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The influence of environmental factors on the structure and formation of inflorescences of the representatives of the genera Matthiola W.T. Aiton, Hesperis L., Lunaria L. and Lobularia Desv. of the Brassicaceae Burnett family under conditions of natural and artificial biocenoses

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In a certain period of his life the plant forms reproductive organs, or organs of sexual reproduction. In angiosperms Magnoliophyta-these are flowers, from which later fruit and seeds are formed. In most cases, flowers arise at the ends of the shoots, forming various groups called inflorescences. The term "inflorescence" was first introduced in the literature in the writings of Carl Linnaeus and was considered as the arrangement of flowers-a way of attaching flowers to the flower buds of the plant. Scientists have identified the following types of inflorescences: a shield, a tassel, an ear, a trunk, and others. The concept of cyme and raceme inflorescence was described by Parkin. According to J. Bentham and J. Hooker, inflorescences can be represented as "a set of flowering branches and flowers on them", also used the term "flowering branch" as an independent. Many types of inflorescences are not categorical or can combine more than one type. Wilhelm Troll has developed an exact typological structure for describing homology among a wide range of inflorescences, which was expanded and translated into English by Weberling. At the end of the XX-beginning of the XXI century, the interest of the botanists to the study of inflorescences increased significantly. Inflorescences of the family Brassicaceae Burnett are very diverse. Among them there are species with single flowers, small-flowered (with two, three flowers) and multi-flowered inflorescences. Despite the interest of tax collectors and morphologists in the family, the works devoted to the study of morphology and anatomy of inflorescences of Brassicaceae are few. Many existing systems of description and classification of inflorescences, different interpretations of certain terms and concepts, in particular, different interpretation of cyme and raceme inflorescences, led to the need to study the floral structure of the system of shoots among representatives of the family Brassicaceae. It should be noted that many species of this family have a great economic value, as food (Brassica oleracea (L.), Raphanus sativus var. radicula (Pers).) oil plants (*Brassica nigra* (L.) Koch., *Eruca sativa* Lam., *Brassica napus* L.), honey plants (*Cardaria draba* (L.) Desv., *Camelina sativa* (Cr.)), technical (*Isatis tinctoria* (L.)), forage plants (*Brassica rapa* subsp. rapifera (Metzger)), spice-flavored plants (Sinapis (L.), *Armoracia rusticana* (G. Gaertn.), B.Mey. & Scherb., Eutrema japonicum (Miq.) Koidz.) and others. Certain species are used in decorative flower gardening and landscape design (*Matthiola longipetala* (Vent.) DC., *Lobularia maritima* (L.), *Lunaria annua* (L.), *Hesperis sibirica* (L.)).
Keywords: Inflorescence; flower; bract; bracteole; meristem

Introduction

The first notions of inflorescence are first encountered in the works of ancient Greek scholars in the writings of Pliny, Dioscoride and Theophrastus, which were descriptive. In his work, The Plant Study, Teofrast describes the role of inflorescence in dusting of fig trees (Theophrastus, 1951).

The most important contribution to the development of the perception of inflorescence in the historical aspect was made by Carl Linnaeus and set out in his work Philosophia botanica, 1751. The terms concerning the structure of inflorescences such as an arrow (scapus), pedunculus (pedunculus), a pedicel (pedicellus) (Linnaeus, 1989).

By the way of attaching and linking the flowers at the top of Linnaeus and his followers, they feature single-flowered, two-flowered and multi-flowered inflorescences. They also introduced into the botanist the following types of inflorescences: a beam, a head, an ear, a shield, a scattered and compressed void, a pyramid, a tassel, a shaft, an umbrella (a simple, complex, half-dressing), the beginning. For each type of inflorescence the author selects examples from plants known to him. At this stage, Carl Linnaeus introduces the notion of flower arrangement as a way of attaching flowers to a flower peduncle or, as the predecessors of a scientist called, a method of flowering (Linnaeus, 1989; Parkin, 1914; Harder et al., 2013).

