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## Botanical Studies on Egyptian Henbane (*Hyoscyamus muticus* L.) I- Morphology of Vegetative and Reproductive Growth and Alkaloidal Content

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### ABSTRACT

Most information in the literature about the botanical characteristics of *Hyoscyamus* are dealt with *Hyoscyamus niger* L. (European Henbane) rather than *Hyoscyamus muticus* L. (Egyptian Henbane). Thus, any new botanical information about Egyptian Henbane are urgently to be welcomed. The present study intends to introduce a detailed botanical information about germination of seeds and the morphology of vegetative and reproductive growth as well as information about alkaloidal content of Egyptian Henbane throughout the consecutive stages of its entire life span. The morphology of vegetative growth includes: plant height, length of the main stem, thickness of the main stem, number of internodes of the main stem, length of successive internodes of the main stem, number of secondary branches per plant, number of leaves per plant, total leaf area per plant and fresh weight of leaves (yield of leaves) per plant. The morphology of reproductive growth includes: general characters and a detailed description of various reproductive organs. Various parameters of the yield were investigated including: number of harvested inflorescences per plant, average number of fruits (capsules) per inflorescence, number of fruits per plant, average number of seeds per fruit, number of seeds per plant, specific weight of seeds and seed yield per plant. Such knowledge would be useful to specialists in various aspects of biology of this important species of the family Solanaceae.

**Key words:** *Hyoscyamus muticus* L., Egyptian Henbane, Seed germination, External morphology, Vegetative organs, Reproductive organs, Alkaloidal content.

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### Introduction

The family Solanaceae (Nightshade or Potato family) consists of about 85 genera and 2800 species of tropical and temperate distribution (Cronquist, 1981 and Jones and Luchsinger, 1987). The greatest number of genera (40) are found in Central and South America. Several plants are cultivated all over the world for their great economic uses. Members of the nightshade family provide drugs and food; some are weedy, some are poisonous, and others are handsome ornamentals (Jones and Luchsinger, 1987 and Shukla and Misra, 2001).

Many members of Solanaceae contain powerful alkaloids. Tropane alkaloids have been found in 21 genera of the Solanaceae of which *Hyoscyamus* is one of the most important genera in this respect. *Hyoscyamus* is the ancient Greek and Latin name formed from two Greek words 'Hyos' meaning a 'Hog' and 'Kyamos' meaning a 'Bean'. The genus *Hyoscyamus* comprised of about 15 species distributed in North Africa and Western Europe to Central Asia (Boulos, 2002). Two species of the genus *Hyoscyamus* are of high economic importance for their tropane alkaloids (hyoscyamine and hyoscyne) which are used medicinally as a sedative and hypnotic. The first species is called *Hyoscyamus niger* L. (Henbane, Black Henbane or European Henbane). It is cultivated in South-Eastern England, in Thuringia and Northern Bavaria in Germany and Russia and Hungary. The second species is called *Hyoscyamus muticus* L. (Egyptian Henbane) which growing in the sandy districts of Egypt (Wallis, 1999).

Egyptian Henbane, the subject of the present investigation, is an herbaceous perennial plant about 60 cm in height and richly branched from the neck, with dense flower-spikes (Täckholm, 1974 and Evans, 2002). The stems are yellowish, terete, hollow and longitudinally grooved as a result of drying. The leaves are pale green and brittle, fleshy up to 15 cm long, ovate-lanceolate to lanceolate; the radical ones are petiolate and the lamina has two or three large teeth on each side and an acuminate apex; the upper leaves are sessile, more lanceolate and have an entire margin. The flowers are crowded at the ends of the stems; each flower has a hairy campanulate-cylindrical calyx, about 3 to 4 cm long with ten longitudinal ribs and five short triangular teeth; the corolla is deep purple with yellowish streaks and five unequal lobes, projecting beyond the calyx; the epipetalous stamens have hairy purple filaments and oblong, yellow anthers. The fruit is bilocular cylindrical pyxis with numerous fawn-coloured to brown seeds; about 1.5 cm long and 6mm wide; it is enclosed by the persistent calyx. The seed about 1 mm in diameter; contains a coiled embryo embedded in an oily endosperm.

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The dried leaves and flowering tops (together) contain 0.7 to 1.5 % of total alkaloids, most of which is hyoscyamine (Täckholm, 1974; Tyler *et al.*, 1988 and Wallis, 1999).

Worthy to mention that, most information in the literature about the botanical characteristics of *Hyoscyamus* are dealt with *Hyoscyamus niger* L. rather than *Hyoscyamus muticus* L. (Hill, 1952; Bunney, 1992; Kumar *et al.*, 2001; Dewick, 2002; Pandey, 2003 and Sharma, 2004). Thus, any new botanical information about Egyptian Henbane are urgently to be welcomed.

Therefore, the present study intends to introduce a detailed botanical information about the morphology of vegetative and reproductive growth of *Hyoscyamus muticus* L. plant (Egyptian Henbane) throughout the consecutive stages of its entire life span. Moreover, alkaloidal content in leaves of Egyptian Henbane was also investigated. Such knowledge would be useful to specialists in various aspects of biology of this important species of the family Solanaceae.

## **Materials and Methods**

Seeds of *Hyoscyamus muticus* L. (Egyptian Henbane) were procured from Experimental Station of Medicinal Plants, Faculty of Pharmacy, University of Cairo, Giza, Egypt.

### **Test of germination:**

Germination of investigated species was followed up. Seeds were planted in pots filled with a mixture of sand, peat moss and vermiculate at a ratio of 1:1:1 by volume. Seedlings were taken out daily for morphological investigations up to the end of the seedling stage (21 days).

A germination test was conducted in the Seed Testing Department, Agricultural Research Center, Giza to determine the speed and the capacity of germination. Recommended conditions of germination for Egyptian Henbane seeds are summarized in the following:

Substrate : Top of filter paper  
Temperature °C: 20 - 30  
First count (days): 7  
Final count (days): 21

### **Field work procedure:**

The field work was carried out in the Agricultural Experiments and Research Station, Faculty of Agriculture, Cairo University, Giza, Egypt during the growing season of 2015 to provide the experimental plant material. Date of cultivation was 26<sup>th</sup> February. The trial included five replicates, each represented by one plot. The plot was 4x5 m. with eight ridges 60 cm. apart. Seeds were sown in hills spaced 30 cm. The plants were thinned to one plant per hill. All field practices were carried out as recommended for Egyptian Henbane in the vicinity.

