MORPHOLOGICAL AND ANATOMICAL STUDIES OF *Artemisia vulgaris* L. (ASTERACEAE)

I. Morphological characteristics

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Abstract: Mugwort has a long history of use in herbal medicine especially in matters connected to the digestive system. However, it is ill-defined especially under local conditions. This is the first part in a two-part study concerning with the botanical attributes of mugwort. In this paper a detailed morphological study of the plant is carried out. Herbaceous stem cuttings of *Artemisia vulgaris* L. were procured from the Experimental Station of Medicinal Plants, Faculty of Pharmacy, Cairo University where the field work was carried out. Plant identification and authentication procedures were carried out at CAIM. Cultivation was carried out on October 20th., 2006. Plants were followed up through 2006/2007 and 2008/2009 seasons. Eight plants, two of each of the four replicates (replicate 3×4 m, 5 ridges 60 cm apart and plants 50 cm distance in between) were fixed to follow up the vegetative growth at monthly intervals. In addition, 40 fixed plants, 10 per replicate were followed up at seven-day intervals for reproductive growth. Mugwort is a perennial herb locally reproduced by rhizomes which give the transplants (10-15 cm long). Rhizomes develop adventitious roots at the nodes to fix the plant in soil. Some 75% of rhizome buds produce shoots. The main stem is mainly responsible of the plant height. The maximum plant height was 105.8 cm (September 2007) in the first season and 121.8 cm. (November 2008) in the second season; reddish-purple in color and the upper ⅓ of stem is typically branched. At the end of the growing season, number of branches reached a maximum of 17.1 and 19.0 in the two growing seasons. Number of internodes of the main stem reached 57.6 and 81.3 in the two seasons. Both of main stem length and its internode number increased parallel to each other. Fresh and dry weights of both of the leafless shoot and leaves were followed up at the consecutive ages of the two growing seasons. Flowering stage continued from September to December in the two seasons. The maximum inflorescences production and start of seed formation occurred at mid November. Flower heads formed in spike-like clusters at the terminal ¼ to ⅓ of the main stem and lateral branches. Number of inflorescences was about 10-20 per branch. Each inflorescence developed 15-30 only tubular flowers on the central part of the receptacle. Ray flowers are absent. Flowering behavior was followed up by recording the cumulative number of inflorescences developing flower buds, inflorescences in blooming and the total number of developed inflorescences at seven day intervals. Mugwort plant developed a maximum number of 307 inflorescences per plant. Mugwort fruit is a cylindrical achene encloses the seed without a pappus. Seed is ridged, brown, oblong (1-2 mm long) with a narrow base and have minute bristles at the apex.[Journal of American Science 2010; 6(9):806-814].(ISSN: 1545-1003).

Keywords: *Artemisia vulgaris*; Mugwort; herbal medicine; Morphological characteristics**.**

1. Introduction

Much has been published, not only on systematics (at various levels), but on biology, chemistry and economic and medical uses of Asteraceae worldwide, particularly in proceedings (from conferences and symposia) such as that edited by Heywood *et al.* (1977).

The Asteraceae consist of more than 1100 genera and perhaps as many as 20000 species, being the second largest family in the flowering plants. The only other family of comparable size is the Orchidaceae with some estimates run as high as 30000 species (Cronquist, 1981).

On recent molecular phylogenetic data, the Angiosperm Phylogeny Group (Anon., 2010) abbreviated APG III, 2010, have suggested that Asteraceae are better treated as part of a more widely defined Asterales within the asterids II informal clade (or campanulid clade suggested by Judd and Olmstead, 2004).

The genus *Artemisia* (388 species; Boulos, 2002) is one of the largest and most widely distributed of the several genera in the tribe Anthemideae of Asteraceae.

Barney *et al.* (2002) stated that *Artemisia vulgaris* L. exhibited extreme morphological and physiological variability in different ecological regions; including: (1) branching habit (branched or non-branched), (2) degree of branching, (3) leaf morphology within an individual and within a

population and (4) diameter of rhizomes (hair-like to 1 cm).

