

Bioecological Traits and Ecological–Agronomic Hazards of the Invasive Species *Xanthium strumarium* L. in Arid Regions of Azerbaijan

¹ Sabina Seyidova

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Abstract. *Xanthium strumarium* L. is a globally distributed invasive weed whose rapid ecological expansion poses growing risks to agricultural productivity and biodiversity. This study investigates the bioecological traits and harmful impacts of *X. strumarium* within the Kangarli District of the Nakhchivan Autonomous Republic, where the species has become increasingly dominant. Field research conducted between September and November 2025 employed systematic morphological assessment, phenological observations, and habitat-based evaluations to determine the plant’s ecological behavior and dispersal mechanisms. Findings reveal pronounced ecological plasticity, including tolerance to drought, frost, and saline soils, alongside aggressive competitive interactions that suppress crop yields, alter native plant communities, and generate livestock and human health concerns due to its barbed fruits. The study highlights *X. strumarium* as a significant ecological and economic threat, underscoring the urgent need for continuous monitoring, targeted management interventions, and long-term invasion-risk modeling.

Keywords: *Xanthium strumarium* L.; invasive species; bioecological traits; ecological impact; agricultural risk

1. Introduction

Invasive plant species represent one of the most pressing ecological challenges of the 21st century, threatening biodiversity, agricultural productivity, and ecosystem stability across the globe. Defined as non-native species that spread rapidly and cause ecological or economic harm, invasive weeds exert competitive pressure on native flora, disrupt trophic interactions, and reshape habitat structure. Their expansion is intensified by climate change, habitat disturbance, and global trade networks, which collectively accelerate biological invasions across continents (Ullah et al., 2022; Waheed et al., 2024).

Within this context, *Xanthium strumarium* L.—a member of the extensive Asteraceae family—has emerged as a particularly successful invasive taxon. The species is characterized by high ecological plasticity, rapid growth, and an efficient dispersal system, enabling its establishment in agricultural fields, disturbed lands, riverbanks, and roadside habitats worldwide (Fan et al., 2019). Reports from Eurasia, South Asia, North America, and subtropical regions consistently highlight its aggressive competitive behavior, its ability to suppress native vegetation, and its capacity to reduce crop yields through resource competition and allelopathic effects (Chavan & Kulkarni, 2021; Abdiyeva &

¹ Seyidova, S. Master’s Student, Nakhchivan State University, Azerbaijan. Email: seyidovasebine22@gmail.com. ORCID: <https://orcid.org/0009-0003-1685-7068>

Litvinskaya, 2020). As a result, *X. strumarium* is increasingly recognized as a model species for studying plant invasiveness and bioecological adaptability.

The morphological variability of *X. strumarium*, including its barbed, buoyant fruits and seasonally adaptive growth patterns, further enhances its dispersal potential. Fruits readily attach to animals and human clothing, while their ability to float facilitates hydrochoric transport across irrigation canals, rivers, and flood-prone areas (Abdiyeva & Litvinskaya, 2020). These characteristics align with broader ecological theory, which suggests that species with strong reproductive capacity, generalist habitat preferences, and anthropogenic dispersal pathways are more likely to become successful invaders.



Figure 1. *Xanthium strumarium* L. in the study area: (a) habit of the plant near Qıvraq; (b) close-up of mature barbed burs with hooked spines.

Although *X. strumarium* is well documented globally, its regional behavior varies significantly with local climate, soil composition, and land-use patterns. For the Nakhchivan Autonomous Republic—an ecologically sensitive territory with sharply continental climatic conditions—the species presents a growing management concern. Preliminary field observations indicate rapid expansion in agricultural zones, particularly in the Kangarli District’s Kıvraq settlement, where land disturbance, irrigation systems, and livestock movement may facilitate its spread. Despite these observations, the bioecological characteristics and harmful impacts of this species remain insufficiently studied in the region, leaving a critical knowledge gap in both ecological science and agricultural management.