### **Observations and recording of data:**

#### *I- Vegetative growth:*

Ten plants, two plants from each of the five replicates, were assigned at two-weeks intervals to follow up the vegetative growth of Egyptian Henbane plant.

At each sampling date the root and shoot systems were described morphologically. The branching system of the shoot was followed up to determine the plant habit of growth. The following measurements were recorded for the shoot:

- 1- Plant height (cm), measured from the cotyledonary node up to the uppermost point of the plant.
- 2- Length of the main stem (cm), measured from the cotyledonary node up to the shoot apex.
- 3- Thickness of the main stem (mm) at its median portion.
- 4- Number of internodes of the main stem.
- 5- Length (cm) of successive internodes of the main stem.
- 6- Number of secondary branches per plant.
- 7- Number of leaves per plant.
- 8- Total leaf area (cm<sup>2</sup>) per plant.
- 9- Fresh weight (g) of leaves per plant.

## *II- Reproductive growth and yield components:*

General characters and a detailed description of various reproductive organs were reported. Fresh weight of reproductive organs (g) per plant was recorded at each sampling date. Flowering and fruiting periods were determined. Time taken for different reproductive developmental stages was fixed; *i.e.*, flowering onset, full blooming, fruit set and maturity. Various parameters of the yield were recorded throughout the experimental season on 25 plants, five plants from each replicate were assigned for this purpose. The following characters were recorded:

- 1- Number of harvested inflorescences per plant.
- 2- Average number of fruits (capsules) per inflorescence.
- 3- Number of fruits per plant.
- 4- Average number of seeds per fruit.
- 5- Number of seeds per plant.
- 6- Yield of seeds (g) per plant.
- 7- Average weight of 1000 seeds (g).

## *III- Biochemical studies:*

Biochemical studies included determination of total alkaloids in leaves of Egyptian Henbane at two-weeks intervals starting from the age of 6 weeks and ending at the age of 16 weeks (full blooming and starting of fruiting). Total alkaloids were determined according to the method described by Milan *et al.* (1990).

## *Statistical analysis:*

Data of the present investigation were subjected to various conventional methods of statistical analysis according to Snedecor and Cochran (1982).

## **Results and Discussion**

### **I- Germination of seeds and seedling growth:**

Seed of Egyptian Henbane is very small in size and in weight (one gram comprised more than 1500 seeds), brownish in colour, flattened, somewhat reniform in shape and about 1 mm in diameter and 0.5 mm in thickness, with a curved embryo embedded in an oily endosperm, the curvature amounts to semicircle or more, the testa marked by fine wavy-walled reticulations.

After sowing of seeds, germination takes place in about 7-10 days. Generally, the seeds take a longer time comparatively to germinate and the growth of seedling is also very slow. First, seed testa imbibes water and becomes softened. The embryo also imbibes water, causing it to swell and burst at the basal end of the seed. This lasted about 3-4 days from sowing. As germination proceeds, the structure of the seedling soon becomes evident. The radical emerges from the lower end where the seed has been bursted. This takes about 6 days. Seed germination of Egyptian Henbane is epigeal, the hypocotyl elongates and raises the two cotyledons above the ground. This almost takes place 10 days after sowing. The hypocotyl is somewhat bent in its growth before emergence above the soil, then becomes straight towards the age of 12 days. The two cotyledons take an accumbent position. The completely developed cotyledons, the age of two weeks, are small in size, petiolate, fleshy, green in colour and narrowly elliptic in shape and averages 1.4 cm in length and 5 mm in width.

At the age of three weeks, the first simple two foliage leaves are formed and seedling stage comes to an end. The whole length of the seedling including the first two foliage leaves averaged 8 cm. The radical average 2.5 cm long and the hypocotyl is some 3 cm long (Figure 1).

The speed of germination (after 7 days) was 35.8% and the capacity of germination (after 21 days) was 61.9%.

### **II- External morphology of vegetative growth:**

#### **1- The root system:**

The tap root develops directly below the hypocotyl and is similar to its thickness. The root then is tapering towards the apex. Lateral roots develop acropetally in two longitudinal rows. The root system is mainly composed of a stout tap root developing a large number of lateral roots in acropetal succession.

No measurements could be taken for the root system since it was difficult to obtain an intact root sample as the root was ruptured easily when pulled out of the soil.

## 2- The shoot system:

### a- Growth behaviour:

The seedling stage came to an end almost at the age of three weeks, where plants average 5.5 cm in height and the first two foliage leaves are formed.

As plants were four weeks in age, plant height reached 7.5 cm, three simple foliage leaves (long petiolated, ovate-lanceolate in shape, have entire margin and reticulate pinnate venation) were seen, internodes are too short to be detected easily.

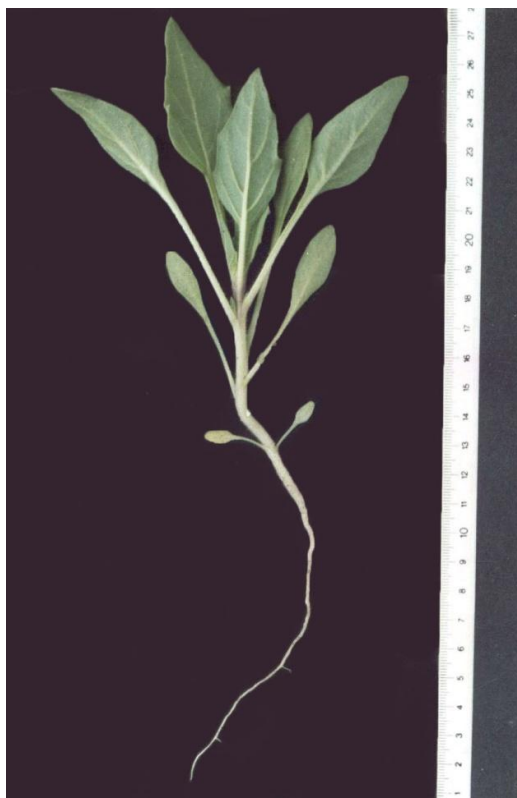
When plants were six weeks in age, the number of developing leaves increased to seven, the lamina of each of the newly formed leaves being ovate-lanceolate in shape. The main stem is easily determined due to the elongation of the formed internodes (Figure 2). The number of differentiated internodes seen at this age of the plant growth ranged between 3 to 5. The plant reached 14.6 cm in height and the main stem was 11.1 cm in length. The two cotyledons are still intact at this age.

At the age of eight weeks, plant height averaged some 27.1 cm. Main stem was about 21.3 cm in length and 7.0 mm in diameter. Number of internodes ranged between 6 to 9 and number of leaves per plant was almost 33. The two cotyledons shriveled and defoliated.