Mugwort is distributed worldwide. It is mostly native to temperate North America, Europe, some in South America and North Africa to Siberia. It is a very common plant growing on nitrogenous soils, like weedy and uncultivated areas, such as waste places and roadsides. Mugwort is thought to have originated in Europe (Holm *et al*., 1997).

Täckholm (1974) listed *Artemisia* as one of the genera found in the flora of Egypt. She described *Artemisia* as fragrant shrubby plants with finely dissected leaves. Heads discoid, very small, sessile or short-peduncled in rich panicles. Pappus absent. Four species belong to *Artemisia* were recorded; namely, *A. scoparia* Waldst. & Kit. *A. monosperma* Del., *A. judaica* L. and *A. inculta* Del.

Boulos (2002) listed *Artemisia* in the flora of Egypt. He recorded three species belong to this genus; namely, *A. judaica* L., *A. scoparia* Waldst. & Kit. and *A. monosperma* Del. However, two more species new to the flora of Egypt were added to this genus as imperfectly known species; namely, *A. vulgaris* L. and *A. verlotiorum* Lamotte.

He defined *A. vulgaris* as an aromatic perennial 0.4 - 1.5 m; stems erect, branched, sulcate, pilose; leaves 2.5 - 10 × 4 - 5 cm. the cauline 1-pinnatisect; lobes entire, densely white-felted beneath, green above, entire, the lowermost pair amplexicaul; uppermost leaves smaller than the cauline, near-lanceolate, acute, with 2 small basal clasping lobes; inflorescence a lax panicle; peduncle 0 – 8 mm, ebracteate; capitula 3 – 4 mm diam.; phyllaries 2 – seriate, 3 – 4 mm, the outer about 3×1 mm. narrowly ovate, obtuse, scarious-margined, the inner about 4×1 mm, oblong-lanceolate, obtuse, tomentose; marginal florets female, filiform; the inner florets bisexual, fertile; corolla reddish; achenes not seen.

Mugwort is used in form of infusion, powder, fluid extract, essence, distilled water (Chiej, 1984). It has a long history of use in herbal medicine especially in matters connected to the digestive system, menstrual complaints and the treatment of worms.

In spite of the importance of mugwort, it is ill-defined; especially under local conditions. Thus, any new information dealing with the phytography of this plant either from morphological or anatomical standpoints is to be welcomed. This is the first part in a two-part study concerning with the botanical attributes of *Artemisia vulgaris* L. growing under local conditions. In this paper a detailed study (Phytography) dealing with its morphological characters is carried out to get a better insight on the external features of this plant and highlighted its importance as a medicinal plant. Such knowledge may fulfill information acquisition in this concern and would be useful to specialists in various fields of biology of this plant.

2. Material and Methods

2.1. Plant material

This study dealt with the morphology of Mugwort (*Artemisia vulgaris* L.). Herbaceous stem cuttings of the plant were obtained from an established stand in the Eperimental Station of Medicinal Plants, Faculty of Pharmacy, Cairo University, Giza, Egypt, where mature plants assigned for propagation in the stand were cut near the soil surface in late summer and left 4 weeks to renew their growth. Sections of tender new growth at the top end of the stem, some 25 cm in length were cut. The basal leaves of the foliage were stripped off for a length of 5 cm to encourage rooting. The cuttings were transplanted individually into a shallow plastic container of damp sandy soil. Cuttings developed roots in 1-2 weeks. At this stage, cuttings were transferred from the propagation field to be planted in the experimental location.

2.2. Field work procedure

The field trial was conducted in Section 4 of the previously mentioned Experimental Station. Date of cultivation was October 20^{th,} 2006. The field work continued to January 2009. Due to withering in winter and defoliation associated with aging throughout the period from October 2007 to January 2008, plants were cut near the soil surface early in the second season (February 14^{th,} 2008) to renew their growth for further studies.

The experimental layout was a randomized complete block design at the rate of 4 replicates. Plot dimensions were 3×4 m with 5 ridges 60 cm apart. Herbaceous stem cuttings were inserted at 50 cm distance between each other. Irrigation was carried out immediately after cultivation to encourage root development. All field practices were then performed as recommended for studied plant in the vicinity.

