Sustinere
Journal of Environment and Sustainability
Volume 7 Number 3 (2023) 190-206

Print ISSN: 2549-1245 Online ISSN: 2549-1253
Website: https://sustinerejes.com E-mail: sustinere.jes@uinsaid.ac.id

RESEARCH PAPER

Abundance of *Xanthium spinosum L.* along the different land types and its impacts on invaded plant communities in North Shewa Zone, Ethiopia

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Article history:
Received 15 May 2023 | Accepted 25 November 2023 | Available online 31 December 2023

Abstract. A biological invasion is a form of biological pollution that is most likely more terrible than chemical pollution. *Xanthium spinosum* is one of the most invasive alien plant species. However, its abundance and impacts on invaded plant communities have not yet thoroughly studied. This study aimed to investigate the abundance and impacts of *X. spinosum* on invaded plant communities in the North Shewa Zone, Ethiopia. The study applied the quadrat method, sampling 80 main plots within 1 m^2. Differences in mean cover-abundances of *X. spinosum* across various land types were compared using one-way-ANOVA followed by Tukey's Honestly Significant Difference (HSD) Test. The results showed that roadsides and flooded areas exhibited the maximum mean cover-abundance of *X. spinosum* compared to farmland and rangeland. The number of plant species recorded was 106 in the control areas, compared to only 73 in the invaded areas. Hence, the number of plant species decreased by 31.13% in the infested area compared to the control. Thus, *X. spinosum* was among the factors contributing to the reduction of plant diversity, affecting the sustainability of biodiversity in the study areas. Therefore, implementing management measures against the spread of *X. spinosum* is to address the ongoing threat to biodiversity.

Keywords: Control; farmland; flooded areas; rangeland; roadside

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1. Introduction

Invasive alien species (IASs) are unwelcome species not native to a specific ecosystem and whose establishment harms biodiversity and ecosystem services (McNeely, 2001). IASs have been identified as the second cause of species extinction at the world level, next to habitat deterioration, affecting the biological diversity of many ecosystems (Mussa et al., 2018). Hence, IASs are one of the five direct drivers of biodiversity loss. The globalization of trade, travel, and transport is significantly increasing the number of IASs being moved worldwide (Burgiel et al., 2006). Africa is particularly vulnerable to IAS annexation due to the climate-sensitive distribution of its native flora and fauna (Genovesi et al., 2015). Ethiopia recognized the threats posed by IASs to local biodiversity and incorporated this fact into its various policy and strategy documents. IASs are damaging agricultural land, national parks, waterways, rivers, roadsides, rangeland, and urban

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DOI: https://doi.org/10.22515/sustinere.jes.v7i3.343

green spaces, with severe economic and environmental consequences in the country. Various Invasive Alien Plant Species (IAPSs) were recorded, and X. spinosum is among Ethiopia's highly targeted IAPSs (Boy & Witt, 2013).

X. spinosum L. is among the Asteraceae family and is commonly known as spiny cocklebur, prickly bur-weed, and Bathurst burr. This herbaceous annual IAPS is part of the *Xanthium* genus, which includes 25 species (Tutin et al., 1976). Native to South America, it is widely distributed in the Mediterranean, Europe, Australia, African countries, and the southern United States (Munz & Keck, 1973), presenting itself as cosmopolitan weed found throughout the continents. It invades open areas and waste places, readily establishing itself in cultivated land, roadsides, disturbed areas, meadows, canals, ditches, and riverbanks, potentially posing a threat to native or endemic wildlife. *X. spinosum* likely spread worldwide by clinging to animal hair or wool, clothing, feed sacks, and muddy tools. It is considered a serious weed in numerous agricultural crops and animal production (Holm et al., 1977; Wang et al., 2015; Zhao et al., 2006).

X. spinosum has the ability to form impenetrable stands, displacing native plant species. It is also considered to be allelopathic. Infestations on riverbanks can lead to increased soil erosion, affecting water flow, while invasions in croplands have led to reduced yields of soybeans and cotton. In certain regions of Australia, it is common in irrigated crops such as sunflower, soybean, maize, and cotton, where it reduces yields due to competition. Additionally, its spiny fruits lodged in the fleeces of grazing animals, leading to significant wool faults (Andrews, 1993). The plant is toxic, especially to pigs and horses. Severe poisoning can lead to convulsions, spasmodic running movements, and death within a few hours (Julien et al., 2012). Hence, *X. spinosum* contributes the loss of plant and animal biodiversity. This loss can lead to various detrimental effects such as droughts, flooding, increased vulnerability to severe weather events like hurricanes and heatwaves, disruption of ecological cycles, polluted waterways, heightened susceptibility of food supplies to pests and disease, and overall environmental damage (Hald-Mortensen, 2023; Singh et al., 2021).

The study conducted by Syliver et al. (2020) indicated that *X. spinosum* was among the dominate IAPSs, causing damage to plant biodiversity, particularly impacting grassland biodiversity. This species is a cause for concern due to its adeptness in adapting to Mediterranean climates and its preference for nitrogenous-rich soils. The plant is frequently found in farmlands, causing a sanitary risk for cattle. *X. spinosum* possess hooked spines that can attach to animal coats and clothing, contributing to the dispersal over large areas (Andreani et al., 2016). It is identified as one of the IAPS significantly causing global biodiversity loss (Sylvain et al., 2022). This species exhibits robust adaptability in arid desert areas and is a prevalent malignant IAPS in Xinjiang, China. Due to its adaptability in desert environments, it often dominates communities as a mono-dominant species. At the end of each growth cycle, numerous mature involucres form a seed bank, ensuring a constant seed source that fosters community succession, malignant expansion, and invasion into sandy habitats, aggravating environmental invasion. Therefore, IASs can threaten local ecosystems and biodiversity through competition with native species, predation, environmental changes, and disease transmission (Hald-Mortensen, 2023; Tao et al., 2022).

Generally, when *X. spinosum* and other IAPSs out-compete local organisms for resources, native species may decline or even face extinction. The alteration of local food web dynamics due to predation by IASs can further lead to imbalances in the ecosystem and environment. Changes in soil chemistry or water flow patterns can create conditions that favor invasive species, amplifying their impact. The economic consequences of invasions are also noteworthy, as they can lead to decreased crop yields or increased costs in managing of native species, leading to severe global environmental problems (Hald-Mortensen, 2023; Linders et al., 2019; Sylvier et al., 2020). Numerous studies in Ethiopia, such as Tola and Tessema (2015), Fufa et al., (2017), Tefera et al. (2020), and Kuma et al., (2021) indicate that *X. spinosum* poses a significant challenge as an IAPS, causing serious biodiversity loss in most regions of the country.

