

BOTANICAL STUDIES ON *Coriandrum sativum* L. OF THE FAMILY APIACEAE.

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ABSTRACT

Acute difficulties are experienced by taxonomists in arriving at satisfactory classifications of various parts of Apiaceae due to little information available on morphological aspects of different umbelliferous species. Thus, *Coriandrum sativum* L. (Coriander) was chosen to undertake a careful study dealing with germination of seeds and external morphology of vegetative and reproductive growth of this plant throughout the consecutive stages of its entire life span. Such knowledge may fulfill information acquisition in this concern.

The morphology of vegetative growth includes: plant height, length of the main stem, number of internodes of the main stem, length and diameter of successive internodes of the main stem, number of secondary branches, length of secondary branches, number of leaves per plant and fresh weight of leaves per plant.

The morphology of reproductive growth includes: number of compound umbels per plant, number of umbellets per compound umbel, total number of umbellets per plant, number of flowers per umbellet, total number of flowers per plant, total number of cremocarps per plant, yield of cremocarps per plant and specific weight of cremocarps.

Keywords: *Coriandrum sativum* L., Coriander, Apiaceae, External morphology, Vegetative organs, Reproductive organs.

INTRODUCTION

Coriander (*Coriandrum sativum* L.), the subject of the present investigation, is an important culinary herb of the family Apiaceae. It is native to southwestern Asia, west to north Africa. It is believed to have originated in the Mediterranean area (Morocco, Malta, Egypt), and in southwest Europe (Evans, 2001). Now, Coriander is extensively cultivated in many temperate countries for its flavouring leaves and fruits. The material of commerce comes mostly from Morocco, Bulgaria, Romania, Turkey, India, France and the former USSR (Kapoor, 1990; Wichtl and Bisset, 1994 and BHP, 1996).

The name Coriander derives from Latin *Coriandrum*, which was first noted by Pliny. The Latin word derives in turn from Greek *corys*, a bedbug, plus *ander*, "resembling", and refers to the supposed similarity of the scent of the crushed leaves to the distinctive odour of bedbugs.

Coriander is an annual herb cultivated for its flavouring leaves and fruits. It is a soft, hairless, foetid plant growing to 50 cm tall. The leaves are variable in shape, broadly lobed at the base of the plants, and slender and feathery higher on the flowering stems. The flowers are borne in small umbels, white or very pale pink, asymmetrical, with the petals pointing away from the centre of the umbel longer (5-6 mm) than those pointing to the middle of the umbel (only 1-3 mm long). The fruit is a globular dry schizocarp 3-5 mm diameter.

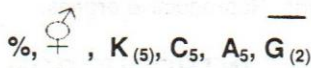
Shukla and Misra (1979) described vegetative and reproductive organs of Coriander as follows:

Vegetative characters: A branched tap root. Stem erect, cylindrical, branched, hollow, herbaceous, glabrous, aromatic, green. Leaves alternate, exstipulate, sessile, sheathing leafbase, decomposed, 2-4 pinnate, upper segments ovate or lanceolate with serrate margins, the upper leaves have linear segments, green glabrous, leaflets 2-3 lobed, lobes linear, ovate or lanceolate, entire or serrate, venation reticulate unicostate, usually the leaves are aromatic.

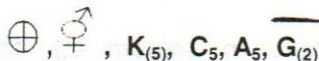
Floral characters: Inflorescence a compound umbel, involucre and involucrel reduced or absent. Flowers ebracteate, pedicellate, complete, outer flowers zygomorphic, inner actinomorphic, bisexual, epigynous, pentamerous, cyclic, white. Sepals 5, fused, 5 toothed, valvate, slightly petaloid. Petals 5, free, bifid at apex, unequal in the outer flowers-two posterior petals smaller than the three anterior ones, in the inner flowers the petals are of equal size, imbricate, white. Stamens 5, free, alternate with petals, filaments as long or slightly shorter than the petals, anthers dorsifixed, bithecal, dehiscent longitudinally, introse. Carpels 2, pistil syncarpous, ovary inferior, bilocular, each locule with a single pendulous ovule, ovary placed antero-posteriorly, styles 2, terminating the stylopodium, a bilobed nectar secreting disc lying at the base of style, stigma capitate. Fruit subglobose cremocarp with less prominent ridges and vittae or oil cavities under the secondary ridges. Seeds endospermic, concave and about thrice as broad as thick.