The German Botanical School originated in the 19th century. Its founder was a poet, philosopher and naturalist IV Goethe (1749-1832). He perceived nature as something integral, living and continuously changing, and created the doctrine of metamorphosis of plants. They represented them as a change in the form of organs of plants (leaves) in the processes of their growth from cotyledons and ordinary green to small scales in inflorescences and petals in the flowers. These Goethe's representations depicted in the form of drawings Uhrpflanz ("plant"), and this was the first graphic representation of the plan of the plant's structure. Goethe is rightly considered the founder of theoretical morphology of plants. Also later, Johann Wolfgang Goethe in his book "Plant Metamorphosis" presents morphological descriptions of inflorescences for some plant families, including the Brassicaceae family (Goethe, 1957).

Later, the term "inflorescence" can be found in numerous works (Goebel, 1957; Troll, 1969; Imes, 1964; Stebbins, 1973; Weberling, 1989; Shroeder, 1987; Fedorova 2006; Ilyinskya, 2015). Each of the authors understands it ambiguously, adding to this definition new characteristics. For example, (Imes, 1964), in the monograph "Morphology of Flowering Plants", the inflorescences are considered, as collected in groups of flowers, together with the axes bearing them, and defects (until the 50's of the last century, inflorescences were separated from the vegetative part of the plant precisely signs of the presence of leaves), that is, under the inflorescence, he understood part of the plant without green photosynthesizing leaves. Isolated flowers which called by Imes single flowers. «Often, we can not precisely define the concept of «inflorescence», because the specialized inflorescences of different types of the bottom gradually pass into flowers-single or collected in small groups (in the axes of the green leaf), for example, in Lysimachia and Campanula».

G. L. Stebbins under the inflorescence understood «specialized fertile part of a plant, which after flowering does not take part in vegetative growth and either disappears or fades». In this case, inflorescence is seen as a one-season structure, dying entirely after flowering and fruiting, which remains out of participation in the formation of a perennial axial skeleton of a plant (Stebbins, 1973).

F. G. Shroeder defines inflorescence as a part of a plant, which, at the time of flowering, exhausts all its apical and axillary meristems and, after ripening of the fruits, dies (Shroeder, 1987). However, there may be «reserve» axillary buds in the proximal parts of the shoots of enrichment, as well as the occurrence of axillary stem cells on the growths of the previous year or earlier years (intercalary inflorescences), that is, after flowering and blooming, the main axis continues to grow (Lysimachia nummidaria, Veronica chamaedus, Hoya australian, Dischidia merrillii) (Goebel, 1931; Goebel, 1933). Various researchers have attempted to formalize the description of inflorescences, to make them more accurate, by introducing numerical indices or converting into a compact formula, but none of them played a significant role in the development of morphology inflorescences, perhaps because formalization was carried out superficially, without taking into account the patterns of inflorescence structure, and in the formula on an equal footing included both existing and secondary features.

In the middle of the XX century, N. Rickett, in a review of the history of the study of inflorescences comes to a similar conclusion and says that the terminology applied to inflorescence was confused from the very beginning (Ricket, 2011).

To provide a complete, exhaustive definition of inflorescence, with which it would be possible to describe and clearly distinguish between all groups of flowers to which this term is used. Along with the concept of «inflorescences» in modern morphological literature is widely used the term «synflorrescence». The term «synflorrescence» introduced K. Goebel in «Organographie» (1928-1933) and applied it as a visual concept (Goebel, 1957).

L. Nukhimovsky considered «inflorescence» as a part of a plant with one phase of growth, which arose as a result of a visible growth quantum-that is the result of sillipsis. However, the characteristic of inflorescence, as an organ with one phase of growth, can be attributed not only to inflorescence, but also to the flower, as well as to some vegetative organs, such as leaf (Nukhimovsky, 2002).

T. V. Kuznetsova called inflorescence «a specialized system of sileeptic shoots whose stems are flowered, more or less modified leaves (defects) and completely die after flowering and fruiting. The border between inflorescence and the vegetative part is usually determined by differences in the presence of leaves on the stalk; in some cases all distinctions are clearly expressed, others are vague» (Kuznetsova, 1991).

Materials and methods

Morphological and anatomical analysis of inflorescences of family plants Brassicaceae among the representatives of the genera Matthiola, Hesperis, Lunaria and Lobularia conducted through the study of morphogenesis, in stages, taking into account the phases of development of shoots, morphological and anatomical features of inflorescences of the following species: *Matthiola longipetala* (Vent.) DC., *Lobularia maritima* (L.), *Lunaria annua* (L.), *Hesperis sibirica* (L.).

