) studied.



Figure 4. *L. minor* weed smuggled through the RMIGA that was found planted in a pond in the Hwedza district during the period 2020-2024.

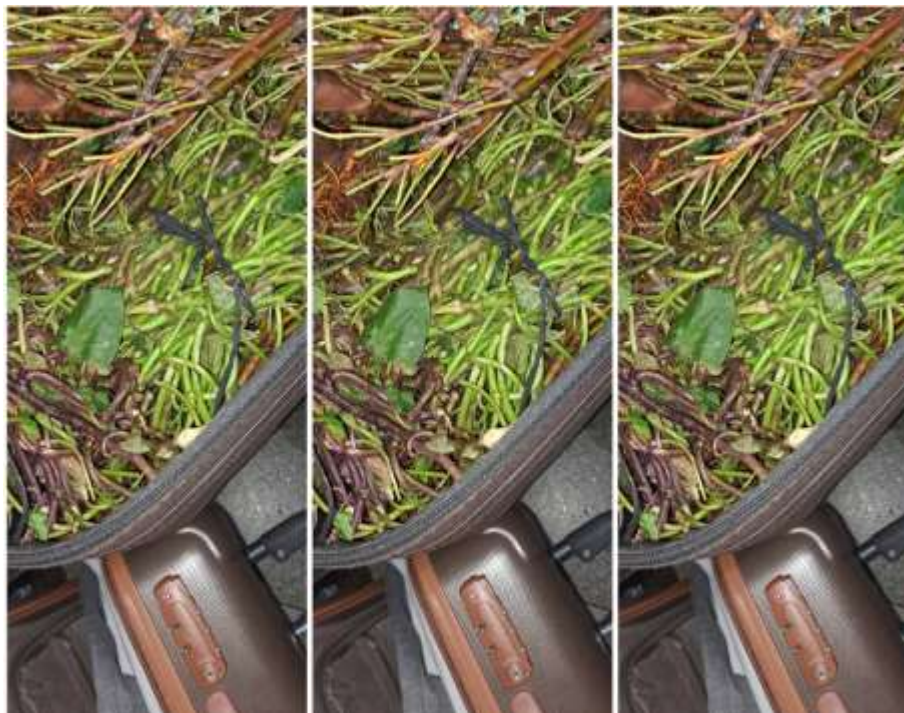


Figure 5. A consortiums of smuggled plants intercepted in passenger baggage at the RGMIA during the period 2020-2024.

DISCUSSION

As depicted from these studies, six weed-plant species were found in association with the human-aided cross-

border human aided pest pathways. Similarly, water hyacinth was introduced into the country as plants brought for ornamental purposes. From this research, the hitch hiking of two weed threats was noted (*C. arvensis* (L) and

Table 3. Weed Approach rates of pest categories found in samples collected from the cross-border traffic at Zimbabwe ports of entries for the period, January 1, 2020 to December 31, 2024.

Pest category	Samples size analysed	Pest approach rate	Pest approach rate frequency (%)	Pest infestation rate (%)
Weeds	1668	182	16.95	10.91
Other pests	1668	894	83.05	53.60
Freedom from pests	1668	725	-	35.49
Mean	1668	600	50	33
Standard deviation	0	372	47	21

Table 4. Sites effect by pest pathways in cross border traffic during the period 2020--2024 at ports of entries into Zimbabwe.

Site/Port of entry	Mean total pest approach rate	Mean weed approach rate	Mean pest infestation/infection rate (%)	Mean weed infestation rate
Beit-bridge	5	6.67 ^b	41.00 ^a	10.09
Chirundu	2.1	0.0	26.5ab	0
Forbes	6.8	0.83 ^a	27.5 ^{ab}	4.05
Kariba	0.8	0 ^a	18.3 ^b	0
Kazingula	0.3	0 ^a	15.3 ^{bcd}	0
Maitengewe	0.3	0 ^a	7.0 ^{cd}	0
Mphoengs	0.3	0 ^a	1.8 ^{cd}	0
Mkumbura	0.0	0 ^a	0 ^{cd}	0
Nyamapanda	2.1	0 ^a	25.4 ^{ab}	0
Plumtree	2.3	0 ^a	23.7 ^b	0
R.G.M.I Airport	3.5	0.4 ^a	24.5 ^b	4.18
Sango	0.0	0 ^a	0 ^{cd}	0
Unofficial entry port	0.0	0.0 ^a	21.9 ^b	0
Victoria Falls	0.40	0 ^a	25.8 ^{ab}	0
Victoria Falls Airport	0.2	0.04 ^a	12.5 ^{bcd}	2.78
Grand mean	4.5	0.51	18.1	1.41
F Probability	P=0.181	P<0.001	P<0.001	P<0.001
LSD (5%)	NS	1.382	15.66	3.885

*Means with same letters were not significantly different.

A. obesum (Forssk)), which were destined for feed production. Similarly, *Lemna aequinoctialis* is a nuisance in water bodies, rice field agro-ecosystems, irrigation and drainage channel reservoirs, and recreational lakes. Several mosquito larvae, particularly those of *Culex bitaeniorhynchus* (which vectors of arboviruses), *C. tritaeniorhynchus* and *Ficallbia minima*, are closely associated with *Lemna* (Njambuya et al., 2011).

