

CARPOLOGICAL ADAPTATIONS AND HETEROCARPY IN ASTERACEAE SPECIES OF THE ARID KYZYLKUM REGION

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Abstract. This article examines the fruit morphology, pericarp structure, adaptive traits, and dispersal strategies of several Asteraceae species distributed in arid regions, including *Amberboa turanica*, *Epilasia hemilasia*, *Garhadiolus papposum*, and *Heteracia szovitsii*. Special attention is given to heterocarpy and hydrocytic tissues as adaptive traits in desert environments. The results highlight the functional significance of carpological traits in enhancing seed protection, dispersal efficiency, and overall adaptive success in arid and semi-arid habitats. The study underscores the evolutionary and ecological importance of heterocarpy and specialized pericarp structures within desert Asteraceae.

Keywords: asteraceae; fruit anatomy; heterocarpy; pericarp structure; hydrocytic cells; xeromorphic adaptations; dispersal strategies; arid habitats; Kyzylkum Desert; desert flora.

Introduction

The Asteraceae family is one of the most widespread and ecologically dominant groups in Central Asia, particularly in arid environments such as the Kyzylkum Desert. This article investigates the fruit morphology, pericarp anatomy, adaptive structural traits, and dispersal mechanisms of several representative species—*Amberboa turanica*, *Epilasia hemilasia*, *Garhadiolus papposum*, and *Heteracia szovitsii*. Micromorphological analyses revealed a range of xeromorphic adaptations, including sclerenchymatization of the pericarp, development of hydrocytic tissues with spiral-reticulate porosity, variable pubescence, and the presence of elaiosomes. Pronounced heterocarpy was documented in *G. papposum* and *H. szovitsii*, contributing to diversified dispersal strategies and ecological plasticity. Dispersal modes varied among species and included ballisto-anemo-mymecochory, anemochory, and anemo-epizoochory.

Materials and Methods

Fruits of selected Asteraceae species were collected from natural populations in arid and semi-arid habitats of Central Asia. Anatomical sections were prepared using standard paraffin embedding and microtomy. Structural features of the pericarp, spermoderm, embryo, and pappus elements were examined under light microscopy. Morphometric measurements were taken for different achene morphotypes, including marginal and central achenes in heterocarpic species. Comparative analyses were used to identify adaptive traits and dispersal mechanisms. Figures referenced in the text illustrate cross-sections and morphological details of the examined fruits.

Family Asteraceae. This family is the most abundant in terms of species and dominant vegetation in Central Asia, and ranks third in the southwest Kyzylkum (Granitov, 1964). Due to the bioecological and economic significance of the family, research on seed material (fruits) has been ongoing for a long time and reflects various aspects from both systematic and applied perspectives (Razdorskaya, 1944; Aleksandrov, Savchenko, 1949; Muradyan, 1987). A program

for studying the heterocarpic characteristics of certain Asteraceae species has been developed, which is considered one of the adaptive properties of the taxon, ensuring widespread distribution.

The fruits of Asteraceae have been of interest to carpologists, particularly in terms of their development and phylogeny (Alyavdina, 1931; Maximova, 1977; Khandzhan, 1977; 1990; Muradyan, 1970; 1987); heterocarpic traits and evolutionary analysis (Voitenko, 1986; 1988; Nikolaeva, 1998). In ecological terms, there is limited research on Asteraceae fruits. V.G. Aleksandrov and M.I. Savchenko (1949) noted mixospermy and the spiral-reticulate hydrocytic apparatus of the pericarp in the seeds of *Matricaria* and *Pyrethrum*, traits typical for arid habitats. A.A. Korobkov (1973) confirmed the adaptive significance of these traits in the seeds of species of *Artemisia*. Adaptive fruit traits in ephemerals of Kyzylkum were noted by U.N. Zhapakova and G.F. Begbaeva (1995; 1996).