At the age of ten weeks, plants continued growth. Plant height averaged some 44.8 cm. However, main stem was about 28.8 cm in length and 9.4 mm in diameter. Number of internodes ranged between 9 to 12 and leaves per plant were almost 65 in number. At this age of plant growth, about 4 to 7 branches developed from the basal portion; *i.e.* from the neck. Flowering stage started as flower buds developed.



**Fig. 1:** A photograph of completely developed seedling of *Hyoscyamus muticus* L., aged three weeks, showing its epigeal pattern of growth where the two cotyledons are brought above the soil. Two simple foliage leaves developed at this age of plant growth.



**Fig. 2:** A photograph of *Hyoscyamus muticus* L. plant, at the age of 6 weeks. The two cotyledons still intact. Seven simple leaves develop. Internodes of the main stem are detected easily.

When plants were 12 weeks in age, plant height was some 59.4 cm and the main stem reached to its maximum length being 35.6 cm. The diameter of the main stem at its median portion was almost 13 mm. Number of internodes ranged between 11 to 14. Number of leaves per plant was about 117. Basal branches were some 10 in number. Opening of the flower buds on the inflorescence of the main stem started (Figure 3).

At the age of 14 weeks, plant height averaged 78.8 cm. The length of the main stem showed no significant increase, being 33.3 cm in average. Whereas, the diameter of the main stem at its median portion showed significant increase, reached to 16.1 mm in average. Number of internodes of the main stem ranged between 13 to 16. Leaves were about 194 in number. Number of basal branches ranged between 12 to 14, each terminated in an raceme inflorescence with dense flowers at the tops. The number of branches as well as all other morphological aspects, except that of stem diameter, attains their maximum at this age of plant growth. Worthy to mention that total alkaloidal content in leaves reached its maximum at this age of plant growth, being 45.6 mg/g dry weight of leaves.

Full blooming and start of fruiting formation take place at the age of 16 weeks (Figure 4). Number of leaves per plant reached to its maximum being some 244. Also, stem diameter reached to its maximum being 19.7 mm. No more internodes or basal branches developed.

At the age of 20 weeks, all inflorescences developed into fruits. Harvest take place at the age of 18 to 20 weeks.

Egyptian Henbane plant is indigenous and cultivated in Egypt. It is treated as an annual herb when cultivated, reaching more than 80 cm in height. The plant is stout, fleshy, puberulent and richly branched from the neck. The main stem and each of the basal branches terminate in an raceme inflorescence. Flowers are crowded at the ends of the stems. The leaves are simple, fleshy, pale green in colour, up to 15 cm. long, ovate and the lamina in most has two or three large teeth on each side and an acuminate apex.

The morphological description here given for Egyptian Henbane plant is generally in accordance with that recorded by Täckholm (1974) and Wallis (1999).



**Fig. 3:** A photograph of *Hyoscyamus muticus* L. plant, at the age of 12 weeks, showing the onset of flowering. At this age of growth, plant forming 9 to 12 branches differentiated from the base of the stem (neck).



**Fig. 4:** A photograph of *Hyoscyamus muticus* L. plant at full blooming stage, the age of 16 weeks. Stout fleshy puberulent plant, reached more than 80 cm in height, richly branched from the neck, with dense flower-spikes. The main stem and each of the primary branches terminated in an raceme inflorescence.

**b- Plant height:**

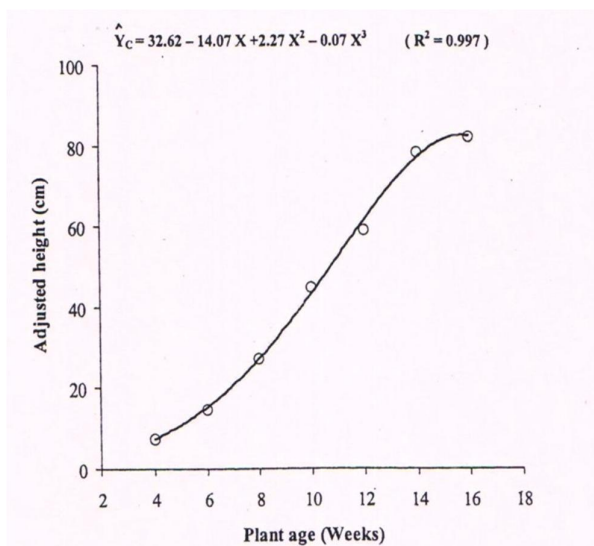
Results belonging to plant height of Egyptian Henbane throughout the growing season and their statistical analysis are given in Table (1). A significant cubic effect of plant age was detected for this character. The cubic equation and line of plant height and periods at consecutive ages are shown in Figure (5).

It is clear that the increase in plant height continued during most of the entire life span of the plant at almost a uniform rate throughout consecutive periods of plant growth. The maximum height was recorded at the age of 16 weeks (82.5 cm), which in turn being statistically indifferent with the height recorded at the age of 14 weeks (78.8 cm). This means that Egyptian Henbane plant attains its maximum height, generally, at the age of 14 weeks.

**Table 1:** The periodic growth and statistical parameters of plant height (cm) of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean± S.E.
4	5.8-9.2	7.52±0.41 F
6	11.8-19.6	14.64±0.87 E
8	22.5-31.3	27.08±0.93 D
10	38.4-52.6	44.85±1.64 C
12	49.7-67.4	59.39±1.95 B
14	68.5-87.2	78.76±2.11 A
16	72.5-91.5	82.47±2.00 A
L.S.D. (0.05)		4.83 cm

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



**Fig. 5:** Graph of regression of plant height on plant age in *Hyoscyamus muticus* L.

**c- The stem:**

**1- Length of the main stem:**

Data pertaining to length of the main stem of Egyptian Henbane plant during the growing season and the results of their statistical analysis are given in Table (2). A significant cubic effect of periods was achieved for this character. The cubic equation and line of length of the main stem and periods are presented in Figure (6).