To compare the obtained results, the morphological features of the inflorescence structure in the representatives of families of the order were analyzed Brassicales: Caparaceae, Cleomaceae i Resedaceae. As objects have been selected *Capparis herbacea* (L.), *Cleome spinosa* (Jacq.), *Reseda lutea* (L.).

Determination of the limits of the floral unit on the shoots during the research was carried out on the basis of generalization of works (Gaussen, 1952; Maresquelle, 1970; Kuznetsova, 1985). In determining the limits of the floral unit, a complex of morphological and physiological characteristics is taken into account, namely: the order of flowering of buds on the flowering shoots, the length of interstices, the size of leaves on the shoots and in the shoots of inflorescence, and others like that.

The plants of *M. longipetala* and *L. maritima* were grown and investigated in laboratory conditions (according to the technique developed directly for the given objects (Kharchenko et al., 2010) and on the experimental site. Ontogenetic changes were recorded from the moment the emergence of germs and period of the entire life cycle. *L. annua* (L.), *H. sibirica* (L.), *R. lutea* (L.), *C. spinosa* (Jacq.), *C. spinosa* (L.) plants were grown exclusively on the experimental site under open ground conditions.

In order to study the features of the anatomical structure of inflorescences and leaves in the inflorescence and beyond, the method of making permanent micropreparations of plants has been improved. Experimental way has been adapted already known methods to the research needs. The found method allows you to shorten the work time of some operations to 10-15 minutes instead of several hours. The method gives the opportunity to use less reagents for small objects (5-10 ml), which is more rational, instead of the previously proposed.

Results and discussion

The study of the inflorescence morphogenesis of *Matthiola longipetala* (Vent.) DC found that the sprouts appear 6-8 days after sowing them into a Petri dish. At the stage of the cotyledon leaves, the apex shoots are presented by the apical meristem, which forms the leaf tubers. The transition to the phase of the formation of a pair of these leaves occurs 10-12 days.

The results of anatomical studies have shown that the laying of meristem inflorescences in plants *M. longipetala* occurs in the phase of formation of 5-7 true leaves. It has the form of a cone consisting of hills, which later form part of the inflorescence.

At stage 8-10 of these leaves, at the top of the main shoug, flower buds are formed, which then become morphologically noticeable in the phase of 12-13 leaves. The formed inflorescence, in this case, represents a cluster of flower buds that are spirally arranged, with the angle of divergence between the buds being 60°.

The flowering on the axis of inflorescence occurs from the bottom up (acropentally). In the inflorescence can be formed from 3 to 10 flowers, which are located on truncated pedicels, in basis of which there are pair leaf like structures, differing in their anatomical and morphological characteristics from the stem leaves-bracteoles.

By histological preparations, which were obtained at different phases of inflorescence development, it was established that the next flower tubercle is laid in the basis of the flower buds of the bud, which is developed in the inflorescence to the smallest extent. In the process of its further growth and development there is a shift of previously formed flowers in the lateral position.

Morphologically, inflorescence is differentiated after the formation of a plant of 9-11 leaves, when at the top of the shoian becomes noticeable bud, which occupies the apex position. In the future, the second and third flowers develop on its basis, which differ from one size (Figure 1).

Figure 1. Formation and development of the main peduncle *M. longipetala*: 1-4-flower buds in the order of their formation, 5-bracteoles.

In the process of development of inflorescence there is not only an increase in the number of flowers in the inflorescence, but also the rapid extension of the axis of the inflorescence, which is due to proliferation and an increase in cells of sub-epithelial

tissues, or «meristem of primary growth», which in turn is a derivative of apical meristem (Kine et al., 1991; Kwiatkowska, 2006). In this case, previously formed flowers are found in the basis of inflorescence, and the youngest-near the apex.
At the apex of the peduncle there is a meristem, from which inflorescence develops. In the transition of the plant to the reproductive stage of development apical meristems go to limited growth, since the formation of the flower is usually the final stage of development of the apex. In Figure 2, serial representation of the transformation of the apical meristem in the formation of inflorescence.