Floral Formula:

Outer flowers:



Inner flowers:



Bunney (1992) mentioned that Coriander is an annual herb with an erect, furrowed, solid, branched stem. The alternate leaves are pinnate or bipinnate, the lower ones with broader leaflets than the upper ones which are finely divided. The white or pink flowers, with outer petals longer than the inner ones, are arranged in compound umbels. The fruit is an ovoid, ribbed, red-brown double achene. All parts of the plant smell strongly of bed bugs. However, the fruits lose their disagreeable scent when they ripen and become pleasantly spicy and aromatic.

Pandey (2003) pointed out that the plant is generally 2-3 feet in height, with white or pinkish flowers. The lower leaves have broad segments, while the upper are very narrow. The fruits are small, oval and aromatic. Technically the fruit is known as "cremocarp". Each fruit consists of two one-seeded carpels, or mericarps with numerous oil ducts (vittae).

Wallis (1999) as well as Evans (2001) mentioned that the fruits of Coriander occur usually as entire cremocarps, which are sub-spherical, about 3 to 5 mm in diameter, brownish-yellow, crowned by five small sepals and a stylopod.

The aforementioned information dealing with different aspects of Coriander has been compiled from various sources; i.e., Parry (1945), Harrod (1960), Heywood (1971), Hedge and Lamond (1972), Girenko (1974), Harten

(1974), Kuzina (1975), Dimri *et al.* (1976), Lukjanov and Reznikov (1976), Jansen (1981), Baswana (1984), Ljubavina (1984), Cernodubov and Berestovaja (1986), Mouterde (1986), Agrawal *et al.* (1990), Ivanova and Stoletova (1990), Kapoor (1990), Bhandari and Gupta (1991), Bunney (1992), Pimenov and Leonov (1993), Wichtl and Bisset (1994), BHP (1996), Leung and Foster (1996), Lange and Schippmann (1997), Wallis (1999), Mohamed (2000), Evans (2001), Dewick (2002), Pandey (2003) and Fragiska (2005).

The present study intends to introduce a detailed botanical information about the morphology of vegetative and reproductive growth of *Coriandrum sativum* L. plant throughout the consecutive stages of its entire life span. This would be an effort to proper delimitation of this species in the family Apiaceae and even more such knowledge would be useful to specialists in various aspects of biology of such plant.

MATERIALS AND METHODS

The current investigation was performed on *Coriandrum sativum* L. (Coriander) of the family Apiaceae (Umbelliferae).

Seeds were procured from the Experimental Station of Medicinal Plants, Faculty of Pharmacy, University of Cairo, Giza, Egypt.

Test of germination:

Germination of the investigated species was followed up. Seeds were planted in pots filled with light loamy soil. 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 Centre, Giza to determine the speed and the capacity of germination according to the Rules for Seed Testing (Anonymous., 1985). Recommended conditions of germination for Coriander seeds are summarized as follows:

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

Field work procedure:

The field work was carried out in the Agricultural Experiments and Researches station, Faculty of Agriculture, Cairo University, Giza, Egypt during the growing season of 2004 / 2005 to provide the experimental plant material. Date of cultivation was October 4th, 2004. The trial included five replicates, each represented by one plot. The plot was 4x5 m. with eight ridges 60 cm. a part. Seeds were sown in hills spaced 20 cm. the plants were thinned to two plants per hill. All field practices were carried out as recommended for Coriander 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-week intervals to follow up the vegetative growth of Coriander 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 of the base of the terminal compound umbel when being developed.
- 3 - Number of internodes of the main stem.
- 4 - Length (cm.) and diameter (mm.) of successive internodes of the main stem.
- 5 - Number of secondary branches per plant.
- 6 - Length of secondary branches, cm.
- 7 - Number of leaves per plant.
- 8 - Fresh weight of leaves per plant, g.