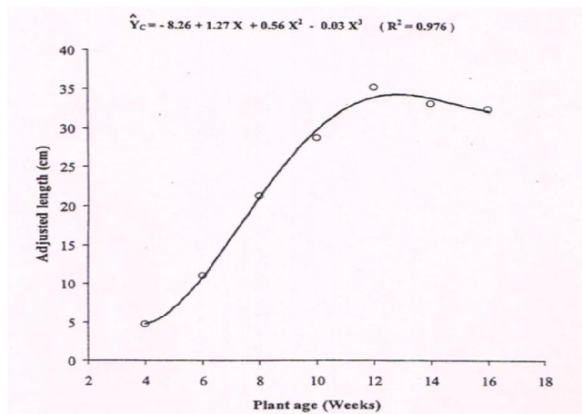
Results of length of the main stem at successive ages proved that a significant increment in length occurred from the age of four weeks through the age of 12 weeks where the average length reached to its maximum, being 35.6 cm. This was statistically indifferent with the average length recorded at the age of 14 weeks (33.3 cm) or with that recorded at the age of 16 weeks (32.5 cm). It is realized that the period of 6 to 8 weeks was the most active one throughout the entire growing season, since the length of the main stem increased from 11.14 to 21.28 cm. Such increment (10.14 cm), which was added during these two weeks represented 28.5% of the maximum length of the main stem (35.6 cm).

It is noted that the growth pattern of the main stem had been shown to be determinate, since it terminates in an inflorescence reaching a maximum length at 12 weeks old when there was no other significant increase in length of the main stem was recorded up to the end of the growing season.

**Table 2:** The periodic growth and statistical parameters of main stem length (cm) of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean ±S.E.	
4	3.9-5.8	4.68±0.24	E
6	8.6-14.4	11.14±0.59	D
8	17.5-25.3	21.28±0.83	C
10	23.6-34.2	28.79±1.19	B
12	28.9-42.5	35.62±1.42	A
14	28.5-41.2	33.25±1.39	A
16	27.5-39.7	32.47±1.32	A
L.S.D. (0.05)		3.26 cm	

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



**Fig. 6:** Graph of regression of main stem length on plant age in *Hyoscyamus muticus* L.

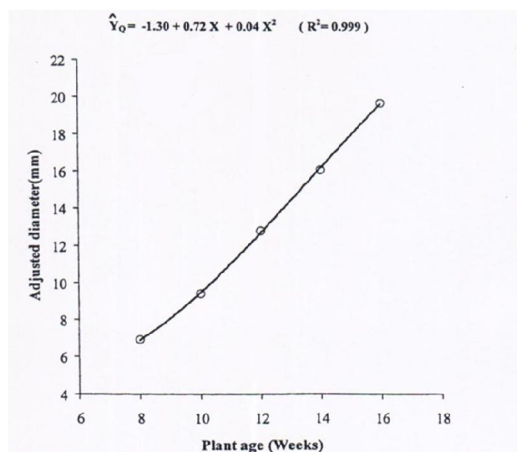
## 2- Thickness of the main stem:

Results of the main stem thickness of Egyptian Henbane plant throughout the growing season are presented in Table (3). It is evident that a significant quadratic effect of plant age was detected for this character. The quadratic equation and line of thickness of the main stem and periods are shown in Figure (7).

A continued significant increase in stem thickness was observed during the entire life span of Egyptian Henbane plant at almost a uniform rate throughout consecutive periods of plant growth. The maximum thickness of the main stem was recorded at the age of 16 weeks (19.7 mm).

**Table 3:** The periodic growth and statistical parameters of main stem thickness (mm) at its median portion of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.	
8	6-9	6.9±0.35	E
10	8-12	9.4±0.45	D
12	11-14	12.8±0.62	C
14	14-18	16.1±0.59	B
16	17-22	19.7±0.68	A
L.S.D. (0.05)		1.21 mm.	



**Fig. 7:** Graph of regression of main stem diameter, at its median portion, on plant age in *Hyoscyamus muticus* L.



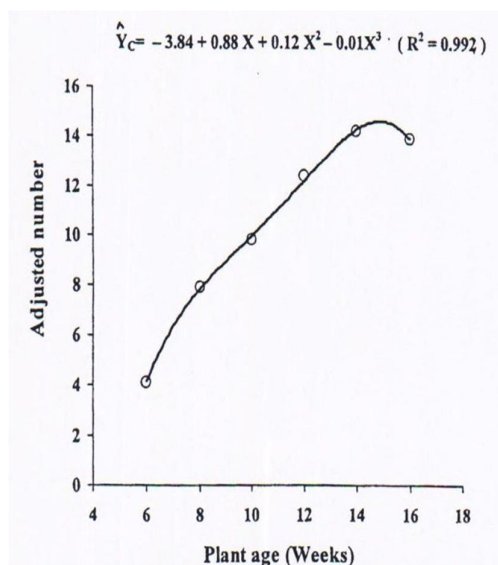
### 3- Number of internodes of the main stem:

Data in Table (4) show number of internodes of the main stem of Egyptian Henbane plant at successive ages. A significant cubic effect of plant age on this character was detected. Figure (8) depicts the cubic equation and line of periods effect on number of internodes of the main stem during the growing season.

**Table 4:** The periodic increase and statistical parameters of number of internodes of the main stem of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.	
6	3-5	4.1±0.23	E
8	6-9	7.9±0.35	D
10	9-12	9.8±0.47	C
12	11-14	12.4±0.39	B
14	13-16	14.2±0.45	A
16	13-16	13.9±0.38	A
L.S.D. (0.05)		0.93 internode.	

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



**Fig. 8:** Graph of regression of number of internodes of the main stem on plant age in *Hyoscyamus muticus* L.

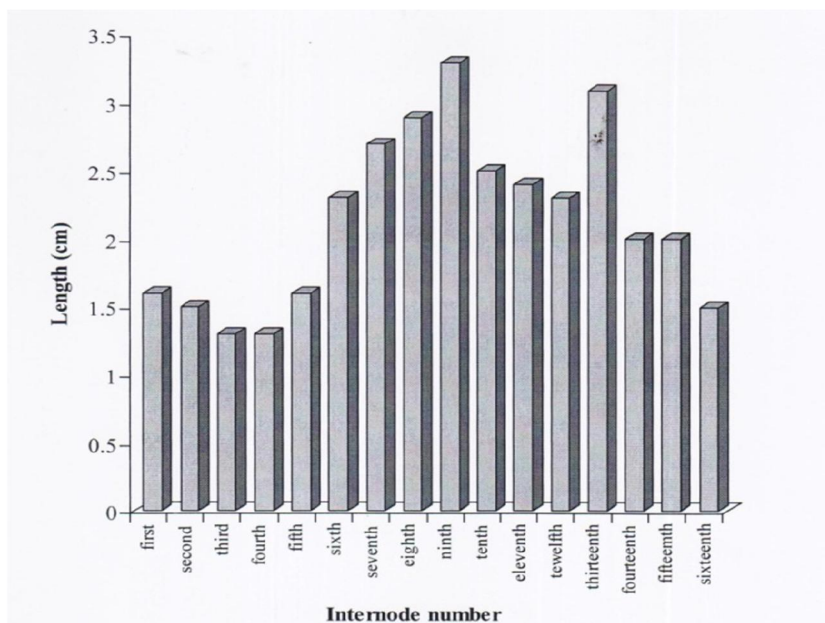
Data included in Table (4) indicate that number of internodes of the main stem averaged 4.1 at 6 weeks old. This number increased significantly at the following sampling dates up to 14 weeks old reaching to an average of 14.2. No further significant increase in number of internodes of the main stem was recorded till the end of the growing season.