In Ethiopia, it is considered a weed in irrigated fields, farmland, flooded areas, rangeland, and roadsides in the northeast, northern and central highlands, and southern rift valley, having direct and indirect effect on environmental changes (Witt & Luke, 2017). *X. spinosum* has been identified as an evolving problem affecting the sustainability of biodiversity in the country, leading to significant economic, environmental, and ecological impacts. Especially, ecosystems in the North Shewa Zone of the Amhara region have been harshly affected by *X. spinosum.* However, there have been no studies conducted about the cover abundance *X. spinosum* and its impact on invaded floral communities in Ethiopia. Therefore, this study was aimed to assess the cover abundance of *X. spinosum* and its impacts on the diversity and composition of invaded plant communities in the North Shewa Zone, Amhara region, Ethiopia.

2. Methods

2.1. Description of the study area

North Shewa is among of the zones in Amhara Region, Ethiopia and it derives its name from the kingdom or former province of Shewa. This zone shares its borders with the Oromia region to the south and west, South Wollo to the north, the Oromia Zone to the northeast, and the Afar region to the east. Comprising a total of 24 districts, this study was conducted in Ankober, Minjar Shenkora, and Tarma-Ber districts (Figure 1). Ankober, bordered by Asagirt, Basona Werana, Tarma-Ber, and Afar regions to the south, west, north, and east respectively, serves as the administrative center of the district. Minjar Shenkora, located at the southern end of the North Shewa Zone, shares its borders with the Oromia region to the east, south, and west by; Hagere Mariamna Kesem to the northwest; and Berehet to the northeast, Arerti as its administrative center. Tarma-Ber, located at the eastern edge of Ethiopia's highlands in the North Shewa Zone, is bordered by Ankober, Basona Werana, Mojana Wadera, Menz Mama Midir, Kewet, and Afar regions, to the south, south-west, west, northwest, northeast, and southeast respectively, with Debra Sina Serving as its administrative center.

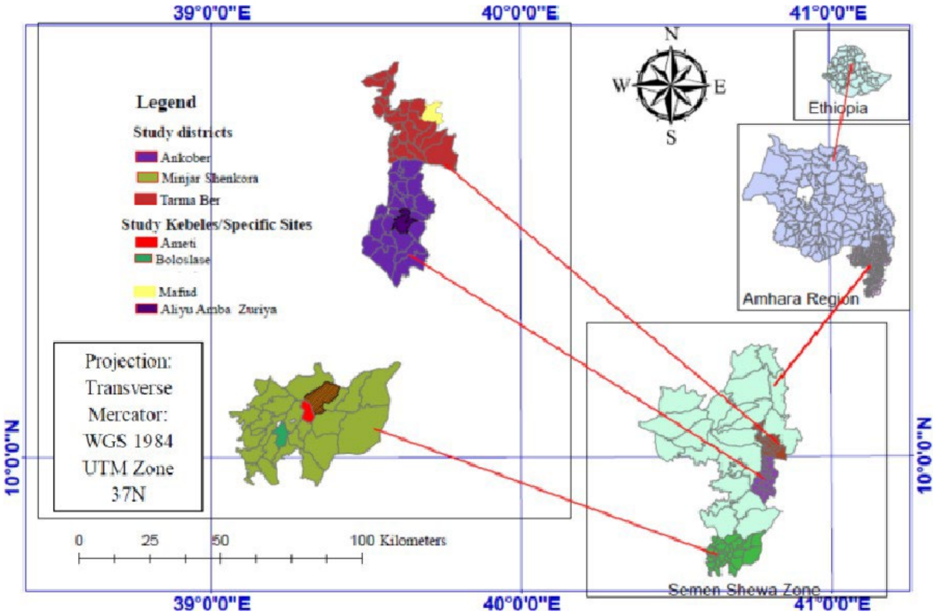

Figure1. Map of Ethiopia showing Amhara Region and the study districts

2.2. Method of data collection

The study zone and districts were purposively selected on the basis of the level of *X. spinosum* invasion, utilizing information obtained from Agricultural Office of North Shewa Zone. Following the outlined selection criteria, three districts and four Kebeles (the smallest administrative zone in Ethiopia) were selected. Specifically, Ankober, Minjar Shenkora and Tarma-Ber districts were identified for this research. The four selected Kebeles were Aliu-Amba from Ankober, Ameti and Bolosilase from Minjar Shenkora and Mafud from Tarma-Ber. The study investigated the cover-abundance of *X. spinosum* across different land types and its impacts on the diversity and composition of plant species within invaded plant communities using the quadrat method.

Sampling the cover of *X. spinosum*

Four land types were selected to study the cover abundance of *X. spinosum* (farmland, rangeland, flooded areas, and roadside) in each study site. In each land type, five 1 m x 1 m vegetation plots were sampled (20 plots for each study site). By using a modified Daubenmire frame, within each 1 m^2 plot, 50 cm x 50 cm micro-plots were samples along the transect line to record the percentage of cover-abundance of *X.spinosum*. Daubenmire (1959) Cover Class Method uses six separate cover classes (Table 1). A total 40 sub-plots or micro-plots were sampled in each study sites (160 micro-plots in all sites). The laid plots per land types were classified into one of the six cover classes by visual estimation of their cover. The sample sites were categorized into three infestation levels; low (0–25% land cover), medium (26–50%), and high (> 50%) infestation levels of the total percent area coverage of *X. spinosum*. These sites of low, medium, and high infestation were selected by ocular estimation from randomly thrown sample plots within the selected study sites (Shaheen et al., 2019; Tiwari et al., 2005). Additionally, to examine the effects of *X. spinosum* invasions on the species diversity and composition of invaded plant communities, 1 m^2 vegetation plots were sampled (80 plots for invaded and 80 for uninvaded/control). Among the transact lines, a 50 m interval was set to distinguish one transact from another, but the distance between the plots, length of transect lines, and the number of quadrates laid on the transact line were determined based on the length of the specific land types invaded by *X. spinosum* (Alves et al., 2010; Bonham et al., 2004).

Table 1. Cover class method (Daubenmire, 1959)

Cover class's	Range of coverage's	Midpoint of range's
1	0-5%	2.5%
2	5-25%	15%
3	25-50%	37.5%
4	50-75%	62.5%
5	75-95%	85.0%
6	95-100%	97.5%

A control was designated to compare the diversity and composition of plant communities in the invaded and non-invaded areas. In each vegetation type, one plot of the pair was placed in heavily invaded vegetation ("invaded plots") where *X. spinosum* dominated and had a high coverage, while the second plot was placed in neighboring vegetation where *X. spinosum* had no cover (control). The control was chosen to have similar site conditions (within ≤ 10 meters) to the invaded plot. The location of each plot and study site was recorded using GPS.