2.3. Plant identification

Mature plant specimens were collected from the experimental site and subjected to identification at the Herbarium, Flora & Phyto-Taxonomy Researches, Horticulture Research Institute, Agricultural Research Centre, Dokki, Giza, Egypt (CAIM). Authentication of specimens was carried out using botanical keys before being compared with reference herbarium specimens of CAIM collection which confirmed that the investigated plant species is *Artemisia vulgaris* L.

Herbarium specimens of studied plant deposited in CAIM and Dept. of Agric. Botany, Fac. of Agriculture, Cairo University, Giza, Egypt. Scientific name of studied plant species was revised according to the Annual Checklist of Bisby *et al.* (2010).

2.4. Vegetative growth

Eight fixed plants, two of each replicate were assigned to follow up the vegetative growth of plant at monthly intervals. At each sampling date the shoot system was described morphologically. Measurements recorded for the shoot system were plant height, length and number of internodes of the main stem and number of the lateral branches. Fresh and dry weights (70^{o}C) of leafless shoot and leaves, 8 plants, were determined.

2.5. Reproductive growth

General characters and detailed description of various reproductive organs were reported. Moreover, flowering curve was constructed at seven-day intervals using 40 fixed plants, 10 per each replicate. Characters followed up included the inflorescences number at flower bud stage, at opened flowers stage and the total number of inflorescences.

Data were subjected to various conventional methods of statistical analysis according to Snedecor and Cochran (1982) and MSTAT (1986).

3. Results

3.1. Propagation

Mugwort is a rhizomatous perennial herb locally reproduced by rhizomes. However, dependent on the specific geographic region, mugwort might reproduce from seeds. Normally, propagation in this species occurs principally *via* fragments of the shallow rhizomes which gave transplants (herbaceous cuttings) of about 10-15 cm long.

3.2. The root system

Mugwort growth is depending on rhizomes which are light brown in color, up to 1 cm in diameter and typically branching at nodes. Rhizomes remain in the upper 20 cm of the soil and often forming an extensive underground network. Rhizomes develop adventitious roots at the nodes to fix the plant in soil (Fig. 1). Due to difficulty in taking intact underground samples which were easily ruptured when pulled out no measurements of the rhizomes and the adventitious roots could be obtained under conditions of this study.

3.3. The shoot system

The density and vigour of shoots produced depend largely upon the density and vigour of the underground rhizome system. Worthy to note that some 75% of rhizome buds produced shoots. Mugwort is a tall herbaceous perennial plant growing up to 1-2 m in height. Shoots turn reddish-purple in color. Stem is erect, pilose, semiwoody and the upper one-third of stem is typically branched. The basal internodes of the main stem are visible. The other developed internodes are too short and are surrounded with crowded leaves. Throughout the following ages, the upper internodes elongate and become distinct. After 6 months from cultivation (April 2007), the number of internodes were 20.8 while the plant height was 31.4 cm but remained unbranched (Fig. 1). A month later (May 2007) the branches developed. At the end of the growing season, number of branches reached a maximum of 17.1 and 19.0 in the first and the second season, respectively.

Flowering stage started in September and continued up to December in the two seasons. Flower heads formed in spike-like clusters at the terminal ¼ to ⅓ of the main stem and lateral branches (Fig. 2). Number of inflorescences was about 10-20 per branch.

The aforementioned description of the vegetative and reproductive organs agrees with those stated by Chiej (1984), Barney *et al.* (2002), Boulos (2002), Barney and DiTommaso (2003), Singh and Panda (2005) and Sammbamurty (2006).

3.3.1. Plant height

The increase in plant height continued during most of the entire life span of the plant (Table, 1). The maximum height was reached after 11 months (September 2007) in the first season and 10 months (November 2008) in the second season being 105.8 and 121.8 cm in the two seasons, respectively. Noteworthy that, elongation of plant progressed consistently throughout the consecutive periods, of the two growing seasons.