### 4- Length of successive internodes of the main stem:

Histogramme shown in Figure (9) representing average length of successive internodes of the main stem of Egyptian Henbane plant at full blooming stage, the age of 16 weeks.

It is clear from Figure (9) that the first internode of the main stem, the basal one, averaged 1.6 cm in length. The length decreased reaching to 1.3 cm for the fourth internode. Average length of internodes then increased gradually up the ninth internode reaching 3.3 cm.

The average length of internodes decreased upwards reaching 2.3 cm for the twelfth internode then increased recording 3.1 cm for the thirteenth internode. The average length of internodes then decreased upwards reaching 1.5 cm for uppermost internode (sixteenth one).



**Fig. 9:** Histogramme representing length of successive internodes of the main stem of *Hyoscyamus muticus* L. at the age of 16 weeks

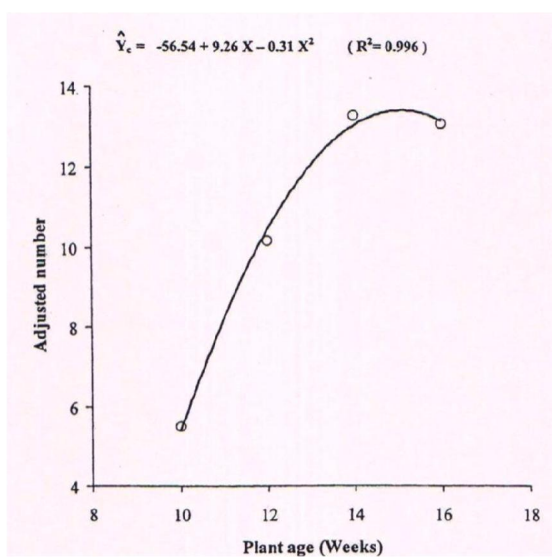
**5- Number of secondary branches/ plant:**

Values belonging to the number of secondary branches of Egyptian Henbane plant during the growing season and their statistical analysis are presented in Table (5). It is evident that a significant cubic effect of periods was recorded for this character. The cubic equation and line of periods and number of secondary branches at successive sampling dates are shown in Figure (10).

**Table 5:** The periodic growth and statistical parameters of number of secondary branches per plant of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean±S.E.	
10	4-7	5.5±0.27	C
12	9-12	10.2±0.33	B
14	12-14	13.3±0.29	A
16	12-14	13.1±0.28	A
L.S.D. (0.05)		0.82 branch.	

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



**Fig. 10:** Graph of regression of number of branches on plant age in *Hyoscyamus muticus* L.

It is obvious that up to the age of 10 weeks Egyptian Henbane plant formed 5.5 secondary branches in average. This number was almost double throughout the following two weeks recording an average number of 10.2 secondary branches. At the age of 14 weeks, the average number of secondary branches increased significantly reaching 13.3. No substantial increment was achieved after this sampling date (14 weeks old). Worthy to state that basal branches play a vital role in yield production. They are mainly responsible of flowering since each of basal branches terminates in an raceme inflorescence.

**d- The leaf:**

Egyptian Henbane plant formed more than 240 leaves. The leaves are simple, pubescent, fleshy, pale green, broadly ovate to rhomboidal and up to about 15 cm long. Midrib broad and have reticulate pinnate venation. The lower ones are petiolate (petiole up to about 9 cm long) and the lamina has two or three large teeth on each side and acuminate apex. The upper leaves are sessile, almost lanceolate and have entire margin.

The above mentioned aspects of Egyptian Henbane leaves are generally in agreement with those reported by Evans (2002).

**1- Number of leaves developed/ plant:**

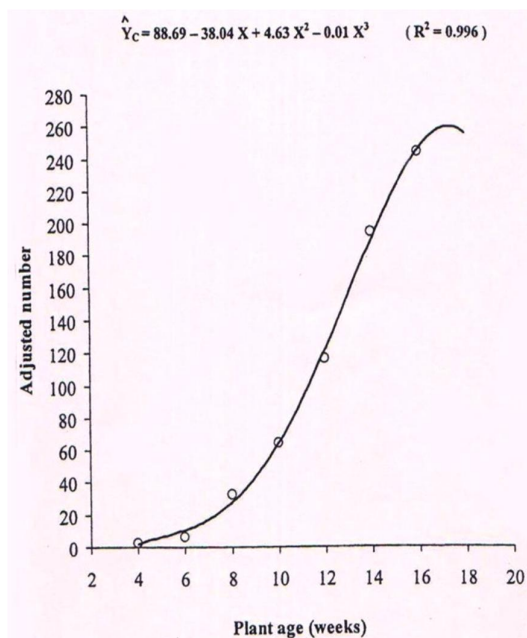
Data pertaining to number of leaves per plant of Egyptian Henbane throughout the growing season and their statistical analysis are represented in Table (6). A significant cubic effect of plant age was detected on this character. The cubic equation and the number of leaves per plant and ages are illustrated in Figure (11).

Results presented in Table (6) clearly show that the increase in number of leaves was statistically indifferent till the age of six weeks, reaching 6.7 leaves in average. In the following periods, leaf number recorded significant prominent increments, being 32.9, 64.8, 116.5, 194.1 and 244.3 leaves at 8, 10, 12, 14 and 16 weeks old; respectively.