2.3. Method of data analysis

The R-package (version 3.6.2) was used to analyze the gathered data. Descriptive statistics were employed to examine the cover-abundance of *X. spinosum* and its impacts on the diversity and composition of invaded plant communities. The significance of the impacts of *X. spinosum* on plant species diversity was assessed through a simple linear regression analysis. The cover abundance of *X. spinosum* and diversity of plant species per plot were considered as independent and dependent variables, respectively. The recorded cover-abundance data for the study were subjected to a one-way ANOVA for each land type to establish differences among the mean cover abundance of *X. spinosum* for each land type. Significance levels among the mean cover abundance of *X. spinosum* for each land type were compared using Tukey's Honestly Significant Difference (HSD) Test at a 5% significance level to determine significant differences among groups. Additionally, a principal component analysis (PCA) was conducted to explore the relationship between plots and the cover abundance of plant species in both invaded and non-invaded floral communities.

3. Results and discussion

3.1. Variation in cover- abundance of *X. spinosum* along different land types

The results of this study revealed significant variations in the cover abundance of *X. spinosum* for each land type in the study sites (see Figure 2). Roadsides and flooded areas exhibited the highest mean percentage of *Xanthium spinosum* across all study sites compared to other land types. The one-way ANOVA results demonstrated substantial variation in the cover abundance of *X. spinosum* the different land types (refer to Table 2). Specifically, *X. spinosum* displayed an extreme mean percentage of cover abundance (41.5%) at roadsides in Mafud sites, followed by 38% (flooded areas) in flooded areas, when compared to others land types. On the other hand, farmlands and rangelands exhibited the lowest mean percentage of *Xanthium spinosum.* In the Ameti site, farmland had the lowest mean percentage of *X. spinosum* (7.2%), succeeded by 8.8% in the Bolosilase site (see Table 3).

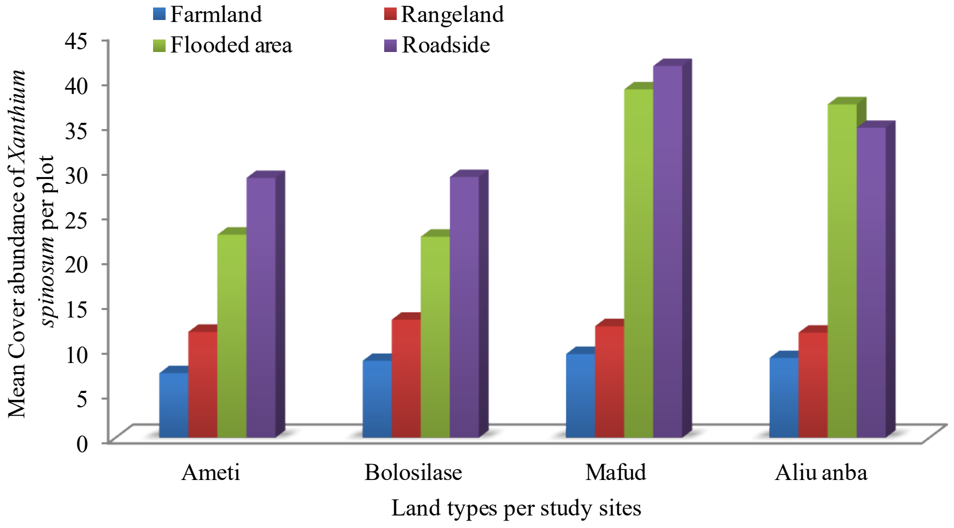

Figure 2. Cover abundance (%) of *X.spinosum* across different land types in the study sites

Table 2. One-way ANOVA was conducted on the cover abundances of *X. spinosum* across various land types of the study sites

Parameters	Tested between groups of	Study sites	D-F	F -value	P value
Cover abundance	land types	Ameti	3	10.7	≤ 0.001
		Bolosilase	3	22.8	≤ 0.001
		Mafud	3	25.3	≤ 0.001
		Aliu-Amba	3	42.9	≤ 0.001

Tukey's Honestly Significant Difference (HSD) Test, used for multiple comparisons, was conducted to compare the variation in percentage of cover abundance of *X. spinosum* among different land types in the study sites. Accordingly, in the Ameti site, the percentage of cover abundance of *X. spinosum* differed significantly between farmland and roadside ($p \le 0.001$), as well as between rangeland and flooded areas ($p \le 0.05$). However, the cover abundance of *X. spinosum* in rangeland did not significantly different from that in farmland. Similarly, the abundance of *X. spinosum* along the roadside was not significantly different from that in the flooded areas. At the Bolosilase site, significant differences in the cover abundance of *X. spinosum* between various land types were observed, with roadside and flooded areas different significantly from farmland ($p \leq 0.001$). Additionally, the rangeland differed significantly from the flooded area ($p \leq 0.01$) and roadside ($p \leq 0.001$), respectively. However, the cover abundance of *X. spinosum* in rangeland was not significantly different from that in farmland, and flooded areas did not significantly differ from roadside areas.

Regarding the cover abundance of *X. spinosum* across various land types at the Mafud site, roadside and flooded areas exhibited significant differences from farmland and rangeland ($p \leq 0.001$). However, the abundance of *X. spinosum* in flooded areas did not significantly differ from that along roadside, and rangeland was not significantly different from farmland. Similarly, concerning the percentage of cover abundance of *X. spinosum* among various land types at the Aliu-Amba site, roadside and flooded areas were also showed significantly differences from farmland and rangeland ($p \leq 0.001$). Conversely, the abundance of *X. spinosum* in flooded areas did not significantly different from that on roadsides, rangeland was not significantly different from farmland. Thus, the result of this study indicated a degree of invasion by *X. spinosum* across the selected land types in the following order: roadside > flooded areas > rangeland > farmland.

Table 3. Percentage of Cover-Abundance of X. spinosum along different land types in the study areas, values expressed as Mean ± standard error (SE).