***Amberboa turanica*.** The fruit is an achene, elongated without a beak, covered with short, upwardly pressed hairs and a multi-rowed pappus (Fig. 6a). The fine-toothed bristles of the pappus are of unequal length, elongating towards the inner circle, and overlap like shingles. The achenes of *A. turanica* have a structural formation in the root area—an elaiosome in the form of a rounded-triangular pad containing oily substances. The main tissue of the pericarp consists of extremely small rounded cells with thickened walls, with 5 cells at the ribs and 2 cells at the intercostal areas.

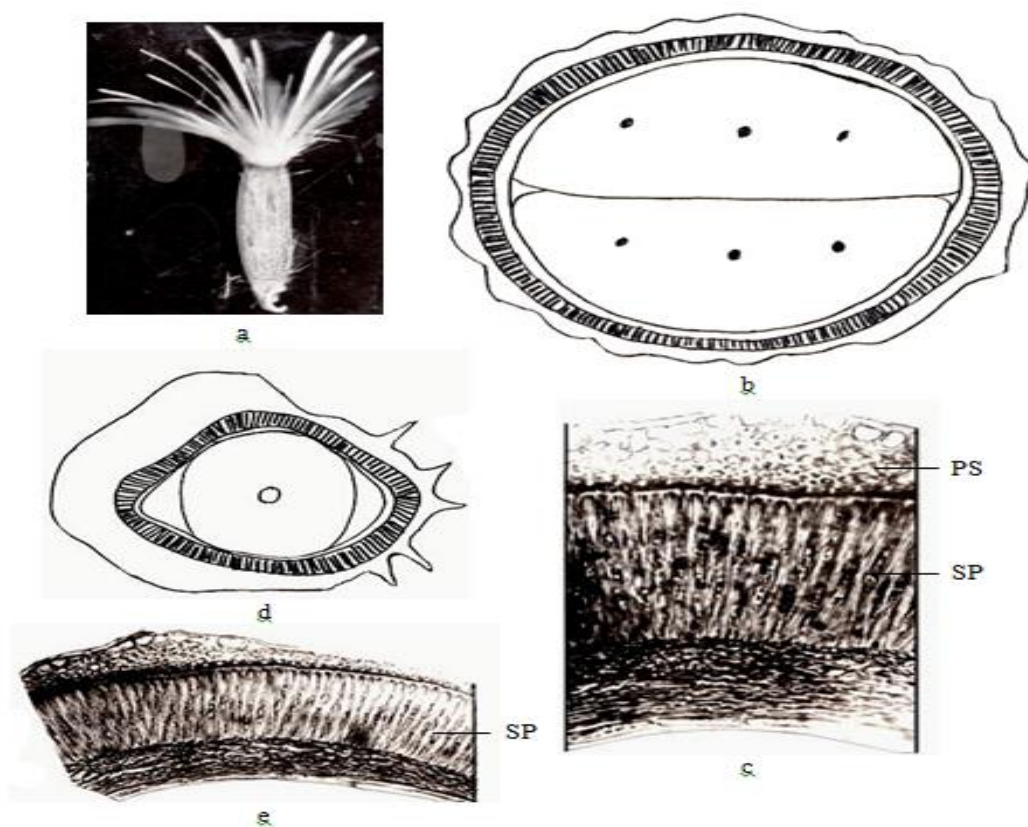


Fig. 6. Structure of the fruit of *Amberboa turanica*:

- a – external appearance of the achene;
- b – diagram of the middle part;
- c – cross-section;
- d – diagram of the lower part;
- e – cross-section.

Mainly, the function of protecting the embryo is carried out by the spermoderm, which is twice as thick as the pericarp. The spermoderm consists of two distinct zones: I – a 3-layered sclerenchyma, and II – a 5-7 layer parenchyma (Figures 6 b-d). The sclerenchyma cells are spindle-shaped, radially elongated with heavily thickened walls, so that the cell cavities occupy about one-fifth of the cross-section. The dense parenchyma layer consists of hard-to-identify rows of cells with thickened tangential walls and narrow cavities. The round-triangular ring partially surrounding the root of the embryo is made up of small rounded parenchyma cells with thickened walls, among which there are hydrocytic cells with spiral-reticulate porosity.