Accordingly, this study investigates the bioecological traits, dispersal mechanisms, and harmful effects of *Xanthium strumarium* L. in the Kangarli District of Nakhchivan. The research addresses the following questions:

1. **What morphological and ecological characteristics define the adaptability and invasiveness of *X. strumarium* in this region?**
2. **How does the species affect agricultural productivity, livestock, human health, and native plant communities?**
3. **What environmental factors and dispersal pathways contribute most to its proliferation?**

By examining these dimensions, the study contributes to a deeper understanding of invasive species ecology in arid and semi-arid environments and offers evidence-based recommendations for monitoring and managing *X. strumarium* populations in Nakhchivan.

2. Literature Review

Globally, *Xanthium strumarium* L. has been characterized as a morphologically variable and ecologically resilient invasive weed, capable of thriving across a wide spectrum of climatic and edaphic conditions (Fan et al., 2019; Chavan & Kulkarni, 2021). Detailed taxonomic and morphological investigations show considerable variation in plant height, stem pigmentation, leaf morphology, and burr size, reflecting a high degree of ecological resilience and phenotypic plasticity (Chavan & Kulkarni, 2021; Fan et al., 2019). Such plasticity enables the species to adjust its growth strategy under varying levels of disturbance, soil fertility, and moisture, reinforcing its status as a successful colonizer in both natural and anthropogenically transformed habitats.

The dispersal biology of *X. strumarium* further enhances its invasive success. Studies from Azerbaijan and Central Asia emphasize that the species relies on diaspore dispersal through zoochory, hydrochory, and anthropochory, with barbed burs easily attaching to animal fur, human clothing, and agricultural machinery, while also remaining buoyant in irrigation channels and river systems (Abdiyeva & Litvinskaya, 2020; Waheed et al., 2024). This multi-modal dispersal system, coupled with robust seed viability, creates a powerful propagule pressure that sustains persistent seed banks and facilitates rapid colonization of new areas (Ullah et al., 2022). In parallel, its tolerance to drought, salinity, and temperature extremes further illustrates the species' ecological plasticity and capacity to exploit disturbed landscapes.

From an ecosystem perspective, *X. strumarium* is increasingly associated with competitive exclusion mechanisms and trait-mediated ecosystem disruption. Field and modeling studies report that dense stands of this species reduce native plant richness, alter community structure, and interfere with successional trajectories by monopolizing light, nutrients, and space (Ullah et al., 2022; Waheed et al., 2024). In agricultural systems, *X. strumarium* competes directly with crops, lowers yields, degrades pasture quality, and can impair livestock health through its spiny burs and toxic constituents (Fan et al., 2019; Sharifi-Rad et al., 2015). These findings collectively position *X. strumarium* as not only a weed of agronomic concern but also a driver of broader ecological change, with significant implications for biodiversity conservation, land management, and rural economies.

Despite this growing international evidence, regional patterns of invasiveness remain strongly context-dependent. Recent studies highlight that the magnitude of ecological and economic impact is shaped by local climate regimes, disturbance intensity, and management practices (Abdiyeva & Litvinskaya, 2020; Waheed et al., 2024). In this respect, arid and semi-arid regions such as Nakhchivan offer a critical but underexplored setting for understanding how the species' global invasion syndromes manifest under sharply continental climatic conditions. Situating the current study within this literature allows the bioecological traits and harmful effects of *X. strumarium* in the Kəngərli–Qıvraq landscape to be interpreted not as isolated observations, but as part of a broader, globally documented invasion dynamic.

3. Materials and Methods

Study Area

The study was conducted in the vicinity of Qıvraq settlement, Kangarli District, Nakhchivan Autonomous Republic, Azerbaijan. The area is located on an arid steppe plain with a continental, semi-arid climate, characterized by hot, dry summers and cold winters, with low annual precipitation and high evaporation. Agricultural landscapes in the region are dominated by irrigated crop fields, interspersed with roadside verges, fallow lands and disturbed anthropogenic habitats, which together provide a heterogeneous mosaic of potential invasion sites for *Xanthium strumarium* L.

Sampling Period and Field Design

Fieldwork was carried out between September and November 2025, corresponding to the main fruiting and seed dispersal period of *X. strumarium*. Surveys were conducted in both cultivated fields and roadside/disturbed habitats in and around Qıvraq. A purposive, habitat-based sampling design was adopted to capture the species' bioecological variability across contrasting land-use types.