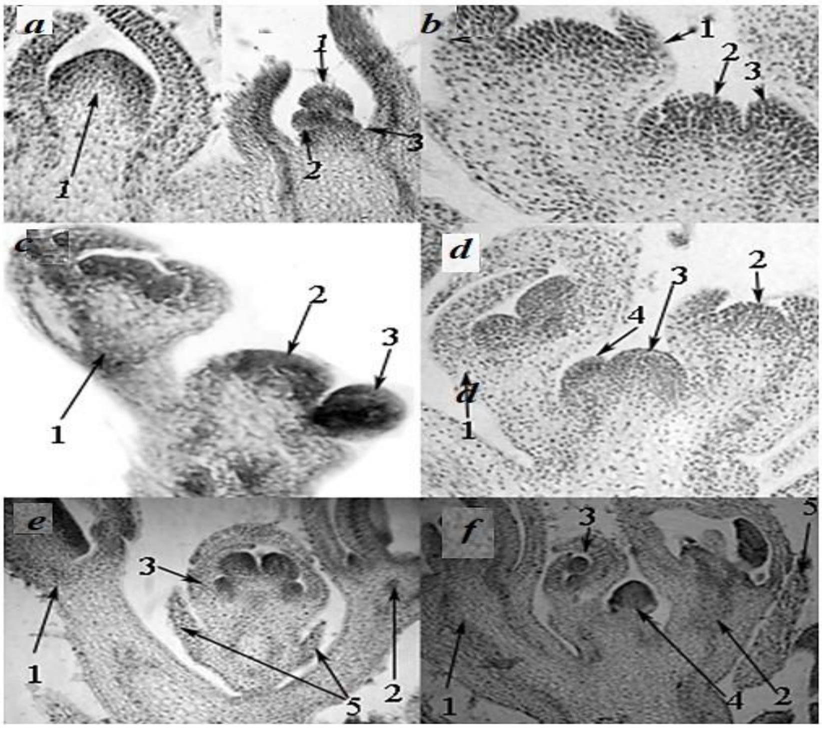

Figure 2. Early stages of development of inflorescence in plants *M. longipetala* (longitudinal cuts): 1-4-flower buds at the apex of inflorescence in the order of their formation, 5-bracteoles.

During the study of inflorescence of morphogenesis on plants of *M. longipetala* leaf-like structures were found near the basis of leaves, chamomile and stamens, which are small in size and are arranged in pairs and oppositely.
At the base of the leaf, oppositely, there are two leaves, a length of 0.5-2.0 mm, of lanceolate form, which are homologous to the assimilation leaves by organs, which can be described as strapping.
At the base of the flower *M. longipetala*, under the abacus pair of chalks, there are two opposite blades. At the same time, the saucers are directly above (Figure 3).

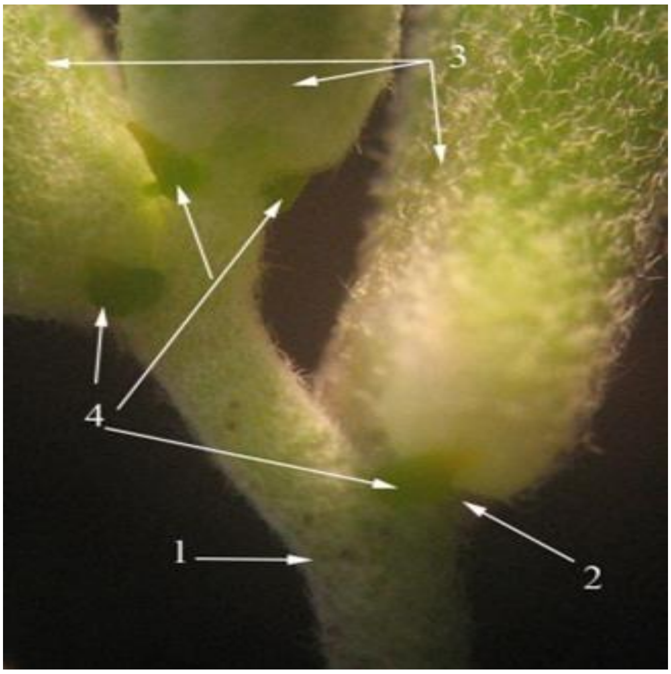

Figure 3. Location of cats on the plant *Matthiola longipetala*: 1-a fir, 2-a reduced peduncle, 3-the basis of the flower, 4-perianth.