The embryo is straight, differentiated into large, semi-valvular cotyledons and an axial part. The cotyledons have dorsiventral mesophyll. Adaptive traits of the seed: sparse pubescence, thin parenchymatous pericarp, with the protective function of the embryo performed by a sclerified spermoderm, and rare hydrocytic cells in the root area. A combination of three methods of dissemination is observed: ballisto-anemo-myrmechory, as during seed collection, attention was drawn to the scattering of freshly fallen diaspores by ants.

***Epilasia hemilasia*.** The fruit is a seed, ribbed, strongly pubescent, cylindrical without a beak, with a stiff pappus made of 5 needle-like bristles and a callous ring consisting of tightly twisted hair bases. The pubescence of the fruit is uneven: from the base to the callous ring, there are small slightly bent spines on the ribs; on the callous ring – stiff bristles; and from the ring to the top – long soft grayish-silvery tangled hairs, almost covering the pappus. The structure of the pericarp is heterogeneous. In the root part, there is a highly cutinized epidermis with papillary outgrowths, hydrocytic parenchyma cells, and woody parenchyma cells in the center of the large ribs. In the middle part, the entire pericarp consists only of sclerenchyma, the cells of which are isodiametric with heavily thickened woody walls (Figures 7 a-g). Adaptive traits of the seed: dense pubescence, sclerified dense pigmented pericarp, groups of hydrocytic cells in the root area. The dispersal method is anemochory (a type of aerohory), where all seeds are easily and simultaneously released from the head and the floating diaspores are carried away by wind gusts.

***Gpapposum*.** The fruit is a seed within a head inflorescence. In the head, two extreme morphotypes of seeds and transitional (closer to the inner) ones are distinguished, meaning heterocarpy. The internal seeds are crescent-shaped, smoothly transitioning into a beak, weakly grooved, sparsely pubescent with small, worn hairs, and have a star-shaped structure.

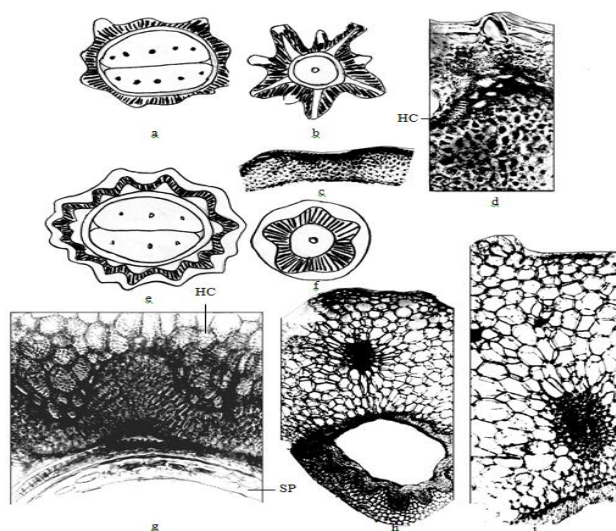


Figure 7. Structure of the fruit in cross-section.

Epilasia hemilasia:

a, b – diagrams of the middle and lower parts;

c, d – fragments of the pericarp. *Garhadiolus papposum*:

e, f – diagrams of the middle and lower parts;

g-i – fragments of the pericarp and seed coat.