Land type	N	Ameti	Bolosilase	Mafud	Aliu-Anba
Farmland	10	7.20±0.416	8.80±0.533	9.40±0.600	8.90±1.629
Rangeland	10	10.00±0.931	11.50±0.860	10.70±0.559	10.40±1.231
Roadsides	10	29.00±6.182	29.10±3.644	41.50±5.377	34.60±2.891
Flooded area	10	23.40±1.310	23.20±1.389	38.00±4.163	36.00±2.824
Total	40	17.40±2.116	18.15±1.647	24.90±2.899	22.48±2.327

3.2. Cover classes of *X. spinosum* within each plot along the selected land types

At the Ameti sites, using Daubenmire's (1959) cover class method, the majority of plots in farmland (70%) were placed within cover class 2, while only 30% fell within cover class 1. In rangeland, 90% of the plots were positioned within cover class 2, with only 10% falling under cover class 1. Within the flooded areas of this study site, 30% and 70% of the plots were categorized within cover classes 3 and 2, respectively. On roadsides, 20%, 30%, 40%, and 10% of the plots were placed within cover classes 1, 2, 3, and 4 correspondingly. Among the three infestation levels, nearly all plots in farmland and rangeland exhibited a low level of infestation (0–25% land cover). In flooded areas, 30% and 70% of the plots were categorized at medium (26–50%) and low (0–25%) infestation levels, respectively. As for roadsides, 50%, 40%, and 10% of the plots were classified at low (0–25%), medium (26–50%), and high (>50%) infestation levels, respectively.

At Bolosilase sites, within the farmland of this study site, 90% of the plots were placed within cover class 2, while 10% fell under cover class 1. Conversely, in rangeland, all plots (100%) were classified within cover class 2. In flooded areas, 40% and 60% of the plots were placed within cover classes 3 and 2, respectively. On roadsides, 10%, 40%, and 50% of the plots were placed within cover classed 4, 3, and 2, respectively. Hence, in both farmland and rangeland, all the plots exhibited low levels of infestation (0–25%). In flooded areas, 60% and 40% of the plots were respectively at low and medium levels of infestation.

At the Mafud site, all plots (100%) in both farmland and rangeland were placed within cover class 2, indicating a low level of infestation (0–25%). In flooded areas, equal percentages (20% each) were distributed among cover classes 4 and 2, while 60% of the plots were within cover classes 3, signifying low (20%), medium (20%), and high (60%) levels of infestation. Along roadsides, 10%, 20%, and 70% of the plots were respectively placed within cover classes 4, 2, and 3.

At the Aliu-Amba sites, 50% of the plots in farmland were placed within 1, and the other 50% within cover class 2, whereas in rangeland, all plots were placed within cover class 2. Thus, all sampled plots in farmland and rangelands were categorized at a low level of infestation. In the flooded area, 80% of the laid plots were placed within cover class 3, while only 20% falling under cover class 4. Along roadsides, the majority (90%) of the plots were placed within cover class 3, while only 10% were in cover class 2. Hence, the majority of the plots in flooded areas and roadsides were placed under medium (26–50%) and high (> 50%) levels of infestation.

3.3. The relationship between the abundance of *X. spinosum* and the diversity of plant species

The results of this study revealed significant variations in the diversity of plant species and the percentage of cover abundance of *X. spinosum* per plot. The number of plant species observed in each plot appeared to be depend on the cover abundance of *X. spinosum*, treated as the independent variable. As the abundance of *X. spinosum* increased, the diversity of plant species per plot dropped. Therefore, to demonstrate the effect of percentage of cover abundance *X. spinosum* on diversity of plant species at Ameti and Bolosilase sites, the liner regression equation are presented as follows: $y = -0.333x + 15.92$, R^2 = 0.6911 (Figure 3) and $y = -0.500x + 20.453$, R^2 = 0.8084 (Figure 4), respectively. The abundance of *X. spinosum* exhibited a negative association with the diversity of plant species in each plot.

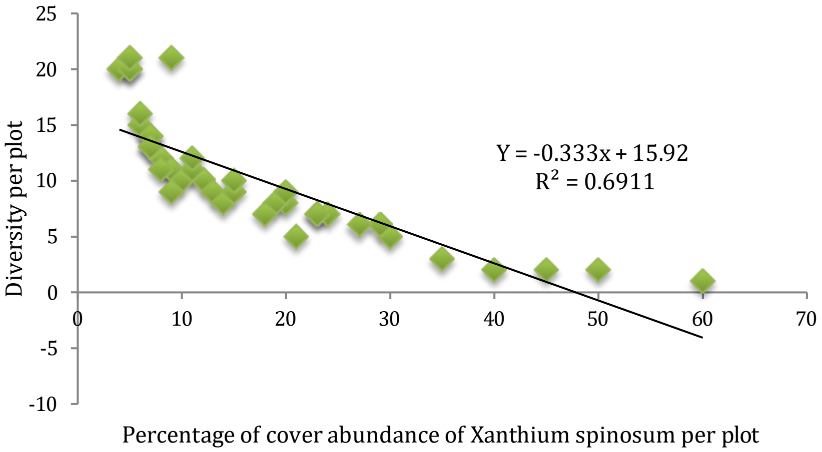

Figure 3. Effects of cover abundance of X. spinosum on diversity of plant species at Ameti sites

The regression equations for cover abundance of *X. spinosum* and diversity of plant species at Mafud and Aliu-Amba sites were: $y = -0.2329x + 14.175$, R^2 = 0.7928 (Figure 5), and $y = -0.3901x + 19.167$, R^2 = 0.8686 (Figure 6), respectively. There was a negative correlation between the diversity of plant species and cover abundance of *X. spinosum*. Generally, as the percentage of cover abundance of *X. spinosum* increased per plot, the diversity of plant species declined.

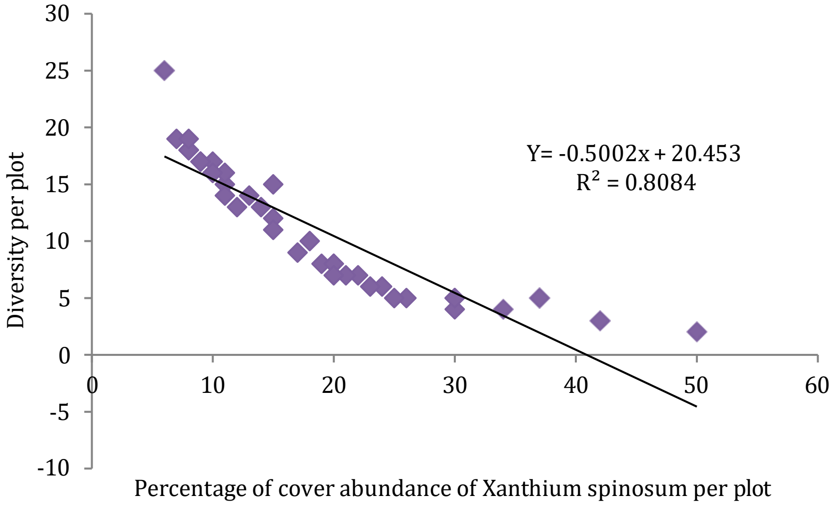

Figure 4. Effects of cover abundance of X. spinosum on diversity of plant species at the Bolosilase site