II-Reproductive characters and yield Components:

Various parameters of the yield of Coriander plant were recorded throughout the growing season. Flowering period was determined; i.e., date of flowering onset and end was assigned. Time taken for different reproductive developmental stages was fixed; i.e., flower bud differentiation, anthesis, full blooming and fruit set and maturity.

General characters and a detailed description of various reproductive organs were reported. The following characters were recorded:

- 1 - Total number of compound umbels per plant, at two week- intervals.
- 2 - Number of umbellets per compound umbel.
- 3 - Total number of umbellets per plant.
- 4 - Number of flowers per umbellet.
- 5 - Total number of cremocarps per plant.
- 6 - Yield of cremocarps per plant, g.
- 7 - Specific weight of cremocarps, g.(weight of 1000 cremocarps).

RESULTS AND DISCUSSION

I- External morphology:

1- Germination of seeds and seedling growth:

The seeds occur usually as entire cremocarps. The double seeded fruit is usually sown entire, since the carpel does not open to liberate the seed. Coriander fruits are sub-spherical (almost globular in shape) about 3 to 5 mm in diameter with alternating straight and wavy ridges. The fruit with short length (2-3 mm) of stalk attached and yellowish-brown in colour.

Seeds imbibe water as a first step in the sequence of events leading to germination. As a result, the seed and fruit coats soften and swell and burst at the basal end of the seed. This lasted about 48 hours from sowing. As germination proceeds, the structure of the seedling soon becomes evident. The radicle emerges from the lower end where the seed has been bursted. This takes about four days. Seed germination of Coriander is epigeal, the hypocotyl elongates and raises the two cotyledons above the ground accompanied by the partially enveloping remains of the seed. This almost takes place six days after

sowing. The hypocotyl is somewhat bent in its growth before emergence above the soil, then becomes straight towards the age of eight days. The two cotyledons take an accumbent position. The completely developed cotyledons are narrowly lanceolate averaged 29 mm in length and 5 mm in width. Cotyledons have pinnately netted venation and a complete margin. By now, the plumule is also upward; the secondary roots developed.

At the age of two weeks, the first 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 15 cm. The radicle averages 4.5 cm long and the hypocotyl is some 5.5 cm. long (Figure 1). The first two foliage leaves are simple and the lamina of each is pinnately lobed.

The rules of germination given by ISTA (Anon., 1985) were followed. The germination speed (after 7 days) was 51.7% and the germination capacity (after 21 days) was 82.9%.

2- The root system:

The primary root, tap root, of Coriander starts its development from the hypocotyl of the embryo. Directly below the hypocotyl the radicle is as thick as the hypocotyl, then tapering toward the growing point. 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 of different branching degrees; i.e., secondary, tertiary and so on.

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.

3- The stem:

a- General characters:

As seedling stage comes to an end (age of two weeks), the plumule starts a prominent development to produce the shoot. When plants are four weeks old, internodes are too short to be detected easily. However, four foliage leaves are developed in a rosette form. The first two foliage leaves are simple and the lamina of each is pinnately lobed. The third foliage leaf is pinnately compound with leaflets three. The fourth foliage leaf is imparipinnately compound with leaflets five. Worthy to note that the two cotyledons are still intact at this age.

When plants are six weeks old, the newly developing internodes are also dwarf and not detected easily. The number of developing leaves averages thirteen. The two cotyledons shrivelled and defoliated. The newly forming leaves at this age, from the fifth to the thirteenth, are bipinnate compound leaves and being large in size.

At the age of eight weeks, plant still has very short stem (about 2 cm in length) and their internodes are not distinguished. The number of developing leaves averages eighteen. The newly forming leaves in this age are also bipinnate compound and large in size (Fig. 2).

When plants are ten weeks old, the main stem is easily determined due to the elongation of internodes upward its basal portion. The internodes are almost seven in number and the main stem being 40 cm long.

This age accompanied by an active development of the axillary buds to produce secondary branches which started from the basal portion of the main stem; i.e., the main stem with several side branches at its basal portion. The number of branches developed at this age reaching seven. The newly developing leaves on the elongated main stem and those on lateral branches are small in size, tripinnately compound and leaflets are parted into linear-lanceolate segments.