In the first season, no significant increments were recorded from December 2006 up to February 2007. This might be due to the effect of winter season. A significant increment was achieved in March 2007 when plant height was 19.7 cm. Increments were observed up to September 2007 to record a plant height of 105.8 cm.

Early in the second season (January 2008) cutting of plants was achieved as usual to enhance plant growth. Thereafter the plant height increased steadily from February 2008 (11.0 cm) to November 2008 (121.8 cm). No further increment was recorded till the end of the second growing season.

Boulos (2002) stated that the plant ranged from 40-150 cm in height. In the present study, however, the plant height reached some 120 cm, being within the same range.

Fig1. A photograph of ***Artemisia vulgaris*** L. plant at the age of 6 months (April 2007) showing the main stem (unbranched) at this age. The rhizomes branched and developing the adventitious roots.

Fig 2. A photograph showing the upper portion of ***Artemisia vulgaris*** L. plant bearing spike-like clusters of inflorescences (capitula) developing through September to December.

3.3.2. Length of the main stem

It was found that length of the main stem increased significantly at the consecutive sampling dates from November 2006 being 9.0 cm up to September (103.8 cm) in the first season and from February 2008 being 9.9 cm up to November 2008 being 118.0 cm. (Table, 1). No increments in length of the main stem were recorded from November 2008 to January 2009 in the second season.

When comparing the data given for the periodic growth of either of the plant height or the length of the main stem; both of them, as being expected, followed a similar growth pattern. Moreover, values obtained of both traits were more or less similar indicating that the main stem is mainly responsible of the plant height.

Table (1) The periodic growth and statistical parameters of some vegetative characters of *Artemisia vulgaris* L. in two consecutive seasons

Date	Plant height (cm)	Length of main stem (cm)	Internodes No. of main stem	Secondary branches No.	Leafless shoot fresh weight (g)	Leafless shoot dry weight (g)	Leaves fresh weight (g)	Leaves dry weight (g)
First season								
Nov. 2006	11.4 I	9.0 J	9.6 I	0.0 F	0.3 H	0.1 F	1.2 H	0.3 G
December	14.5 H	10.8 I	11.3 H	0.0 F	0.5 H	0.1 F	1.9 G	0.4 G
Jan. 2007	15.5 H	12.0 HI	11.4 H	0.0 F	0.5 H	0.2 F	2.5 F	0.6 F
February	16.2 H	13.5 H	12.8 G	0.0 F	1.2 G	0.6 EF	2.7 EF	0.7 F
March	19.7 G	16.6 G	16.4 F	0.0 F	1.9 F	0.8 E	2.8 E	0.7 F
April	31.4 F	29.3 F	20.8 E	0.0 F	2.5 E	0.8 E	3.2 D	0.9 E
May	40.1 E	38.0 E	26.1 D	7.4 E	3.0 E	0.9 E	3.3 D	1.1 D
June	47.5 D	45.5 D	26.3 D	8.9 D	5.5 D	2.4 D	4.6 C	1.2 D
July	61.1 C	57.1 C	32.4 C	12.4 C	7.6 C	3.1 C	5.0 B	1.6 C
August	89.3 B	85.6 B	49.4 B	13.5 B	11.0 B	5.2 B	5.4 A	2.1 B
September	105.8 A	103.8 A	57.6 A	17.1 A	13.0 A	6.6 A	5.6 A	2.4 A
L.S.D. (0.05)	**2.6**	**1.7**	**1.1**	**0.4**	**0.6**	**0.5**	**0.3**	**0.1**
Second season								
Feb. 2008	11.0 J	9.9 J	9.8 J	0.0 F	0.4 F	0.1 H	0.7 H	0.1 G
March	15.0 I	13.5 I	11.1 I	0.0 F	0.5 F	0.2 H	0.9 GH	0.3 FG
April	21.1 H	19.0 H	13.5 H	0.0 F	1.0 F	0.5 GH	1.2 G	0.4 F
May	29.5 G	28.1 G	16.9 G	0.0 F	2.0 E	0.7 FG	1.9 F	0.6 E
June	40.5 F	38.4 F	25.4 F	0.0 F	2.6 E	0.8 FG	2.2 EF	0.8 E
July	54.6 E	52.3 E	35.8 E	6.4 E	3.9 D	1.0 F	2.6 D	1.1 D
August	69.6 D	68.5 D	42.5 D	8.5 D	6.6 C	1.7 E	3.3 C	1.4 C
September	105.3 C	103.4 C	70.5 C	11.1 C	10.1 B	4.4 D	4.4 A	1.8 B
October	113.5 B	111.1 B	80.0 B	15.0 B	11.8 A	5.9 B	4.4 A	2.1 A
November	121.8 A	118.0 A	81.3 AB	18.0 A	12.2 A	6.5 A	4.0 B	2.1 A
December	121.8 A	118.5 A	81.4 A	19.1 A	12.0 A	5.9 B	3.9 B	1.8 B
Jan. 2009	120.4 A	116.6 A	81.4 A	19.0 A	9.7 B	5.4 C	2.4 DE	1.1 D
L.S.D. (0.05)	**2.0**	**2.6**	**1.3**	**1.3**	**0.8**	**0.4**	**0.3**	**0.2**