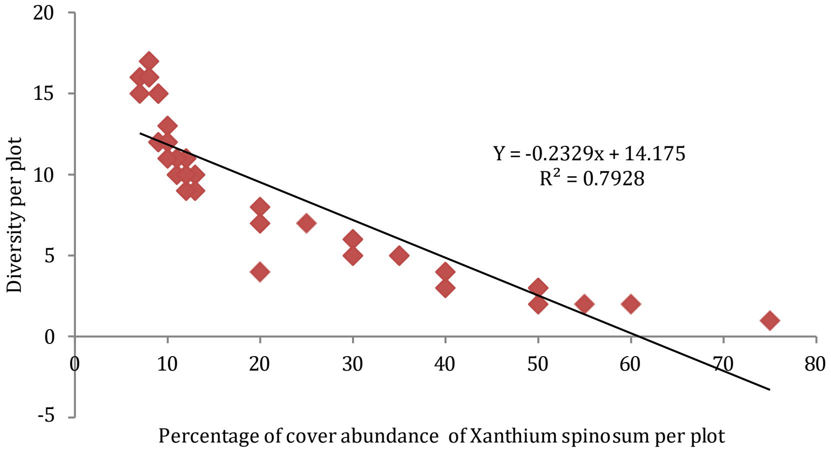

Figure 5. Effects of the cover abundance of X. spinosum on the diversity of plant species at the Mafud site

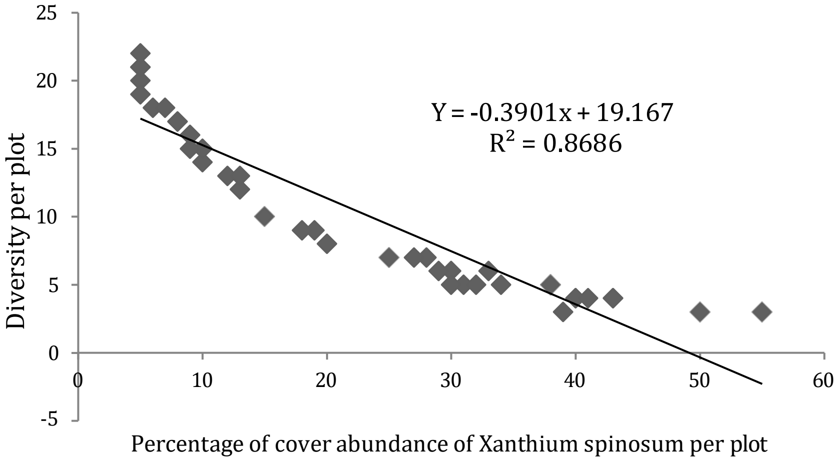

Figure 6. Effects of cover abundance of X. spinosum on the diversity of plant species at the Aliu-Amba site

3.4. Impact of *X. spinosum* invasion on the diversity and floristic composition of the plants

X.spinosum invasion damaged the composition and structure of species in the invaded habitats. A total of 108 plant species belonging to 36 families of flowering plant were identified during this investigation. In contrast, the control area harbored 106 plant species, while the *X. spinosum* – infested areas only contained 73 species. The number of plant species decreased by 31.13% in the *X.* spinosum-infested area compared to the control. Similarly, the number of plant families totaled 35 in the control but reduced to 24 in the *X. spinosum*-infested areas. Therefore, the total numbers of families decreased by 31.43% in the *X. spinosum*-infested area compared to the control. In the control site, among the 35 plant families, *Fabaceae* accounted for the highest percentage (22.64%), followed by Asteraceae (16.98%), Poaceae (9.4%), and Lamiaceae (8.49), among the recorded plant species in the non-invaded study sites. These four families contributed 57.5% of the species in the total flora within the control sites.

In invaded areas, among the 24 plant families, Fabaceae also accounted for the highest (21.92%), followed by Asteraceae at 15.1%, Lamiaceae, Poaceae, and Solanaceae at 12.33%, 10.96%, and 9.59% respectively, ranking as the third, fourth, and fifth among the plant species recorded in the *X. spinosum* invaded study areas. These five families contributed 69.9% of the species to the total flora of *X. spinosum*-infested study sites. Out of the 108 plant species, 37 were not found in *X. spinosum*-infested areas (refer to Table A in Appendix). Therefore, *X. spinosum* emerged as the dominant plant species in invaded sites, followed by *Salvia tiliifolia*, *Parthenium hysterophorus,* and *Cynodon dactyon,* respectively.

3.5. Ordination output

3.5.1. Principal Component Analysis (PCA) for invaded sites

The interrelationships between sites and abundance of plant species in *X.spinosum*-invaded plots were displayed in PCA graphs. According to the result of PCA, the first two principal components (eigenvalues) accounted for more than 36.86% of the total variance in the given datasets (with the cumulative variance of 0.3686). Therefore, the first and second principal component respectively accounted for 29.66% and 7.2% of the variance. The first four eigenvalues contributed to 49.16% of the total variance. The angles between the vectors of plant species, in general, were relatively small, indicating that the majority of the plots were closely grouped together. However, plots 2, 15, 32, 33, 73, and 77 stood apart from the others. Moreover, the vectors representing *X.spinosum* were positioned in an opposite direction compared to the majority of plant species vectors, with *X. spinosum's* vector appearing to be the longest. Additionally, the vectors of the majority of the plant species were clustered together at the origin of the PCA graph (see Figure 7).

3.5.2. Principal Component Analysis (PCA) for non-invaded sites

PCA was also conducted for non-invaded floral communities in the study areas. In this non-invaded floral communities, the first two principal components accounted for 49.9% of the total variance in the datasets, with the first and the second contributing 37.51% and 12.39%, respectively. Furthermore, the first, second, third, and fourth eigenvalues collectively accounted for 64.81% of the total variance in the datasets. Notably, the angles between the vectors of *Salvia tiliifolia* and *Cynodon dactylon* were larger than compared to the angles between vectors of other species, and their vectors were longer than the others. Plots 3, 77, and 47 were notably distant from 73 and the origin of the PCA graph. Additionally, the vectors of *Salvia tiliifolia* were the longest among all species, followed by *Cynodon dactylon* (see Figure 8).