Flowering stage starts at plant age of 12 weeks (Fig. 3). The main stem being 56 cm in length and number of internodes being some nine. The number of secondary branches at this age being some 12, and the leaves develop onward are finely divided feathery pinnate.

At the age of 14 weeks, the main stem almost attains its maximum length, being 67 cm. The number of branches also attains its maximum, being 15 in number.

Full blooming and start of fruiting formation take place at the age of 16 weeks (Fig. 4). At this age, the large bipinnate compound leaves formed on the basal portion of the main stem are shrivelled and defoliated.

At the age of 20 weeks, all inflorescences developed into fruits; i.e., this age represents full fruiting stage.

Coriander is an annual herb and strongly aromatic. The stem is more or less erect and sympodial, monochasial-branched, usually with several side branches at its basal portion (Fig. 5). The shoot apex develops into a compound umbel. Similarly, each secondary branch ends into a compound umbel with the arrest of the elongation of the branch. The colour of the more or less ribbed stem is green and sometimes turns to red or violet during the flowering period. The stem is solid and being hollow at maturity. The leaves alternate and the first ones are often gathered in a rosette. The plant is diversifolious.

The morphological description here given for stem of Coriander plant is in accordance with that recorded by Shukla and Misra (1979) and Bunney (1992).

b- Plant height:

Data pertaining to plant height of Coriander throughout the growing season and the results of 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 presented in Figure (6).

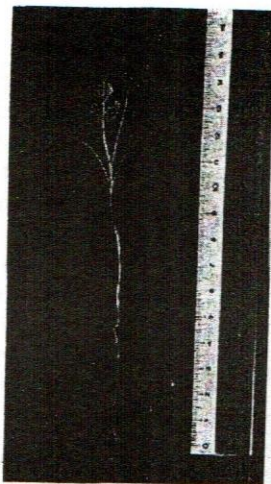


Fig. (1): A photograph of completely developed seedling of *Coriandrum sativum* L., two weeks old showing its epigeous pattern of growth where the two cotyledons are brought above the soil. The first two foliage leaves are developed, they are simple and the lamina of each is pinnately lobed.

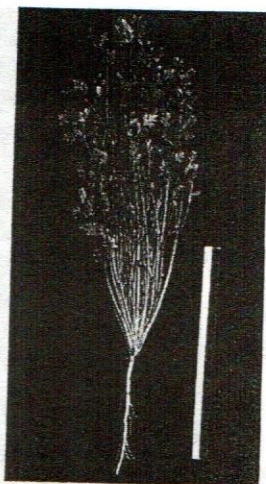


Fig. (2): A photograph of *Coriandrum sativum* L. plant at the age of eight weeks. plant still has very short stem (about 2 cm in length). The number of developing leaves averages eighteen. The newly forming leaves in this age are also bipinnate compound and large in size.

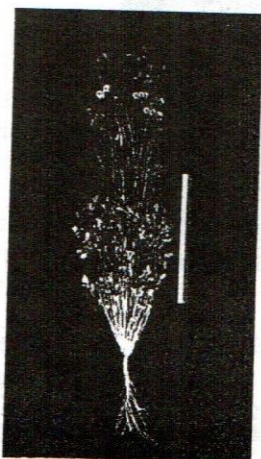


Fig. (3): A photograph of *Coriandrum sativum* L. plant at the age of 12 weeks. The main stem easily determined due to the elongation of internodes upward its basal portion. This accompanied by an active development of the axillary buds to produce secondary branches which started from the basal portion of the main stem. The newly developing leaves on the elongated main stem and those on lateral branches are small, in size, tripinnately compound and leaflets are parted into linear - lanceolate segments. At this age, flowering stage starts.

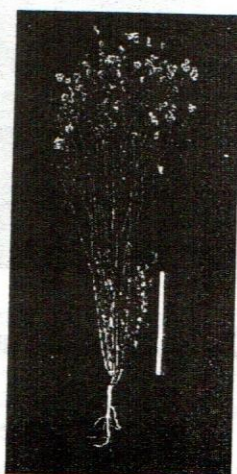


Fig. (4): A photograph of *Coriandrum sativum* L. plant at the age of 16 weeks. At this age, the large bipinnate compound leaves formed on the basal portion of the main stem are shrivelled and defoliated. Full blooming and start of fruit formation take place at this age.