The outer achenes, almost fused to the bracts of the involucre on the adaxial side, are crescent-shaped, flattened-conical with a short beak. In the pericarp of the achene, two distinct layers are visible: I – consists of 2-5 rows of hydrocytic cells with spiral-reticulate porosity; II – a continuous sclerenchymal layer with wavy edges: in the narrow part with 4-5 rows of cells, in the wide part with 10-11. The spermoderm is simplified, few-layered, and thin. Hydrocytic cells are distributed across the entire surface and represent a highly developed system (Fig. 7 e-f). Adaptive characteristics of the achene: epidermal outgrowths – spines, heterocary, and sclerenchymatized pericarp with a highly developed hydrocytic system throughout the achene. Fusion of the bracts with the outer achenes provides additional protection for the embryo, along with dense pubescence, thick-walled exocarp, strong sclerenchymatization of the pericarp, and pigmentation of the spermoderm. The mode of dissemination is anemo-epizoochorous: outgrowths and spines of the achenes easily attach to animal fur.

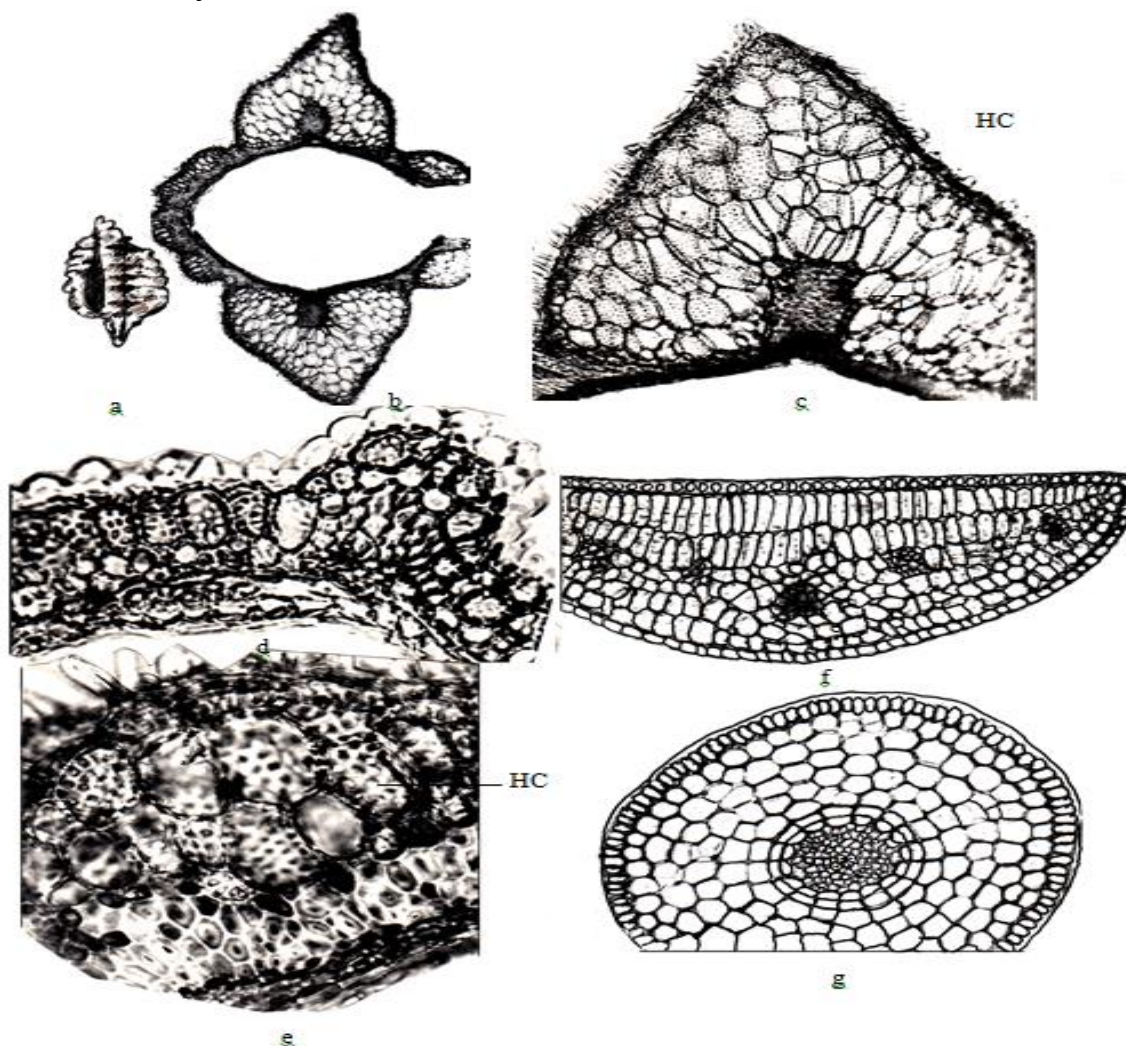


Fig. 8. Structure of the marginal achene of *Heteracia szovitsii* in cross-section:

a – external view of the marginal achene;

b – pericarp;

- c – detail of the outgrowth;
- d, e – details of the pericarp;
- f – cotyledon;
- g – axial part of the embryo.

Heteracia szovitsii: The fruit is an achene, one-chambered with a pappus. The achenes are heteromorphic. Despite a common structural basis, the micromorphological diversity of the marginal and central achenes is so great that they could be mistaken for different species. The radial symmetry of the central achenes defines a uniform structure around the perimeter, while the bilateral symmetry of the marginal achenes is heterogeneous. The length of the marginal achenes is 2.9 mm, width 1.2-1.9 mm, beak length 1.0-1.5 mm; for the central achenes: length 2.9 mm, width 0.3-0.7 mm, pappus length 3.2 mm, beak length 7.7 mm. The robust development of hydrocytic tissue with reticulate porosity in the lateral outgrowths of the marginal achenes gives this morphotype a two-winged appearance (Fig. 8 a-f). The pericarp of the marginal achenes is more robust than that of the central ones. The outer epidermis of the central achenes is covered with a thick membranous cuticular layer, unlike