Human-aided pest pathways in cross-border traffic were also found associated with food and feed safety threats (Toumasis et al., 2025; Kasem et al., 2024). The issue of food poisons carried in plant pest pathways remains a critical issue in plant biosecurity, food safety and animal

health (Musawa, 2022; Njoroge et al., 2016). Similarly, the current research trapped *D. stramonium* and *A. obesum* from human aided cross border pest pathways and these were potential feed and food poisons (Abalaka et al., 2014; Mutebi et al., 2022). *Datura* sp. is associated with toxins of the tropane alkaloids, atropine, hyoscyamine, and scopolamine, all of which are classified as delirants or anticholinergics. As previously highlighted, the exotic plant, *A. obesum* which was brought into the country for ornamental purposes via the Victoria Falls Airport border port, was also reported as a food and feed poisoning agent that may cause slow heartbeat, low blood pressure, lethargy, dizziness and stomach upset (Abalaka et al.,

2014, <https://www.health.qld.gov.au/>; Mutebi et al., 2022).

From this current research, it was noted that the most threatening pathways for weeds were grain consignments destined for other uses as well as passengers carrying planting propagules in their baggage. Grain quality issues for the industry, food safety [CODEX Alimentarius (CODEX)], and the plant quarantine must be harmonized to avoid clashes of quality parameters of pest pathways crossing the border. The CODEX standard for maize (CODEX, 1995) denotes other organic extraneous matter, which is defined as organic components other than edible grams of cereals (foreign seeds, stems, etc.) to be at a maximum of 1.5% m/m max; and inorganic extraneous matter, which is defined as any inorganic component (stones, dust, etc.) to be 0.5% m/m as the maximum threshold of foreign materials; the Grain marketing Board (Zimbabwe), considers 3% as the maximum foreign material required for maize for the first class grain, whereas the plant quarantine policies has zero tolerance to foreign matter in imported maize grain consignments. Such policies cause disharmony in the industry between the grain trading, food safety and plant quarantine on port of entry decision regarding consignment entry acceptance or rejection for commodities including the other grains such as wheat and sorghum (The Head Plant Quarantine Services Institute, 2022, CODEX, 1995).

Furthermore, this research found out that truckloads of maize grain intercepted at the Beitbridge port due to contamination by weed seeds and foreign organic matter had an average of 3% foreign matter content. In such instances, each truck load with 34.5 tonnes of maize grain would literally deliver 1.035 tonnes of rubbish comprised of weed seeds and foreign debris. Thus, rubbish was shipped across borders risking the biosecurity of the country. With over 20,000 truckloads of maize grain with 3% foreign material imported during the period of study, the maize consignment pathway assisted the hitchhiking of over 20,700 tonnes of rubbish comprised of weeds and other debris that can be a serious threat to the country's plant biosecurity.

Weeds such as *Datura* sp. are regulated weed on seed market access and are restricted weed in plants for planting in Zimbabwe (Plant Quarantine Services Institute, 2022, Unpublished), a result similarly reported by Zhang (2012). A weed not known to exist in Zimbabwe (*C. arvensis*) was intercepted in wheat grains destined for consumption further exposing the country to new pests threats, concurring to reports by several authors ((Mujaju et al., 2021; Tshikhudo et al., 2021; Zhang, 2012). The identified mean weed pest infestation frequency of 1.41% from the current study deviated from the expected pest threshold of 0% (IPPC Secretariat, 2008). Pest pathways can carry anything with them (Shafi et al., 2023; Cui et al., 2020).

Weed seeds were found mostly in association with cereal grain, suggesting contamination of the grain during

combine harvesting. The Beitbridge border post and the Forbes border post was associated with large traffic volume. In Beitbridge, Zimbabwe is separated from the Republic of South Africa by a large river called the Limpopo. Most traffic passes into Zimbabwe through normal ports of entry, and a few consignments are smuggled using boats across the Limpopo. The high infestation frequency noted at the Beitbridge port of entry resonates very well with the claims by Nyoni (2022) that few goods are smuggled by boats across the river Zambezi between Zambia and Zimbabwe where the natural physical river barrier causes bulky goods to be channeled through the designated ports of entries where they are subjected to phytosanitary inspections on arrival.

Conclusion

From this study, two potential new weed threats, *C. arvensis* and *A. obesum*, were found in association with human-aided pest-pathways into Zimbabwe. Two weeds (*D. stramonium* and *A. obesum*) associated with cross-border traffic were a threat to food and feed safety. Beitbridge, Forbes, Chirundu and Robert Mugabe International airport ports of entries exhibited high weed pest approach rates. Airports, as depicted at the Victoria Falls and Robert Mugabe International ports, were associated with passenger baggage as pathways of new weed pests into the country.

RECOMMENDATIONS

Given the high potential of passenger baggage to hitchhike potential weed threats at airports, advanced baggage scanners and sniffer dogs are important assets that can be deployed to identify potential dangers. The national sanitary and phytosanitary committees must harmonize border security controls to enhance the protection of plant and animal health as well as food security hazards. Finally, there is a need to strengthen policies for weed and exotic plant inspections at ports to reduce the weed threats associated with human aided cross-border traffic.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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