The leaves at the base of the *M. longipetala* flowers are located on the shoots and the structure similar to the stalks of this plant. They are arranged oppositely (the angle of divergence is 180°), as well as the sticking at the base of the leaf blade, in contrast to the stem leaves, in which the angle of divergence corresponds to 120° (+15) (Table 1).

Table 1. Linear sizes of carnations and shades in *M. longipetala*.

Parameters	Mean	Value Limits	Variability, mm	Difference, %	Student's t-criterion
The length of the flowers	0.47	0.3-0.6	-0.01	2.1	0.014
Length of shadows	0.48	0.3-0.7			
Width of flowers	0.3	0.2-0.4	0.1	33.3	10.34*
The width of the shadows	0.2	0.1-0.3			

Note: *-Probably the first value limit (p>0.9).

The leaf formations at the base of the *M. longipetala* pedunculus and the have a similar shape and size (Figure 4).

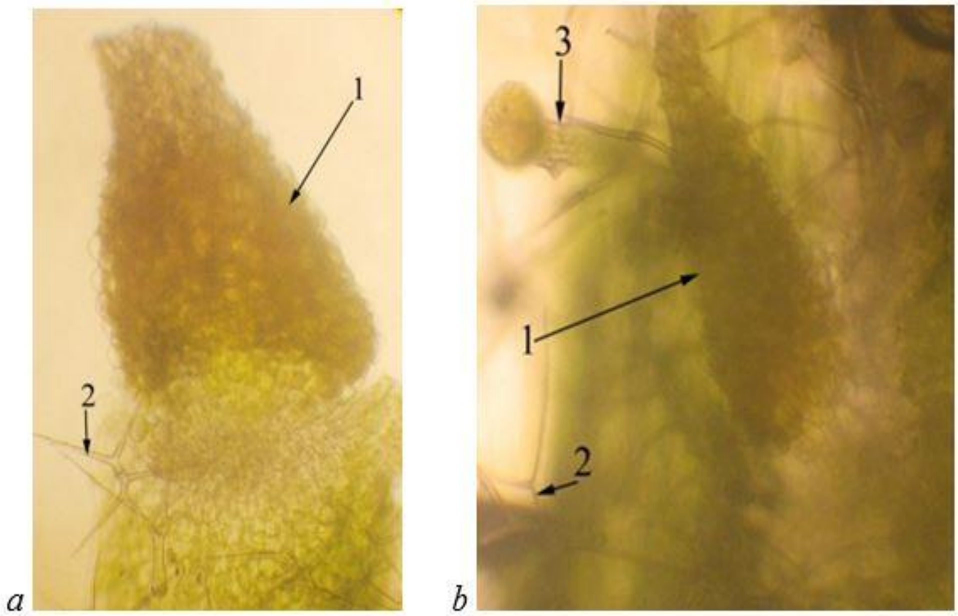

Figure 4. Morphological peculiarities of moles and carnations *M. longipetala*: a-swindler: 1-swift, 2-stellate shrimp trichoma, 3-glandular trichoma; b-bracteole: 1-bracteole, 2-stellate shrimp trichoma, 3-glandular trichoma.

The study of longitudinal sections of micropreparations of stem leaves, shakes and flowers showed the difference in the anatomical structure of these plant structures (Figure 5).

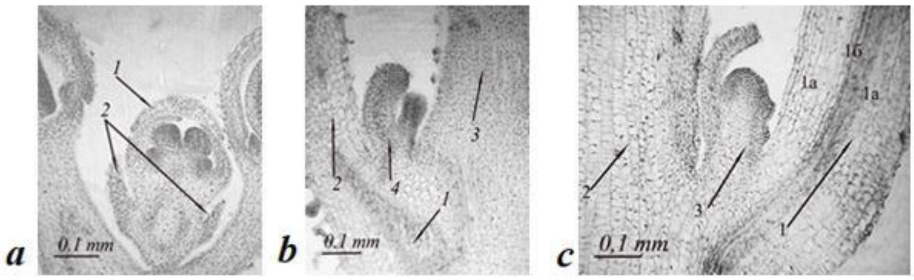

Figure 5. Anatomical structure of leafy forms *M. longipetala*: a-apex of inflorescence: 1-flower, 2-bud at the top of the shoots, 3-bracteoles; b-the sinus of the stem leaf: 1-stinging, 2-leaf, 3-stem, 4-rudimentary spit; c-the sinuses of the stem leaf: 1-leaf, 1a-mesophilus, 1b-conductive beam, 2-stem, 3-rudimentary spit.