Means having the same letter (s) are not significantly different at 0.05 level.

3.3.3. Number of internodes of the main stem

Results reveal that a significant increment in number of internodes occurred through the two growing seasons (Table, 1). These enhancements started at November 2006, being 9.6 up to September 2007, being 57.6 in the first season. However, mugwort plant was cut toward the end of the first season, so number of internodes recorded in the second season at February 2008 was 9.8 reached to 81.3 in November, no further substantial increments were observed in number of internodes of the main stem till the end of the second growing season (January 2009).

It is worthy to note that the main stem of mugwort increased in the mean time in both of its length and the number of internodes.

3.3.4. Number of the secondary branches

The secondary branches started their development at May 2007 in the first season and at July 2008 in the second season, where their number was 7.4 and 6.4 in the two seasons; respectively (Table, 1). Thereafter, significant increments in number of secondary branches through the two consecutive seasons occurred reaching 17.1 and 19.0; respectively. However, no significant increments were observed in number of secondary branches from November 2008 until January 2009, the end of the second growing season.

3.3.5. Fresh weight of leafless shoot

A significant increase in fresh weight of the leafless shoot occurred when plants aged four months in both seasons; *i.e.,* February 2007 being 1.2 g and May 2008 being 2.0 g in the first and the second season, respectively (Table, 1). Thereafter, significant progressive increments took place till the end of the two growing seasons. Weights were 13.0 (September 2007) and 12.2 g (November 2008) in the two seasons, respectively.

No substantial increments were observed in fresh weight of the leafless shoot in the second season after October 2008. Moreover, a decrease in weight was recorded in January 2009 which might be a result of the normal dryness of plant through winter season.

3.3.6. Dry weight of leafless shoot

Comparison between data recorded for both of the fresh and dry weights of leafless shoot of mugwort throughout the experimental period showed, as being expected, the same pattern of behavior (Table, 1).

The dry weight of leafless shoot achieved a significant increase in February 2007 (0.6 g). Similarly, in May 2008 the dry weight of leafless shoot increased to 0.7g. Significant progressive increments took place toward the end of the growing season, being 6.6 g in September 2007 and 6.5 g in November 2008. Normal decrease in weight occurred thereafter reaching to 5.4 g in January 2009 due to winter season and the normal dryness of studied plants.

3.3.7. The leaf

Leaves of mugwort are simple, alternately arranged on the stem, petiolate, stipulate, 1-10 cm in length, 2-8 cm wide and have a distinctive aroma where a pungent odour released from crushed foliage.

Leaf is dark green in colour at its upper (adaxial) surface, being slightly hairy. However, the lower (abaxial) surface is whitish in colour since it is covered with silvery-white wooly hairs. Leaves of the upper portion of the shoot are simple, sessile, exstipulate, and smaller than the lower leaves, lanceolate in shape and margin entire. Leaf blades of the middle and lower portion of the shoot have highly dissected margins, pinnately lobed and the lobes are broadly lanceolate in shape with entire margins and their apex acute. These primary lobes are often shallowly cleft by one or more secondary lobes (Fig. 3).