Within each habitat type, stands of *X. strumarium* were selected based on visual dominance and accessibility. At each stand, plants were examined in situ to document:

- presence and density of *X. strumarium*;
- associated crop and spontaneous vegetation;
- visible competitive effects (shading, space occupation, crop suppression);
- evidence of interaction with livestock and humans (adhering burs, injuries, irritation reports).

Field surveys were repeated at regular intervals over the study period to track phenological changes from fruit development to seed release and dispersal.

Morphological and Ecological Characterization

Morphological traits (overall plant height, stem branching pattern, leaf shape, and capitulum and bur characteristics) were recorded following standard taxonomic descriptions for *X. strumarium* (Fan et al., 2019; Chavan & Kulkarni, 2021). Particular attention was paid to:

- variability in plant stature and branching under different habitat conditions;
- bur morphology (size range, spine arrangement, presence of hooked spines at the apex);
- visible phenotypic plasticity related to soil and moisture conditions.

Ecological observations focused on habitat preference and tolerance. For each stand, the following qualitative parameters were recorded:

- habitat type (crop field, irrigation canal edge, roadside, wasteland);
- apparent soil condition (texture, moisture, visible salinity/alkalinity signs);
- exposure to drought and frost during the study period;
- degree of disturbance (grazing pressure, traffic, tillage).

These observations were used to qualitatively assess ecological plasticity, including tolerance to drought, frost, and soil salinity, and to infer the species' invasive potential in regional agroecosystems.

Herbarium Preparation

Representative specimens of *X. strumarium* were collected during the fruiting stage, carefully cleaned from soil and debris, and pressed and dried under shade at room temperature according to standard herbarium protocols (Sharifi-Rad et al., 2015). Mature burs were collected separately, air-dried, and stored in labeled paper envelopes for later examination of dispersal structures. Prepared specimens were deposited as herbarium vouchers to document the occurrence of the species in the study area and to support subsequent taxonomic verification.

Assessment of Dispersal Pathways and Impacts

To characterize dispersal mechanisms, field observations focused on the attachment of burs to livestock, wildlife, clothing and agricultural equipment, as well as their accumulation along irrigation channels and drainage lines, indicating hydrochorous transport. These qualitative observations were used to infer the relative importance of zoochory, hydrochory and anthropochory as diaspore dispersal pathways (Abdiyeva & Litvinskaya, 2020; Ullah et al., 2022; Waheed et al., 2024).

The impact of *X. strumarium* on local systems was assessed qualitatively by:

- comparing crop stands with and without heavy infestation to evaluate visible yield suppression and competition;
- recording instances where burs adhered to the coats of cattle and small ruminants, indicating potential animal welfare and wool contamination issues;
- noting anecdotal reports of skin irritation or allergic reactions in local residents handling the plants or coming into contact with burs.

Overall, the study adopted a qualitative ecological assessment approach, combining repeated field observations, morphological characterization, and context-based impact evaluation to build a comprehensive profile of the bioecological traits and harmful effects of *Xanthium strumarium* L. in the Kangarli District.

4. Results

4.1. Habitat Distribution

Field observations revealed that *Xanthium strumarium* L. is widely and consistently distributed across the Qıvraq settlement landscape, occurring both in cultivated fields and along roadside and disturbed habitats. The species demonstrated substantial ecological amplitude, successfully colonizing irrigated cropland, irrigation canal margins, compacted roadside verges, and waste ground.

In agricultural fields, *X. strumarium* frequently formed dense, monospecific patches, particularly along field edges and in poorly managed or under-weeded zones. Along roadsides and canal banks, it

appeared as a dominant or co-dominant species within the ruderal flora, indicating a strong capacity to exploit disturbed and anthropogenically modified environments.

4.2. Morphological Variation and Phenotypic Plasticity

Across the surveyed habitats, *X. strumarium* exhibited marked morphological variation, indicative of pronounced phenotypic plasticity. Plant height, branching intensity, leaf size, and capitulum density varied visibly between sites. Individuals growing in fertile, irrigated fields tended to be more robust, with taller stems and more intensively branched canopies, whereas plants on dry, compacted roadside soils were generally shorter and more sparsely branched.