In the leaf formations, which are located near the flower bed, and the true leaves, the cells are undifferentiated (Figures 5a & 5b), and on the anatomical section of the stem leaf, it is possible to distinguish the cells of the mesophilus and a bundle of conducting tissues (Figure 5).

Determination of the morphological affinity of inflorescences of inflorescences from representatives of the family Brassicaceae, has a significant interest in works in the field of botany, plant physiology and structural genetics.

According to Dorofeev's research in the field of Brassicaceae, the family consists of two supraclaves, eleven tribes and twenty one support. For the first time leaf-like formation in the inflorescence of the representatives of this family was identified on the plant *M. longipetala*, belonging to the tribe Hesperideae Prantl. *Hesperis sibirica* L. (Evening Night Violet) belongs to this tribe-a decorative plant is widely distributed in the south-east of Ukraine.

In the plants of *H. sibirica*, the lesions are glandular at the base of the leaves, and after the transition to flowering at the base of the pedicle, morphologically similar to them with apple trees are formed (Figure 6).

The leaves near the basis of the flowers of *H. sibirica* by arrangement on the shoots and in structure are similar to those of the plant, as well as with leafy formations in *M. longipetala*.

Figure 6. Succulents in the inflorescence of *H. sibirica* L: a-inflorescence *H. sibirica*, b-longitudinal section through the apex of inflorescence *H. sibirica* L.: 1-leaves, 2-meristematic cells, 3-stem, 4-flower, 5-bracteoles.

The anatomical and morphological characteristics of the flower buddies in the inflorescence *Lunaria annua* L. are similar to those described above by *M. longipetala*. (Figure 7).

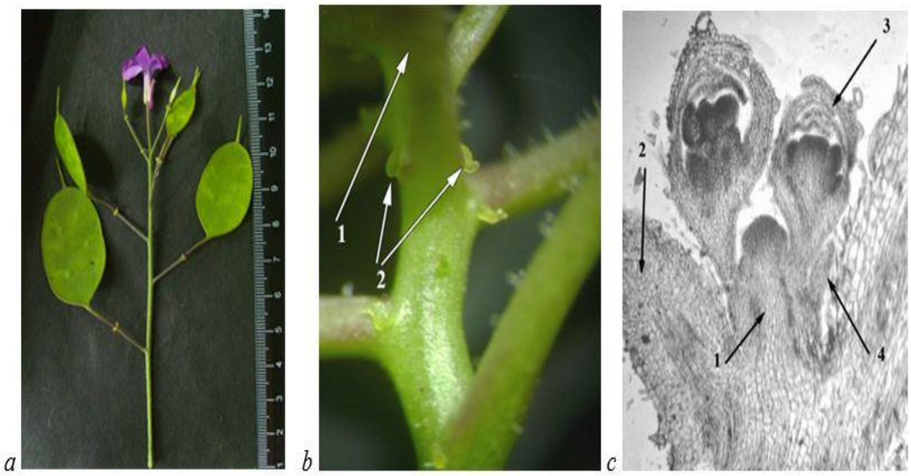

Figure 7. Succulents in the inflorescence *L. annua* L: a-the main peduncle, b-bracteoles in the inflorescence: 1-peduncle, 2-bracteoles, c-anatomical structure of the apex of the inflorescence (longitudinal section): 1-inflorescence axis, 2-stem leaf, 3-flower, 4-bracteoles.

The family Brassicaceae also belongs to the plant *Lobularia maritima* (L.). This is a one-year old, forming thick-leafed, compact or scattered bushes up to 30 cm in height. Leaves are small, linear-lanceolate, grayish-green, pubescent with white hairs. Flowers are small, regular, white or light violet with a strong honey aroma, collected in carnation inflorescences (Fedorova, 2006).