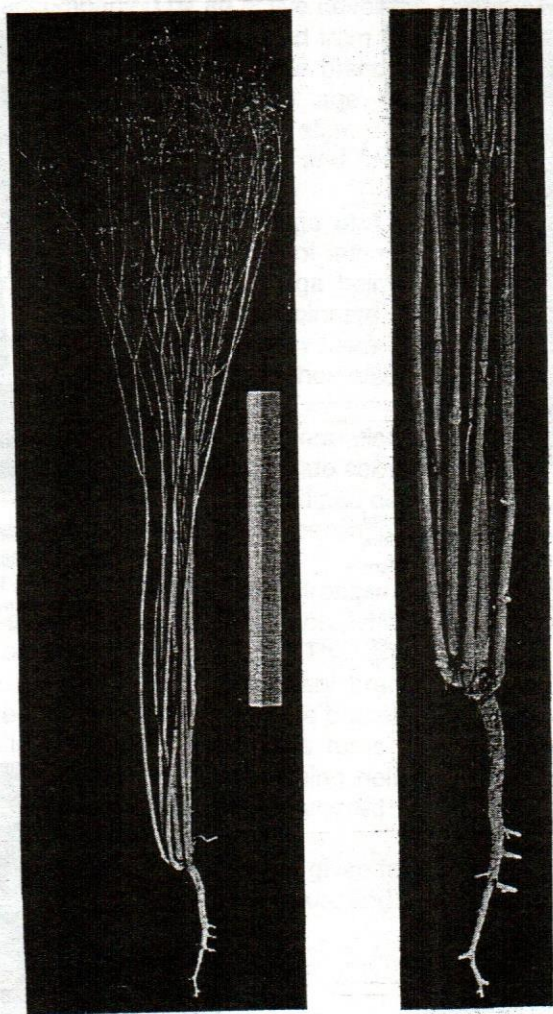


Fig.(5): A photograph of completely mature plant of *Coriandrum sativum* L. one month after harvest time at left. The stem usually with several side branches at its basal portion as clearly shown in the magnified basal portion at right.

It is obvious 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. The maximum height was recorded at the age of 18 weeks (112.1 cm), which in turn being statistically indifferent with the height recorded at the age of 14 weeks (106.4 cm). No further increment was recorded till the end of the growing season. This means that Coriander plant attains its maximum height, generally, at the age of 14 weeks. Worthy to note that the elongation rate of plant was much higher in the period 8 to 10 weeks old, through these period the plant height increased from 45.4 to 78.6 cm. Such increment (33.2 cm) represented 29.6% of the final plant height (112.1 cm). The most active period of elongation (8 to 10 weeks old) occurred prior to flowering stage which starts at plant age of 12 weeks.

c- Length of the main stem:

Results belonging to length of the main stem of Coriander plant during the growing season and their statistical analysis are given in Table (2). A significant cubic effect of plant age was detected for this character. The cubic equation and line of length of the main stem and periods are shown in Figure (7).

Data of length of the main stem at successive ages proved that a significant increment in length occurred from the age of eight weeks through the age of 14 weeks where the average length was 67.36 cm. This was statistically indifferent with the average length recorded at 16 weeks old, being 70.86 cm. It is clear that the average lengths at 18 and 20 weeks old (65.97 and 66.82 cm ; respectively) were statistically indifferent with each other and with that reached at the age of 14 weeks. Worthy to note that the period of 8 to 10 weeks old was the most active one throughout the entire growing season, since the length of the main stem increased from 2.08 to 41.58 cm. Such increment (39.5 cm), which was added during these two weeks represented 55.74% of the final length of the main stem (70.86 cm). It is realized that the most active period of stem elongation (8 to 10 weeks old) was similar to that found in plant height character, occurred just prior to flowering stage which starts at plant age of 12 weeks.