the marginal ones. Differences in the mesocarp and endocarp between the two achene morphotypes manifest in the arrangement and degree of development of the epimesocarp parenchyma, mechanical tissues, and conducting bundles. Heterocary in species of the Asteraceae family is found in various climatic conditions (Voytenko, 1988; 1989). However, in arid habitats, the adaptive role of heterocary is most fully realized. In the fruit, the sclerenchymatization of the mesocarp is most pronounced, characteristic of many other Asteraceae species (Muradyan, 1987), making this trait universal.

Discussion

Across the examined species, a consistent pattern of adaptive strategies is evident. Structural modifications of the pericarp and spermoderm—including sclerenchymatization, pigmentation, and cutinization—enhance desiccation resistance and mechanical protection, vital for survival in arid ecosystems. The presence of hydrocytic cells with spiral-reticulate porosity suggests an important role in water regulation and potentially in hygroscopic movements that aid dispersal. Heterocary, observed in *Garhadiolus papposum* and *Heteracia szovitsii*, contributes to differential dispersal and germination strategies, increasing ecological plasticity. Dense or specialized pubescence, elaiosomes, and fusion with involucre bracts further reflect adaptive diversification. Dispersal mechanisms vary widely—from ballistochory and myrmecochory to anemochory and epizoochory—demonstrating complex ecological relationships between Asteraceae species and their abiotic and biotic environments. These findings confirm that fruit anatomy and heterocary in Asteraceae play crucial adaptive roles in arid landscapes, enhancing species resilience, distribution, and ecological success.

Conclusion

The studied Asteraceae species demonstrate a wide array of fruit structural adaptations, including variation in pericarp anatomy, development of hydrocytic tissue, heterocary, and modified dispersal apparatuses. These features collectively contribute to survival under arid conditions and support efficient seed protection and dispersal. The results reinforce the ecological and evolutionary significance of carpological traits in desert plant species and highlight heterocary as a key adaptive mechanism within the Asteraceae family.

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