4. Discussion

The outcomes of this investigation revealed significant variations in the abundance of *X. spinosum* across different land types. *X. spinosum* significantly affected the diversity and composition of invaded floral communities in the study area. Roadside and flooded areas

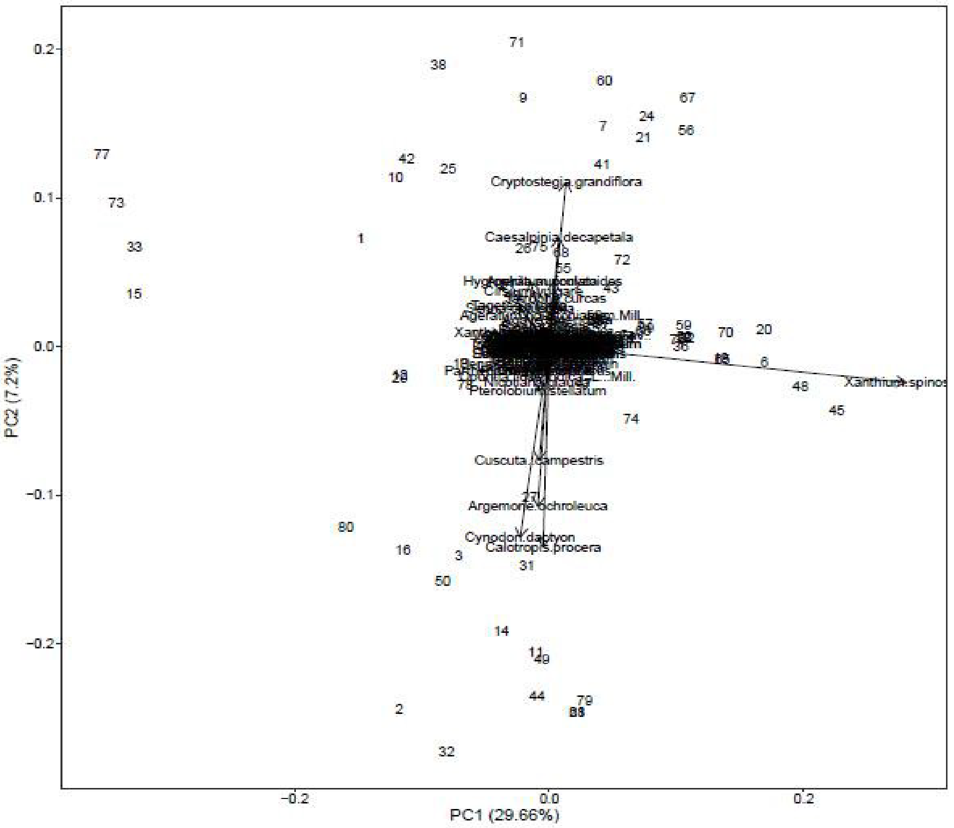

Figure 7. Principal Component Analysis (PCA) for *X. spinosum* invaded plant communities

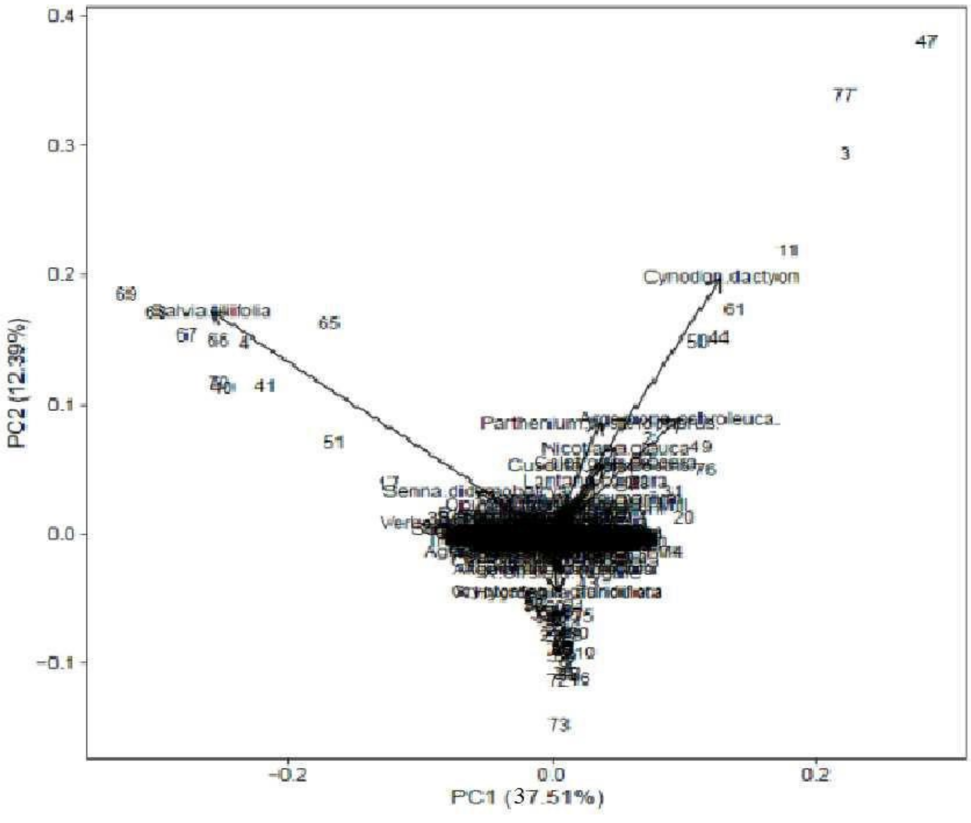

Figure 8. Principal Component Analysis (PCA) for non-invaded floral communities

exhibited higher mean percentage of *X. spinosum* cover abundance in study sites compared to other land types. Studies by Kosaka et al. (2010) and Rutkovska et al., (2013) indicated that the recent construction and use of roads facilitated the establishment of IAPSs along roadsides and railway lines, with higher spread rates observed along roadsides compared to forested and wetland patches. Hence, roadsides are supposed to play a significant role in the spread of IAPSs (Mortensen et al., 2009; Sullivan1 et al., 2009). Besides, roads and rivers/floods serve as pathways for the IAPS invasion, dominating both road-river interchanges and roadsides (Ruwanza & Mhlongo, 2020). The majority of the IAPSs were found invading expanded land types such as roadsides, drainage systems, riversides, habitation areas, and small-scale linear corridors like forest roads, aligning with findings from our study (Matisone et al., 2018; Mohammed & Rezene, 2020; Paini et al., 2016).

The result of this study also indicated reduction in the diversity and composition of plant species in the *X. spinosum*-infested areas as compared to the control. The number of plant species decreased by 31.13% in the *X. spinosum*-infested area as compared to the control. According to Eliáš et al. (2021) *X. spinosum* is a noxious weed that has successfully spread from South America to nearly all parts of the world, exhibiting a remarkable ability to colonize new habitats, ranging from marine coastal areas to desert grasslands and oases. Another study by Kuma et al. (2021) suggested that *X. spinosum*, an invasive IAPSs in the *Asteraceae* family, significantly contributed to the loss of plant biodiversity in Humbo district, South Ethiopia, aligning with our study. Biodiversity loss directly and indirectly affects societal well-being by changing ecosystem, functioning, goods, and services (Millennium Ecosystem Assessment, 2005). In the recent meta-analysis found that the effects of biodiversity loss were similar in magnitude to the effects of environmental changes on two crucial ecosystem functions, production and decomposition (Hooper et al., 2012).