At the end of the growing season, the leaves dryness on the stem commonly occurs. Hence, plant cutting is carried out to revitalize.

The previously given morphology of leaf is in conformity with that mentioned by Chiej (1984), Barney *et al.* (2002), Boulos (2002), Barney and DiTommaso (2003), Singh and Panda (2005) and Sammbamurty (2006).

3.3.8. Fresh weight of leaves

In concern of the first season, fresh weight of leaves at the beginning of the growing season was 1.2 g (November 2006), increased significantly to 2.5 g in January 2007 (Table, 1). No appreciable increase was then achieved up to March (2.8 g). However, the maximum leaves fresh weight was attained in September 2007, being 5.6 g. Regarding the second season, a consistent increment in leaves fresh weight was recorded reaching a maximum of 4.4 g in September 2008.

3.3.9. Dry weight of leaves

As is expected, the dry weight of leaves followed the same manner of growth previously shown by the fresh weight of leaves (Table, 1). A significant increase in leaves dry weight was recorded from November 2006 (0.3 g) to January 2007 (0.6 g). No increment in leaves dry weight was observed up to March. A gradual increment was attained later on reaching a maximum in September 2007 being 2.4 g.

In concern of the second season, leaves dry weight increased consistently from February 2008 (0.1 g) to October (2.1 g). An expected decrease in

leaves dry weight took place from October to the end of the growing season (January 2009) being 1.1 g due to winter season and normal dryness of leaves.

3.4. Reproductive growth

3.4.1. The inflorescence

Inflorescences (flower heads) of mugwort are formed in spike like clusters at the terminal (the top) of the plant (Fig. 4). Flowering stage started in September and continued up to the end of December in the two seasons ;*i.e.,* flowering lasted some four months. Flowers of each inflorescence first differentiate as bud flowers. This occurred through September to mid November.

Anthesis, then takes place and flower buds successively open and inflorescences start their opened flower stage this lasted till the end of December.

The inflorescence is a compact capitulum developing on a short peduncle or sessile and appears in clusters at the upper portion of the main stem and the lateral branches. Number of inflorescences is about 10-20 per branch. Capitula are very small 2.5-3 mm wide, surrounded by two series of lanceolate bracts known as phyllaries. Heads are discoid (only tubular flowers) where flowers consist on a common receptacle, about 15-30 flowers which develop densely on the central part of the receptacle. At the bud stage they are green in colour.

Fig.3. A photograph of *Artemisia vulgaris* L. showing from the right to the left the leaf forms on the main stem throughout their successive developmental stages.

Fig 4. A photograph showing the terminal portion of a branch of *Artemisia vulgaris* L. plant bearing some 15 capitula

3.4.2. Cumulative number of inflorescences

Flowering onset of mugwort plants took place on 4th September. Flowering behaviour was followed up by recording the cumulative number of inflorescences developing flower buds, inflorescences in blooming and the total number of developed inflorescences at seven day intervals. This was also illustrated diagrammatically, as shown in Fig. (5).

Average number of inflorescences developed flower buds per plant increased steadily reaching 205.8 on 9th October. However, number of inflorescences with opened flowers was only 46.3; *i.e.,* the plant developed a total number of 252.1 inflorescences. Number of inflorescences developed per plant continued to increase. The maximum number of inflorescences, bearing opened flowers which in the mean time expressed the total number of inflorescences developed per plant was 307, reached on 20 November.

Thereafter, the recorded number of inflorescences with opened flowers decreased gradually toward the end of the growing season as a result of fruit setting and development of seeds. This continued till the end of December when no more flowering took place.

In essence, flowering of mugwort plants lasted for a period of four months lasted from September to December. The maximum inflorescences production and start of seed formation occurred at mid November.