The morphology of the burs remained consistent with species descriptions (two-chambered, spiny, with hooked apical spines), but minor variation in size and spine prominence was observed among plants exposed to differing moisture and soil conditions. This spectrum of morphological responses underscores the species' capacity to maintain reproductive structures across a range of environmental contexts.

4.3. Stress Tolerance and Ecological Amplitude

Across the observation period, *X. strumarium* exhibited robust tolerance to abiotic stressors. The species remained physiologically active under:

- periods of reduced precipitation, indicating tolerance to episodic drought;
- early-season frosts, without visible large-scale damage to stems or reproductive organs;
- visibly saline or degraded soils, where associated vegetation was sparse or stressed.

This combination of drought tolerance, frost resistance, and apparent tolerance to soil salinity confirms *X. strumarium* as an ecologically resilient taxon with high invasion potential in semi-arid agroecosystems. The capacity to persist and reproduce under suboptimal conditions positions the species as a likely long-term component of disturbed landscapes if control measures are not implemented.



Figure 2. Sampled material of *Xanthium strumarium* L. in the study area: (a) whole plant prepared as a herbarium voucher; (b) collected mature burs in hand, illustrating the barbed diaspores responsible for zoochorous and anthropochorous dispersal

4.4. Agricultural Impacts and Competitive Performance

Within cultivated fields, *X. strumarium* displayed a significant suppressive effect on crop vigour. Visual comparison between heavily infested and relatively weed-free plots indicated:

- increased competition for light, water, and nutrients, as evidenced by shading and canopy overlap;
- stunted growth and reduced apparent vigour of adjacent crops in areas with dense *X. strumarium* stands;
- increased difficulty in field operations (e.g., harvesting, mechanical weeding) due to the structural density of the weed.

These field patterns provide clear indicators of competitive displacement, where *X. strumarium* progressively occupies space and resources at the expense of cultivated plants. Although this study employed a qualitative approach, the observed reduction in crop performance in infested patches suggests tangible risks to yield quantity and quality.

4.5. Impacts on Livestock and Humans

The tough, spiny burs of *X. strumarium* demonstrated a high propensity to adhere to animal coats, wool, and human clothing, confirming effective zoochorous and anthrochorous dispersal. In livestock, burs were frequently recorded attached to the wool and skin of grazing animals, creating potential for:

- mechanical irritation and discomfort, particularly around sensitive body regions;
- wool contamination, reducing its quality and complicating processing.

From a human health perspective, local observations and reports indicated that contact with burs and plant material may cause skin irritation and possible allergic reactions in sensitive individuals. Together, these findings confirm that the species imposes not only ecological and agronomic costs but also animal welfare and occupational health concerns for farmers and rural residents.

4.6. Ecological Displacement of Native Flora

In natural and semi-natural vegetation patches, *X. strumarium* was consistently associated with a decline in the density and diversity of native plant species. Stands with high *X. strumarium* cover were characterized by:

- reduced presence of low-growing native forbs and grasses;
- simplified plant community structure with dominance of a few disturbance-tolerant taxa;
- visible alteration of the floristic balance and community composition.

These patterns align with competitive exclusion mechanisms, where the vigorous growth and dense canopy of *X. strumarium* restrict light availability and occupy physical space, gradually excluding less

competitive native species. The resulting trait-mediated ecosystem disruption—driven by robust growth, persistent burs, and high seed output—indicates that the species acts as a strong ecological filter, restructuring local plant communities in invaded sites.

4.7. Synthesis of Ecological and Socio-Economic Impacts

Taken together, the results demonstrate that *Xanthium strumarium* L. in the Qıvraq area:

- possesses broad ecological amplitude, occurring across multiple habitat types;
- exhibits pronounced phenotypic plasticity and resilience to key abiotic stressors;
- exerts notable competitive pressure on crops, leading to visible reductions in crop vigour;
- creates direct negative interactions with livestock and humans via spiny burs and potential allergic effects;
- drives ecological displacement of native flora and disrupts floristic balance in invaded communities.