The results of the study by Syliver et al. (2020) also indicated that *X. spinosum* was identified as one of the top 26 Invasive Alien Plant Species (IAPSs) potentially threatening biodiversity in the study areas, aligning with our investigation. Moreover, the outcomes of the investigation by Tefera et al. (2020) confirmed that *X. spinosum* was one of the 13 damaging IAPSs affecting the biodiversity of plant species in Wolayita Zone, Ethiopia in agreement with the finding of our study. Some effects of biodiversity loss include the acceleration of climate change, a loss of global food security, destabilization of ecosystem, and an increase in viral infection in humans. Many species affected by biodiversity loss are photosynthetic organisms that aid in extracting excess carbon dioxide from the atmosphere. Without these species, carbon dioxide levels increase rapidly, accelerating the effects of climate change (Gallardo, 2018; Hald-Mortensen, 2023; Linders et al., 2019; Singh et al., 2021).

The results of the study by Fufa et al. (2017) indicated that *X. spinosum* was one of the five major emerging IAPSs causing pronounced damage to plant biodiversity in the central western part of Ethiopia, in agreement with our study. Consequently, *X. spinosum* poses an evolving challenge to the sustainability of biodiversity in the study area. Similarly, the results of the investigation by Tola and Tessema (2015) also highlighted that *X. spinosum* as one of the 16 IAPSs affecting the sustainability of biological diversity in the Illu Ababora Zone of the Oromia National Regional State, Ethiopia, aligning with our current study. Moreover, *X. spinosum* was labeled a noxious weed in South Africa' Cape Province. This species not only invades croplands but also poses toxicity to livestock, and its female flower-heads (burs) adhere to and 'foul' the wool of sheep. A Provincial Weed Inspector, appointed to enforce legislation, was empowered to halt the movement of animal carrying these burrs. Therefore, *X. spinosum* is as a damaging IAPS affecting plants and animals biodiversity in Africa and other parts of the world (Boy & Witt, 2013). Overall, by outcompeting native species, altering the environment, and spreading disease, invasive species have the potential to significantly destabilize ecosystems (Gallardo, 2018; Hald-Mortensen, 2023).

The results of other studies by Hejda et al. (2009) and Wambua (2010) also confirmed the impact of IAPSs on the diversity of invaded communities. The diversity of plant species and number of families decreased significantly in the IAPS-infested areas (Vardien et al., 2012). The total numbers of families were decreased by 31.43% in the *X.spinosum*-infested areas in comparison to the control. Fabaceae, Asteraceae, Lamiaceae, Poaceae, and Solanaceae contributed 69.9% to the total flora in invaded study sites. Fabaceae was the dominant family in both invaded and non-invaded study areas. This might be due to the suitable environmental conditions for the species in the family and the large number of species in this family (Shaheen et al., 2019). The study by Dogra et al. (2009) on the impact of *Ageratum conyzoides* showed how IAPSs reduced the diversity of plant species and their respective families.

A principal component analysis (PCA) was conducted, resulting in a graph featuring labeled vectors and points. The vectors represent the measured variables, specifically the cover abundance of plant species in both invaded and non-invaded sites. The points on the graph denote individual cases, in this case, the plots where the cover abundance of plant species was recorded. Proximity between plots indicates similarity in species composition, while greater distances signify dissimilarity in composition (Chauhauki, 2012). The PCA revealed that the first principal components contained the most information across all parameters, followed by the second principal components. Furthermore, the PCA graph revealed the distribution pattern of species in association with the specific sites within both invaded and non-invaded study sites (Iezzoni & Pritts, 1991).

In invaded sites, the first two principal components accounted for a cumulative variance of 36.86% of the total variance in the given datasets. The plots proximity indicated high similarity in composition among those sites (Oulu, 2016). Moreover, the vectors representing *X. spinosum* were placed in the opposite direction from the majority of plant species vectors, with *X. spinosum's* vector appearing as the longest. This suggests a potentially larger cover abundance of *X. spinosum* in that direction from the origin (Kindt & Coe, 2005). Generally, in invaded floral communities, most plots were closely grouped, implying similarity in species diversity and the decreasing diversity levels with increasing cover abundance of *X.spinosum.* On the other hand, in the non-invaded floral communities, the first two principal components together accounted for 49.9% of the total variance, emphasizing the first principal component's better representation of variation in plant communities' diversity across study sites. Additionally, plots 3, 47, and 77 were notably distant from plot 73 and the origin of the PCA graph, suggesting dissimilarity in species diversity and composition from the other plots (Shaheen et al., 2019).

5. Conclusion

The study's finding revealed that the roadside and flooded areas exhibited the highest mean percentage of *X. spinosum* cover abundance compared to farmland and rangeland across all study sites. *X. spinosum* emerged as the dominant IAPS within the selected study sites, resulting in reduced species diversity and altered composition within invaded plant communities. Therefore, there is an imperative for improved planning aimed to controlling and managing the spread of *X. spinosum* to safeguard biodiversity. Additionally, it is recommended to conduct further phytochemical and molecular studies to explore the diverse properties of *X. spinosum*.

Acknowledgments

The people of North Shewa Zone, Amhara Region, who gave us information, are gratefully acknowledged. The authors are grateful to the Ethiopian Biodiversity Institute (EBI) for financial support during the field work. Finally, we are indebted very much to the agricultural workers of Aliu-Amba, Ameti, Bolosilase and Mafud sites for their unreserved willingness to share their time and knowledge with us.