Placing on shoots *L. maritima* is another (the angle of the divergence between the leaves corresponds to 120° (+15). The leaves in the inflorescences and beyond are morphologically similar: sessile, whole, lanceolate (Figure 8). The linear dimensions of the leaves are reduced on the shoots in the ascending direction.

Anatomical structure of stem leaves and leaves in the inflorescence is similar (Figures 8a-8g). The epidermis has numerical germs in the form of single-celled and multicellular linear hairs-trichomes. Much of the basic tissue of the sheet plate falls on the mesophyll with a large number of chloroplasts in the cells.

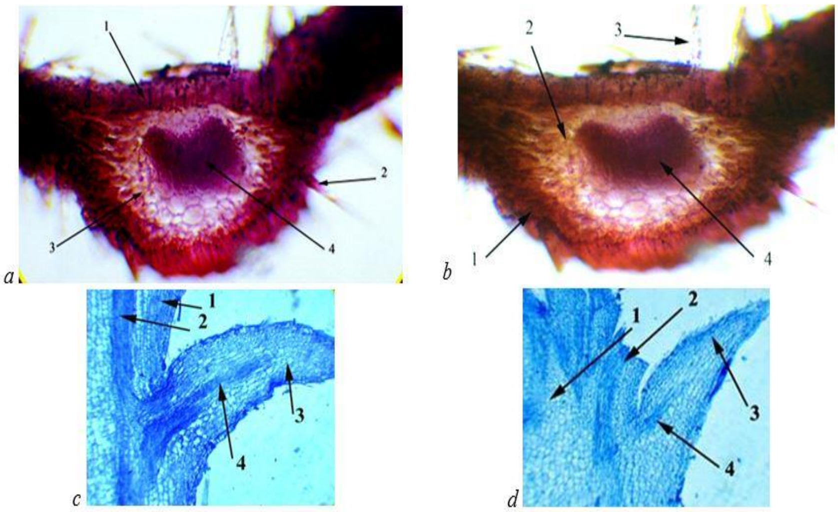

Figure 8. The structure of stem leaves and flowers in *L. maritima* (L.) Desv: a-transverse cut through the base of the stem leaf: 1-epidermis, 2-knee joint, 3-trichomes, 4-conductive bundle; b-cross-section through the base of the bladder: 1-epidermis, 2-trichomes, 3-knee-hima, 4-conductive bundle; c-longitudinal section of the stem leaf: 1-stem, 2-conductive bundle of stem, 3-leaf, 4-conductive bundle of leaf; d-longitudinal section of the flower: 1-stem, 2-conductive bundle of stem, 3-prickles, 4-conductive bundle of leaf.