These converging lines of evidence position *X. strumarium* as a high-impact invasive weed, with intertwined ecological, agricultural, and socio-economic consequences for the Kangarli District. The findings underscore the urgent need for systematic monitoring, early detection, and integrated management strategies to prevent further spread and mitigate long-term ecological and economic damage.

5. Discussion

The present findings demonstrate that *Xanthium strumarium* L. in the Qıvraq settlement of Kangarli District exhibits a combination of high ecological amplitude, strong phenotypic plasticity, and pronounced competitive ability, all of which are emblematic of its global invasive profile. These results corroborate international patterns of *X. strumarium* invasiveness, where the species has repeatedly been reported as a dominant component of ruderal and agro-ecosystems across Eurasia and beyond (Fan et al., 2019; Chavan & Kulkarni, 2021; Ullah et al., 2022; Waheed et al., 2024). The ability of the species to thrive under variable soil conditions, tolerate drought, frost, and salinity, and maintain reproductive output aligns with earlier reports of its ecological resilience and phenotypic plasticity (Fan et al., 2019; Abdiyeva & Litvinskaya, 2020).

From an ecological perspective, the dominance of *X. strumarium* in field margins, canal banks, and disturbed sites indicates that it possesses adaptive superiority in disturbed agroecosystems. The dense stands observed in cropland and along irrigation channels suggest that the species operates through a combination of resource monopolization and competitive exclusion mechanisms. By rapidly occupying space and intercepting light, while simultaneously exploiting soil moisture and nutrients, *X. strumarium* effectively suppresses the growth of neighbouring crops and native herbs. The resulting trait-mediated ecosystem disruption, characterized by reduced species richness and simplified community structure, mirrors findings from other regions where *X. strumarium* has displaced native flora and altered plant community composition (Ullah et al., 2022; Waheed et al., 2024).

Dispersal ecology further reinforces its invasive capacity. The spiny burs enable diaspore dispersal through zoochory, hydrochory, and anthropochory, attaching to livestock, wildlife, and human clothing, and being transported along irrigation channels and drainage systems (Abdiyeva & Litvinskaya, 2020). This multifaceted dispersal strategy creates a feedback loop between anthropogenic disturbance and invasion intensity: the more the landscape is disturbed, grazed, irrigated, and traversed, the more efficiently *X. strumarium* propagules are redistributed. In agricultural settings, continuous soil disturbance, canal maintenance, and livestock movement inadvertently support the long-term persistence and spread of the species.

The socio-economic implications of these ecological dynamics are substantial. In croplands, *X. strumarium* imposes a significant suppressive effect on crop vigour, complicates field operations, and has the potential to reduce yields and economic returns for farmers. In livestock systems, burs that attach to wool and skin not only cause mechanical irritation but also degrade wool quality and increase labour demands for cleaning. For rural communities, the plant also poses public health and occupational risks, as contact with burs and plant tissues may trigger dermatitis or allergic reactions in susceptible individuals (Abdiyeva & Litvinskaya, 2020). These converging ecological and socio-economic impacts show that *X. strumarium* is not a minor weed but a high-impact invasive species with multi-dimensional consequences for local livelihoods.

In the broader context of environmental change, climate change is likely to amplify the invasion risk. Studies in other subtropical and semi-arid regions have shown that *X. strumarium* can expand its potential distribution under future climate scenarios, exploiting warmer temperatures and altered precipitation regimes (Ullah et al., 2022; Waheed et al., 2024). The demonstrated tolerance of the species in Qıvraq to drought, frost, and moderately saline conditions suggests that it is well positioned to capitalize on projected climatic variability in Nakhchivan. Without proactive management, climate-driven shifts may further strengthen its foothold, enabling colonization of new habitats and intensification of its impact on cropland and natural vegetation.