**Table 6:** The periodic growth and statistical parameters of total number of leaves per plant of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean±S.E.	
4	2-3	2.7±0.15	F
6	5-8	6.7±0.31	F
8	27-38	32.9±2.28	E
10	56-72	64.8±2.93	D
12	98-134	116.5±3.72	C
14	174-217	194.1±4.63	B
16	223-274	244.3±6.59	A
L.S.D. (0.05)		8.9 leaves	

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



**Fig. 11:** Graph of regression of total number of leaves on plant age in *Hyoscyamus muticus* L.

## 2- Total leaf area/ plant:

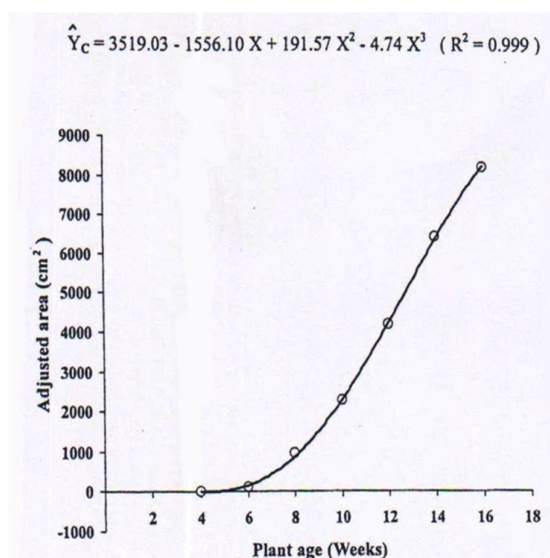
Result of leaf area per plant of Egyptian Henbane throughout the growing season and their statistical analysis are given in Table (7). A significant cubic effect of plant age was found on this character. The cubic equation and line of leaf area per plant throughout successive ages are given in Figure (12).

At sampling dates of 4 and 6 weeks, the leaf area per plant was statistically indifferent, being 121.9 cm<sup>2</sup> at the age of 6 weeks. Significant increments in the leaf area per plant continued throughout the following periods reaching a maximum of 8212 cm<sup>2</sup> at the age of 16 weeks.

**Table 7:** The periodic growth and statistical parameters of total leaf area (cm<sup>2</sup>) per plant of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean±S.E.	
4	16.5-23.1	20.1±0.81	F
6	90.5-143.2	121.9±4.95	F
8	783.4-1102.7	954.8±36.47	E
10	1961.8-2519.7	2268.7±63.58	D
12	3528.6-4823.6	4193.8±133.83	C
14	5759.4-7204.4	6438.5±145.79	B
16	7561.9-9179.8	8212.1±180.4	A
L.S.D. (0.05)		297.5cm <sup>2</sup>	

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



**Fig. 12:** Graph of regression of total leaf area on plant age in *Hyoscyamus muticus* L.

## 3- Fresh weight of leaves/plant:

Values belonging to the fresh weight of leaves of Egyptian Henbane plant throughout the growing season and their statistical analysis are given in Table (8). A significant cubic effect of plant age was recorded on this trait. The cubic equation and line of fresh weight of leaves throughout successive ages are shown in Figure (13).

Data presented in Table (8) clearly show that up to 6 weeks, average fresh weight of leaves was 2.5 g. Thereafter, a gradual significant increase in such weight was achieved reaching to a maximum weight of 434.9 g when plants aged 16 weeks.

**Table 8:** The periodic growth and statistical parameters of fresh weight of leaves (g) per plant of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean±S.E.	
6	1.88-3.04	2.52±0.12	F
8	64.26-90.44	78.23±3.03	E
10	120.39-154.79	139.38±4.95	D
12	203.84-278.72	242.32±7.74	C
14	325.38-405.79	362.97±9.16	B
16	396.94-487.72	434.86±11.25	A
L.S.D. (0.05)		19.48 g.	

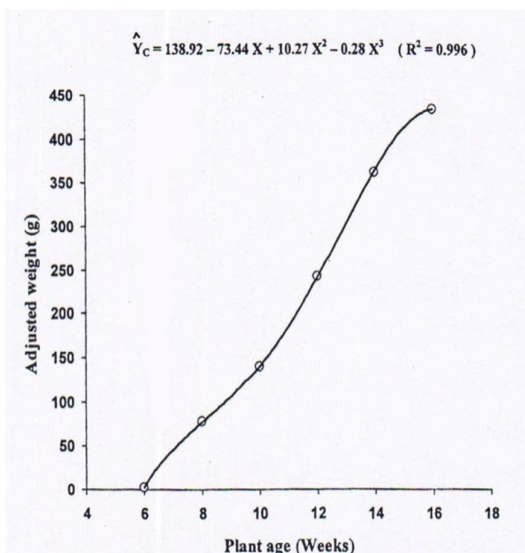


Fig. 13: Graph of regression of fresh weight of leaves on plant age in *Hyoscyamus muticus* L.

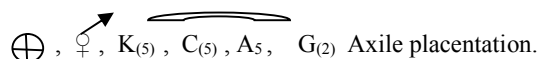
### III- External morphology of reproductive growth:

#### 1- The inflorescences and flowers:

##### a- General characters:

Flowering stage started as flower buds developed when plants aged 10 weeks. As mentioned before, it is evident that Egyptian Henbane is richly branched from the neck. The main stem and each of the basal branches terminate in an raceme inflorescence (Figure 14). Onset of flowering takes place when plants aged 12 weeks, at this age opening of the flower buds on the inflorescence of the main stem started. At the age of 14 weeks number of formed branches reaching to its maximum, being 13 in average, each terminated in an raceme inflorescence with dense flowers at the top. Full blooming and start of fruiting formation take place at the age of 16 weeks (Figure 14).

The flowers are crowded at the ends of the stems, shortly stalked, hypogenous, bisexual, actinomorphic. Each flower has a hairy campanulate-cylindrical calyx, about 3 to 4 cm long with ten longitudinal ribs and five short triangular teeth. The corolla is deep purple with yellowish streaks and five unequal lobes, projecting beyond the calyx. The epipetalous stamens are five, have hairy purple filaments and oblong yellow anthers. Gynoecium is a compound pistil of 2 united carpels, ovary superior of 2 locular, style terminal, ovules very numerous, placentation axile. The flower have the following formula:



The aforementioned characters of Egyptian Henbane flower are generally in harmony with those described by Täckholm (1974), Wallis (1999) and Evans (2002).

##### b- Fresh weight of reproductive organs/plant:

Data of fresh weight of reproductive organs of Egyptian Henbane plant throughout the growing season and their statistical analysis are presented in Table (9). A significant quadratic effect of periods was found on this character. The quadratic equation and line of periods effect on fresh weight of reproductive organs are shown in Figure (15).

At the age of 10 weeks, average fresh weight of reproductive organs per plant was 4.56 g. A significant enhancement in this weight was recorded in the following period reaching 43.94 g when plants aged 12 weeks. At the age of 14 weeks, another substantial increase in fresh weight of reproductive organs was attained. The weight was 179.62 g. At the age of 16 weeks, full blooming stage and start of fruit formation, the weight reached to an average of 302.83 g.