Mesophil leaf is represented by a palisade and spongy parenchyma. Spongiform parenchyma consists of cells of various forms, often irregular. On a transverse section a leaf in the region of the middle vein can differentiate the vascular-fibrous beam. The conductive beam belongs to the type of collateral, around which is the lining consisting of cells of mechanical tissue-kolenchyma.
In plants *L. maritima* on the apex of the main and lateral shoots develop partly carnation inflorescences Inflorescence development is limited by the environment. Most often, in the southeast of Ukraine, the length of inflorescence is 35.6 (± 40.4 cm), in its composition there are 30.3 (± 79.7) flowers.
In the course of morphogenesis, as the flowers form at the top of the shoots, the length of the interstices increases, and the inflorescence of the shield is transformed into inflorescence of the tufts.
Anatomical studies of the apex of the inflorescence, located on the main pedicle, showed that the apical meristem for a long period is active and after the laying of a series of leaf primordials, forms flower rudiments, concentrated at the top of the shoots.
With prolonged exposure to high temperatures, the blossoms temporarily stops, and then, under favorable conditions, it is renewed. The final stroke of inflorescence is due to the extinction of metabolic processes, which manifests itself in the drying of the tops.
In the inflorescence of *L. maritima* plants, some of the flowers are prickly, morphologically similar to the stem leaves of this plant. Inflorescence in plants *L. maritima* develops on the main shoal from the sinus of the upper stalk leaf. In the inflorescence *L. maritima*, part of the flowers (up to 17.2% of the total number of flowers in the inflorescences) is formed in the axils of the leaves, other flowers are formed without leaves.
Among the diagnostic features of the Brassicaceae family in many plant determinants, the flora descriptions are the absence of inflorescences and inflorescences in the inflorescence of the representatives of this taxon (Artyushenko et al., 1979; Takhtadzhyan, 1980; Takhtadzhyan, 1982; Dorofeev, 2002).
According to the research, it was found that the leaves at the base of the pedicel *M. longipetala*, *H. sibirica*, *L. annua* are morphologically and anatomically styled and differ from the stem leaves. Blinds and shoots have similar structure and location on the shoots, but differ from the assimilation leaves, hence the prickles are homologous to the shakes and are not homologous to the assimilation leaves. Therefore, leafy formations at the base of the peduncle *M. longipetala*, *H. sibirica*, *L. annua* are prickles that are homologous to shadows, and can be called prickles (Ricket, 2011; Shirley et al., 1999).
The leaves on the shoots *L. maritima*, in the inflorescence and beyond, have similar morphological features and decrease in size ascending, during the transition to flowering the reduction processes are intensified. In this regard, the *L. maritima* breeders have a similar morphological characteristic in structure and position with stem leaves of this plant.
Thus, leaves on *L. maritima* shoots, in the composition of the flora units and beyond, have similar morphological and anatomical structure. Leaves in the inflorescence *L. maritima* are prickles (Remane, 1951; Harder et al., 2013).
The origin of carnations and shading, in the composition of the inflorescences of the representatives of the order of Brassicales, may be due to the fact that the phylogenetically close families of it: Brassicaceae, Caparaceae, Cleomaceae and Resedaceae in plants have prickles and stingrays that are not representative of the whole for representatives Brassicaceae family.The leaves of the plants Capparis herbacea (Caparaceae) and Cleome spinosa (Cleomaceae) have thorn-shaped obstructions, and Reseda lutea (Resedaceae) leaves are scaly patches. After the transition to flowering, identical morphological signs have prickles (Takhtadzhyan, 1966; German et al., 2011).

The phylogenetic proximity between the families of Brassicales is proved by molecular genetic analysis (Ali et al., 2016; Al-Shehbaz et al., 2006; Bailey et al., 2006; Munch et al., 2017; Ziffer-Berger et al., 2015; Perfect et al., 2017), and through the modular analysis of inflorescences.

According to the latter, in Cleome spinosa L. floral units are formed at the top of the shoots and consist of a multitude of flowers, formed in the axils of the flowers with bristles. The adolescents and whiskers of this representative are morphologically similar. According to a modular analysis near *C. spinoza* Jacq. the floral units are formed at the tops of the shoots, the flowers are formed in the axils of the flowers with the bracteoles and collected in the kite (Kuznetsova et al., 1991).

According to the modular analysis, in *Reseda lutea* L. inflorescences are at the top of the shoots, consist of a multitude of flowers collected in a bunch, whose flowers are formed in the axils of the carnations with the bristles (Kharchenko et al., 2012).

Thus, on the basis of the structure and location of the carnations in the plants of the Brassicaceae family, it has been established that they can be homologous to both the shading of these plants and the stem leaves (German, D. et al., 2011; Bull-Heren et al. 2013; Claben-Bockhoff et al., 2013; Reinheimer et al., 2013; Perfect et al., 2017).

Conclusion

The general conclusions of this research paper rest on the fact that treatment of oilseed poppy plants during the budding period with a mixture (1:1) of retardanthlormequat chloride and a growth stimulator of treptolem resulted in increased crop yield. The redistribution of assimilate flows towards the formation of fruits is due to the growth of the number of leaves, the formation of a larger leaf surface, a more powerful chlorenchyme and the growth of the content of chlorophylls in its cells. The aforementioned led to an increase in the net productivity of photosynthesis and gross photosynthetic productivity of poppy plants and cenosis in general. Such changes resulted in a more intense formation of structural and reserve carbohydrates-sugars and starch. The use of a complex of preparations also caused the formation of a more powerful acceptor sphere due to the strengthening of stem branching, an increase in the number of fruits (pods)-the main acceptor of assimilates in the fruiting phase. The growth of the yield of oil poppy seed under the action of chlormequat chloride and treptolem was accompanied by an increase in the seed oil content. The quality of poppy oil grew owing to an increase in the proportion of unsaturated fatty acids in it.

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