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Appendix

Table A. Diversity and composition of plant species in the control and X. strumarium-invaded areas

No.	Scientific names of plants	Families	Control	Invaded
1.	*Acacia abyssinica*	Fabaceae	√	×
2.	*Acacia amythethophylla*	Fabaceae	√	×
3.	*Acacia etbaica*	Fabaceae	√	×
4.	*Acacia negrii*	Fabaceae	√	×
5.	*Agave Americana*	Agavaceae	√	√
6.	*Ageratum conyzoides*	Asteraceae	√	√
7.	*Ageratum houstonianum Mill.*	Asteraceae	√	√
8.	*Ajuga integrifolia*	lamiaceae	√	√
9.	*Aloe debrana*	Aloaceae	√	×
10.	*Alternanthera nodiflora*	Amaranthaceae	√	√
11.	*Amaranthus graecizans*	Amaranthaceae	√	×
12.	*Amaranthus spinosus*	Amaranthaceae	√	×
13.	*Argemone ochroleuca*	Papaveraceae	√	√
14.	*Balanites aegyptiaca*	Balanitaceae	√	×
15.	*Bidens macroptera*	Asteraceae	√	×
16.	*Bidens pilosa*	Asteraceae	√	√
17.	*Brassica napus*	Brassicaceae	√	×
18.	*Cadaba farinose*	Capparidaceae	√	×
19.	*Caesalpinia decapetala*	Fabaceae	√	×
20.	*Calotropis procera*	Asclepiadaceae	√	√
21.	*Calpurnia aurea*	Fabaceae	√	×
22.	*Carthamus tinctorius*	Asteraceae	√	×
23.	*Cicer arietinum*	Fabaceae	√	×
24.	*Cirsium dender*	Asteraceae	√	×
25.	*Cirsium englerianum*	Asteraceae	√	×
26.	*Cirsium vulgare*	Asteraceae	√	√
27.	*Crotalaria laburnifolia*	Fabaceae	√	×
28.	*Croton macrostachyus*	Euphorbiaceae	√	×
29.	*Cryptostegia grandiflora*	Apocynaceae	√	√
30.	*Cucumis prophetarum*	Cucurbitaceae	√	×
31.	*Cucurbita pepo*	Cucurbitaceae	√	×
32.	*Cuscuta campestris*	convolvulaceae	√	√
33.	*Cynodon dactyon*	Poaceae	√	√
34.	*Datura innoxia*	solanaceae	√	√

No.	Scientific names of plants	Families	Control	Invaded
35.	*Datura stramonium*	Solanaceae	√	√
36.	*Dichrostachys cinrea*	Fabaceae	√	√
37.	*Dodonaea angustifolia*	Sapindaceae	√	×
38.	*Dombia torroid*	Sterculiaceae	√	√
39.	*Dovyalis caffra*	Salicaceae	√	√
40.	*Echinochloa pyramidalis*	Poaceae	√	√
41.	*Echinops giganteus*	Asteraceae	√	×
42.	*Echium plantagineum L.*	Boraginaceae	√	×
43.	*Eleulillo floecifotia*	Poaceae	√	√
44.	*Euphorbia tirucalli*	Euphorbiaceae	√	×
45.	*Foeniculum vulgare*	Apiaceae	√	×
46.	*Galinsoga parviflora*	Asteraceae	√	√
47.	*Guizotia abyssinica*	Asteraceae	√	×
48.	*Helianthus annuus L.*	Asteraceae	√	√
49.	*Hygrophila auriculata*	Acanthaceae	√	√
50.	*Hyparrhenia rufa*	Poaceae	√	√
51.	*Hyparrhenia spp.*	Poaceae	√	√
52.	*Ipomoea cairica*	convolvulaceae	√	√
53.	*Ipomoea purpurea*	Convolvulaceae	√	√
54.	*Jatropha curcas*	Euphorbiaceae	√	√
55.	*Justicia schimperiana*	Acanthaceae	√	×
56.	*Kalanchoe petitiana*	Crassulaceae	√	×
57.	*Lantana camara*	Verbenaceae	√	√
58.	*Lathyrus sativus*	Fabaceae	√	√
59.	*Lens culinaris*	Fabaceae	√	√
60.	*Leucas martinicensis*	lamiaceae	√	√
61.	*Lolium temulentum*	Poaceae	√	√
62.	*Maytenus arbutifolia*	Celastraceae	√	√
63.	*Mimosa pigra*	Fabaceae	√	√
64.	*Mirabilis jalapa L.*	Nyctaginaceae	√	√
65.	*Nicotiana glauca*	Solanaceae	√	√
66.	*Ocimum americanum*	lamiaceae	√	√
67.	*Ocimum basilicum*	lamiaceae	√	√
68.	*Ocimum lamiifolium*	lamiaceae	√	√
69.	*Ocimum urticifolium*	Lamiaceae	√	√
70.	*Olea europaea*	Oleaceae	√	√
71.	*Opuntia ficus-indica (L.) Mill.*	Cactaceae	√	√
72.	*Osyris quadripartita*	Santalaceae	√	×
73.	*Otostegia integrifolia*	lamiaceae	√	√
74.	*Oxytenanthera abyssinica*	Poaceae	√	×
75.	*Parthenium hysterophorus*	Asteraceae	√	√
76.	*Pennisetum spbacelatuin*	Poaceae	√	×
77.	*Physalis peruviana L.*	Solanaceae	√	√
78.	*Pisum sativum*	Fabaceae	√	√
79.	*Prosopis juliflora*	Fabaceae	√	√
80.	*Pterolobium stellatum*	Fabaceae	√	√
81.	*Ricinus communis*	Euphorbiaceae	√	√
82.	*Rumex nervosus*	Polygonaceae	√	√
83.	*Saccharum officinarum*	Poaceae	×	√
84.	*Salvia nilotica*	lamiaceae	√	√

No.	Scientific names of plants	Families	Control	Invaded
85.	*Salvia tiliifolia*	lamiaceae	√	√
86.	*Senna alata*	Fabaceae	√	√
87.	*Senna didymobotrya*	Fabaceae	√	√
88.	*Senna obtusifolia*	Fabaceae	√	√
89.	*Senna occidentalis*	Fabaceae	√	√
90.	*Senna septemtrionalis*	Fabaceae	√	√
91.	*Sesbania sesban*	Fabaceae	√	√
92.	*Snowdenia polystachya*	Poaceae	√	×
93.	*Solanum campylacanthum*	Solanaceae	√	√
94.	*Solanum incanum*	Solanaceae	√	√
95.	*Solanum marginatum*	Solanaceae	√	√
96.	*Stephania abyssinica*	Menispermaceae	√	√
97.	*Tagetes minuta*	Asteraceae	√	√
98.	*Trifolium usambarense*	Fabaceae	√	√
99.	*Trigonella foenum-graecum*	Fabaceae	√	√
100.	*Urtica simensis*	Urticaceae	√	√
101.	*Verbascum sinaiticum*	Scrophulariaceae	√	√
102.	*Verbesina encelioides (Cav.)*	Asteraceae	√	√
103.	*Vernonia amygdalina*	Asteraceae	√	×
104.	*Vicia faba*	Fabaceae	√	×
105.	*Xanthium strumarium*	Asteraceae	√	√
106.	*Xanthium spinosum*	Asteraceae	√	√
107.	*Zantedeschia aethiopica*	Araceae	√	×
108.	*Ziziphus spina-christi*	Rhamnaceae	√	×