**Fig. 14:** Photographs showing flowers and inflorescences of *Hyoscyamus muticus* L. plant at full blooming stage, age of 16 weeks.

- A- Flowering tops.
- B- Raceme inflorescences in side view.
- C- An enlarged flower in side view.

**Table 9:** The periodic growth and statistical parameters of fresh weight of reproductive organs (g) per plant of *Hyoscyamus muticus* L. throughout the growing season

Plant age in weeks	Range	Mean±S.E.	
10	3.39-5.52	4.56±0.24	D
12	35.17-51.63	43.94±2.01	C
14	146.18-215.91	179.62±7.51	B
16	256.97-342.97	302.83±9.62	A
L.S.D. (0.05)		17.82	

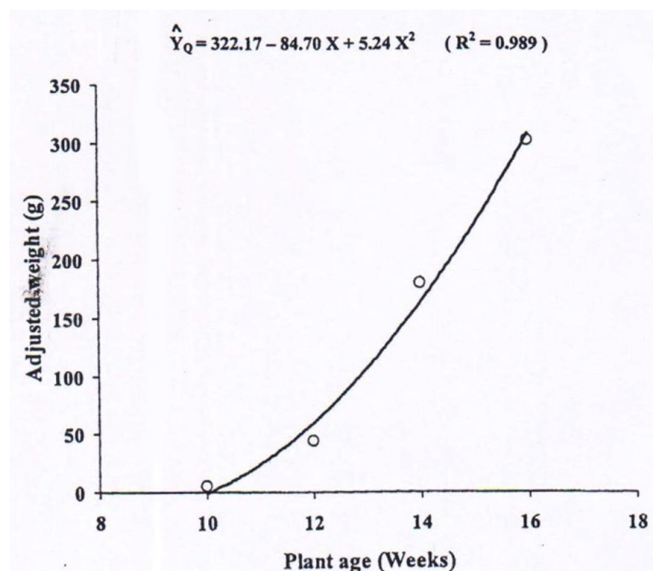


Fig. 15: Graph of regression of fresh weight of reproductive organs on plant age in *Hyoscyamus muticus* L.

## 2- The fruit and seed:

### a- General characters:

Full blooming and start of fruiting formation take place at the age of 16 weeks. Two weeks later more than 70% of the inflorescences developed into fruits. At the age of 20 weeks, all inflorescences developed into fruits. Harvest take place at the age of 18 to 20 weeks, and sometimes continued two weeks later.

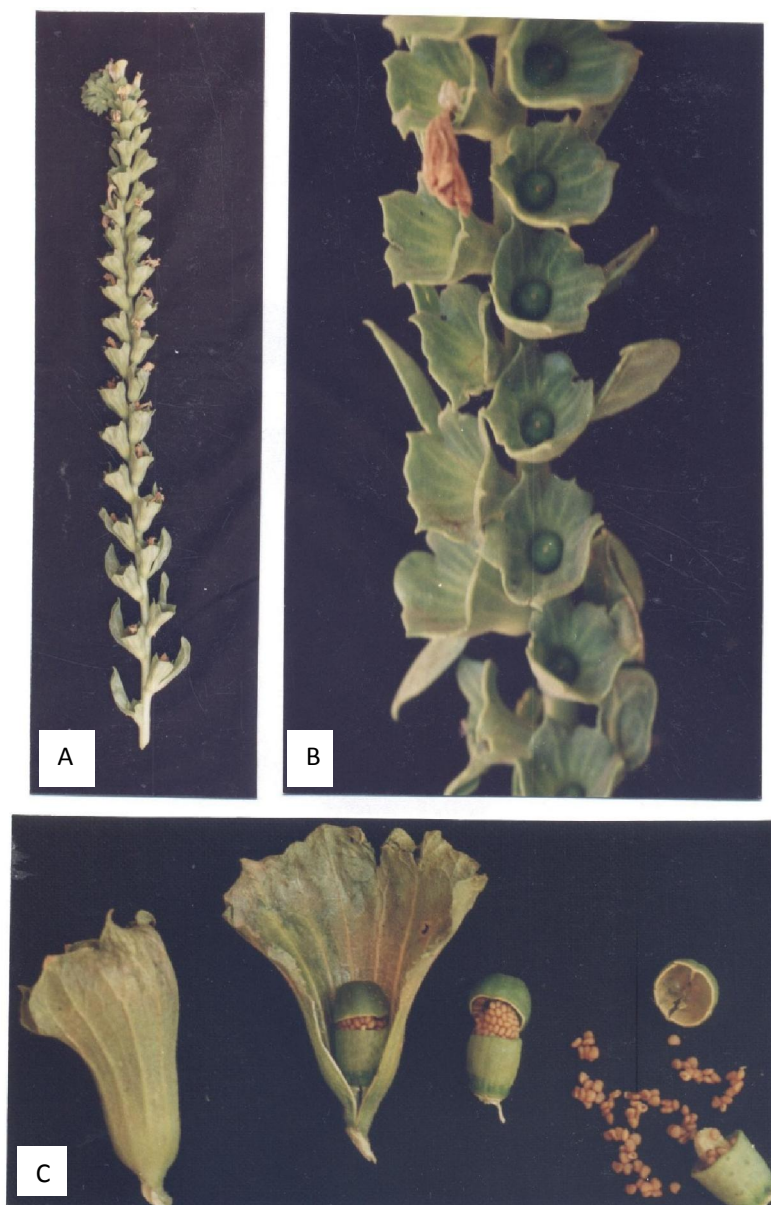
The fruit of Egyptian Henbane (Figure 16) is a bilocular cylindrical pyxis surrounded by a persistent calyx and containing numerous yellowish-grey to brown seeds. The fruit is about 1.5 cm long and 6 mm wide, dehiscent by circular slit around circumference to form an apical lid for dispersal of seeds. Seeds (Figure 17) are very small in size and in weight since one gram comprised of more than 1500 seeds. The seed is flattened, somewhat reniform in shape and about 1 mm in diameter and 0.5 mm in thickness. The seed contains a curved embryo embedded in an oily endosperm. The testa of the seed is marked by fine wavy-walled reticulations.

The abovementioned characters of Egyptian Henbane fruit and seed are agreement with those given by Täckholm (1974) and Wallis (1999) as well as by Boulos (2002) and Evans (2002).

### b- Yield characters:

Results of yield and yield components of Egyptian Henbane plant at harvest time are given in Table (10).