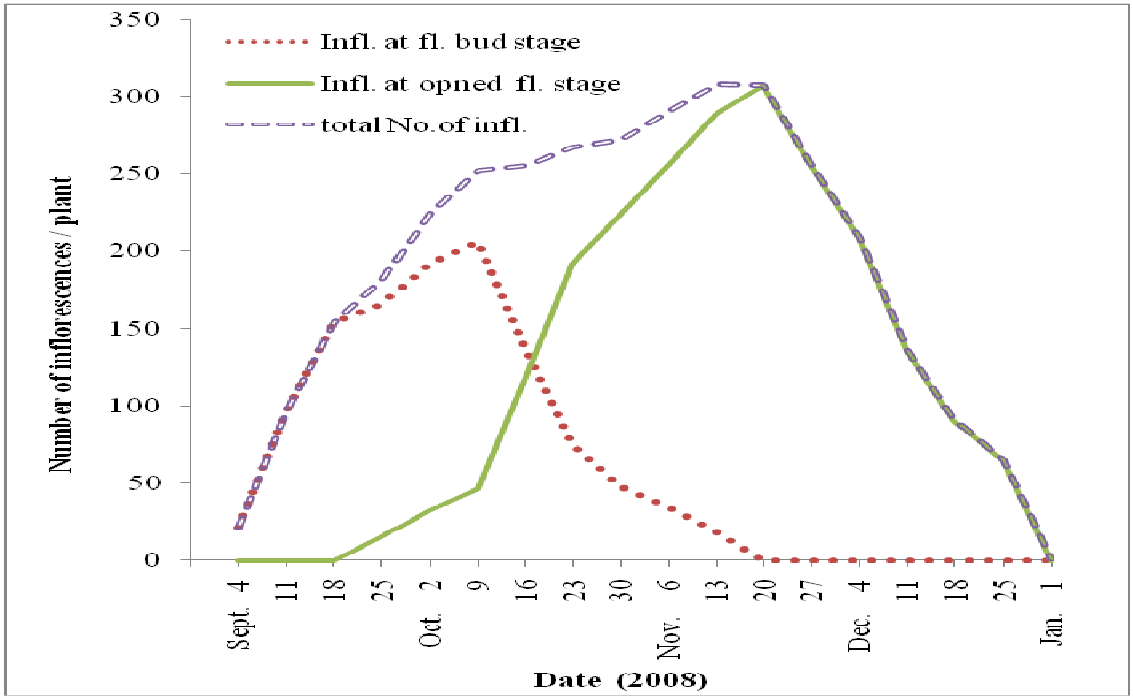
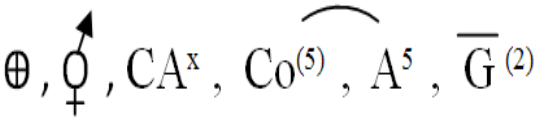


Fig.5. Cumulative number of inflorescences of *Artemisia vulgaris* L. per plant at 7-day intervals at flower bud and opened flower stages.

3.4.3. The flower

Ray flowers of mugwort inflorescence are absent, while disc flowers at blooming are very small (inconspicuous), reddish or greenish yellow and bisexual at the center of each head but may occasionally be just female on the periphery. These flowers are sessile, epigenous and actinomorphic. Calyx is absent. Corolla comprised five united petals tubular with five recurred lobes. It is valvate at its apex, strongly reflexed at maturity and its base and median portion are narrow, while the top is the widest part of the corolla. Androecium consists of five stamens, epipetalous, alternating with the petals, with syngenesious stamens, anthers pointed at the base and filaments free. Gynoecium is a compound pistil of two united carpels, uniloculate, ovule solitary, basal and ovary inferior with glandular hairs. Style divided and branches arched-curved, truncated and ciliate. Stigma is long growing up through the anther tube.

Floral formula of the disc flower is as follows:



The previously given description of the inflorescence conformed to that stated by Chiej (1984), Barney *et al.* (2002), Boulos (2002), Barney and DiTommaso (2003), Singh and Panda (2005) and Sammbamurty (2006).

3.4.4. The fruit

The fruit of mugwort is a cylindrical achene encloses the seed without a pappus.

3.4.5. The seed

Seeds (actually one-seeded fruits known as cypselas) are ridged brown, oblong (1-2 mm long) with a narrow base and have minute bristles at the apex.

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