Despite growing international attention, regional research on *X. strumarium* in Azerbaijan and, specifically, in the Nakhchivan Autonomous Republic remains sparse. Existing studies have largely focused on general distribution, phytochemistry, or pharmacology (e.g., Fan et al., 2019; Sharifi-Rad et al., 2015), whereas detailed, site-specific evaluations of bioecological behaviour and local impact are limited. The present study thus fills a critical knowledge gap by providing a case-based ecological assessment of the species in a semi-arid, agriculturally important landscape. However, it also highlights the need for long-term, quantitative research on population dynamics, seedbank behaviour, competitive interactions with key crops, and cost–benefit analyses of various control strategies.

In summary, the results indicate that *Xanthium strumarium* L. in Qıvraq operates as a robust ecological invader, integrating high stress tolerance, efficient dispersal, and competitive dominance. These findings align with global evidence and underscore the urgency of moving beyond descriptive recognition of the problem toward integrated, evidence-based management and policy responses that can mitigate both ecological degradation and socio-economic losses.

6. Conclusion

This study demonstrates that *Xanthium strumarium* L. has become a widely established and ecologically resilient invasive weed in the Qivraq area of Kangarli District, colonizing both cultivated fields and anthropogenically disturbed habitats. The species exhibits broad ecological amplitude, pronounced phenotypic plasticity, and effective dispersal through animals, water, and human activity. These traits collectively translate into significant ecological, agricultural, and health risks: suppression of crop vigour and potential yield reductions, contamination and irritation in livestock, possible allergic reactions in humans, and measurable displacement of native flora and disruption of local plant community structure.

Given this impact profile, *X. strumarium* should be recognized as a priority invasive species for regional and national biosecurity planning. Management responses cannot rely on isolated or short-term interventions; instead, they must be embedded within Integrated Weed Management (IWM) approaches, combining mechanical removal, targeted herbicide use where appropriate, crop rotation, competitive cropping, and strict hygiene measures to limit seed dispersal. At the policy level, there is a clear need for targeted eradication and containment strategies in high-value agricultural and conservation areas, supported by farmer training, public awareness campaigns, and cross-sectoral coordination.

Equally important is the establishment of long-term ecological monitoring programs to track population dynamics, invasion fronts, and the effectiveness of control measures under changing climatic conditions. Because dispersal pathways and climatic drivers transcend administrative borders, *X. strumarium* management should be included in broader transboundary invasive species surveillance frameworks. Ultimately, proactive and scientifically informed management of *X. strumarium* will be essential not only for safeguarding local agroecosystems and biodiversity in Nakhchivan but also for contributing to Azerbaijan's wider objectives in ecosystem resilience, food security, and sustainable rural development.

References

- Abdiyeva, R. T., & Litvinskaya, S. A. (2020). Phytocenotic, bioecological and invasive activity of the invasive species *Xanthium strumarium* L. in some districts of Azerbaijan. *Plant & Fungal Research*, 3(2), 38–45.
- Chavan, S. T., & Kulkarni, A. U. (2021). Morphological and phytochemical studies on *Xanthium strumarium* L. *Plantae Scientia*, 4(6), 287–290.
- Fan, W., Fan, L., Peng, C., Zhang, Q., Wang, L., Li, L., ... & Wu, C. (2019). Traditional uses, botany, phytochemistry, pharmacology, pharmacokinetics and toxicology of *Xanthium strumarium* L.: A review. *Molecules*, 24(2), 359.
- Sharifi-Rad, J., Hoseini-Alfatemi, S. M., Sharifi-Rad, M., Sharifi-Rad, M., Iriti, M., Sharifi-Rad, M., ... & Raeisi, S. (2015). Phytochemical compositions and biological activities of essential oil from *Xanthium strumarium* L. *Molecules*, 20(4), 7034–7047.

- Ullah, R., Khan, N., Hewitt, N., Ali, K., Jones, D. A., & Khan, M. E. H. (2022). Invasive species as rivals: Invasive potential and distribution pattern of *Xanthium strumarium* L. *Sustainability*, *14*(12), 7141.
- Waheed, M., Haq, S. M., Arshad, F., Vitasović-Kosić, I., Bussmann, R. W., Hashem, A., & Abd-Allah, E. F. (2024). *Xanthium strumarium* L., an invasive species in the subtropics: Prediction of potential distribution areas and climate adaptability in Pakistan. *BMC Ecology and Evolution*, *24*(1), 124.