It is clear from Table (10) that average number of harvested inflorescences per plant was about 10.9 inflorescences. Each inflorescence formed an average number of 26.2 fruits (capsules). Therefore, the average number of capsules produced by plant was about 286.1 capsules. The capsule has an average number of 205.9 seeds. Thus, the number of seeds produced by plant was 58415 seeds weight 38.63 gram in average. The average weight of 1000 seeds was about 0.665 g.



**Fig. 16:** Photographs showing inflorescence and fruits of *Hyoscyamus muticus* L. plant at harvest time, age of 20 weeks.

A- Raceme inflorescence in side view.

B- Magnified portion of A in front view showing fruits.

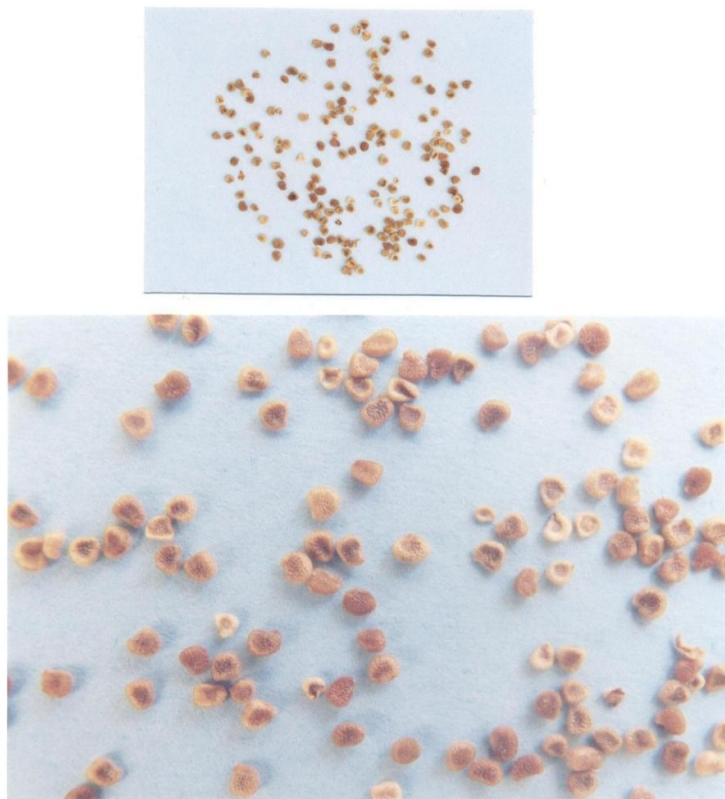
C- Fruit enclosed by persistent calyx, capsular, dehiscent by a circular slit around circumference to form an apical lid for dispersal of seeds.

#### **IV- Alkaloidal content:**

Results belonging to total alkaloids in leaves of Egyptian Henbane throughout the growing season and their statistical analysis are given in Table (11). A significant quadratic effect of plant age was achieved for this character. The quadratic equation and line of total alkaloids and periods at consecutive ages are shown in Figure (18).

Results of total alkaloids at successive ages proved that a steady significant increase from the age of six weeks through the age of 14 weeks where the average content of total alkaloids reached to its maximum, being 45.6 mg/g DW of leaves. Then the content of total alkaloids in leaves showed a significant decline towards the end of the growing season reaching 42.2 mg/g DW of leaves at the age of 16 weeks.





**Fig. 17:** Photographs showing seeds of *Hyoscyamus muticus* L.  
A- Normal size.  
B- Magnified ten times.

**Table 10:** Yield and yield components of *Hyoscyamus muticus* L. plant at harvest time (age of 18 to 20 weeks)

Characters	Range	Mean $\pm$ S.E.
Number of harvested inflorescences / plant .	9 – 13	10.93 $\pm$ 0.38
Average number of fruits / inflorescence .	23.2 – 30.5	26.18 $\pm$ 0.55
Number of fruits / plant .	220 – 366	286.07 $\pm$ 12.06
Average number of seeds / fruit .	176.8 – 233.7	205.9 $\pm$ 4.31
Number of seeds / plant .	47322 – 67172	58415.6 $\pm$ 1644.9
Yield of seeds per plant (g) .	30.69 – 43.01	38.63 $\pm$ 1.08
Average weight of 1000 seeds (g) .	0.59 – 0.76	0.67 $\pm$ 0.02

**Table 11:** Total alkaloids (mg/g DW) in leaves of *Hyoscyamus muticus* L. and their statistical parameters throughout consecutive stages of its entire life span

Plant age in weeks	Range	Mean $\pm$ S.E.
6	24.8 - 31.2	27.5 $\pm$ 0.92 E
8	29.3 - 36.6	33.8 $\pm$ 1.13 D
10	34.3 - 40.5	37.2 $\pm$ 1.46 C
12	38.1 - 43.6	40.9 $\pm$ 1.38 B
14	42.8 - 48.9	45.6 $\pm$ 1.52 A
16	39.2 - 44.5	42.2 $\pm$ 1.29 B
L.S.D.(0.05)		1.96 mg

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

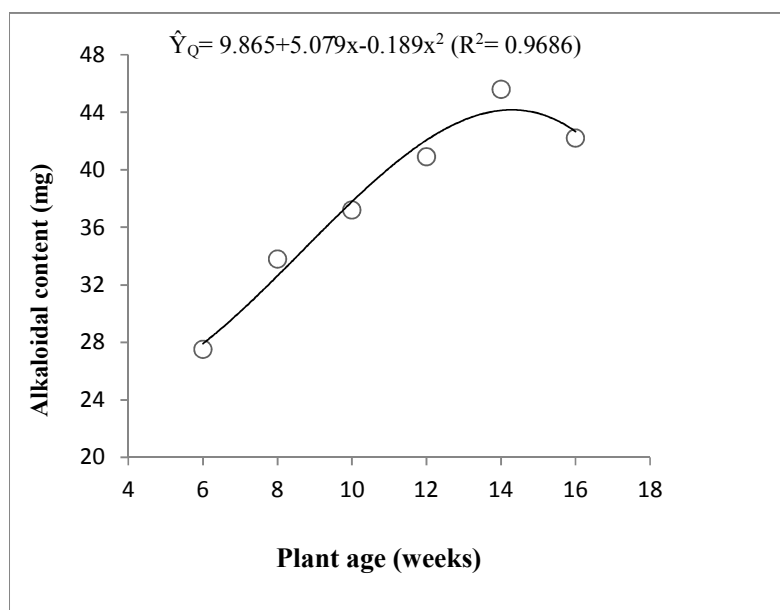


Fig. 18: Graph of regression of total alkaloids of leaves on plant age in *Hyoscyamus muticus* L.

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