It is obvious 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 14 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.

d- Number of internodes of the main stem:

Values in Table (3) show number of internodes of the main stem of Coriander 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.

Data presented in Table (3) reveal that number of internodes of the main stem were 1.3, 6.6 and 8.4 at the ages of 8, 10 and 12 weeks; respectively. No further increase in number of internodes of the main stem was recorded till the end of the growing season.

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

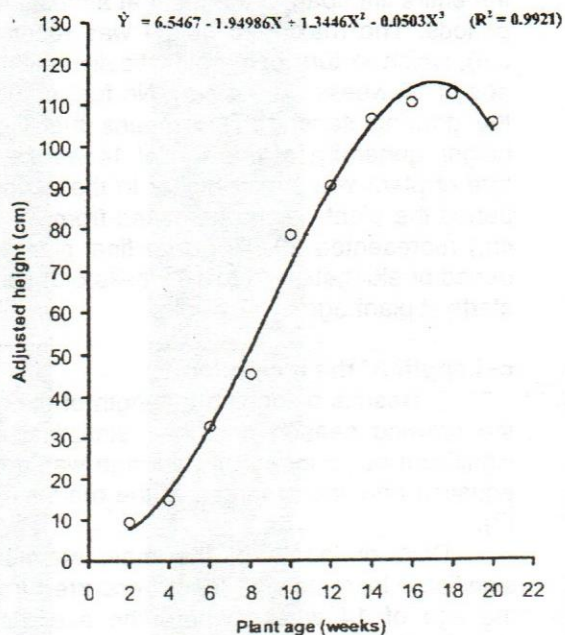
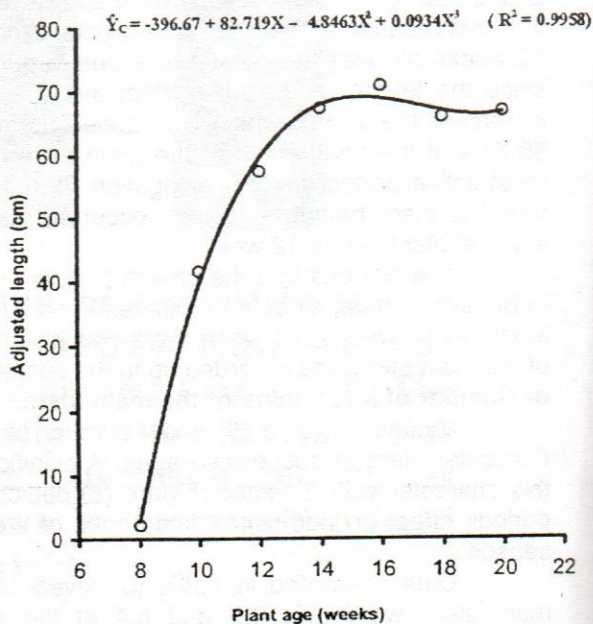
Plant age in weeks	Range	Mean \pm S.E.	
2	8.0 - 11.5	9.4 \pm 0.39	F
4	11.0 - 18.0	14.8 \pm 0.78	F
6	28.0 - 38.0	32.9 \pm 1.20	F
8	36.0 - 51.0	45.4 \pm 1.68	D
10	64.0 - 92.0	78.6 \pm 3.31	C
12	73.0 - 105.0	90.2 \pm 3.46	B
14	87.0 - 123.0	106.4 \pm 4.05	A
16	91.0 - 126.0	110.2 \pm 3.99	A
18	93.0 - 127.0	112.1 \pm 3.97	A
20	85.0 - 122.0	105.3 \pm 4.11	A
L.S.D. (0.05)		7.59 cm.	

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

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

Plant age in weeks	Range	Mean \pm S.E.	
8	1.5 - 2.8	2.08 \pm 0.14	D
10	34.9 - 50.8	41.58 \pm 1.79	C
12	47.7 - 64.9	56.52 \pm 2.22	B
14	59.4 - 74.6	67.36 \pm 1.77	A
16	62.9 - 77.4	70.86 \pm 1.66	A
18	59.8 - 74.5	65.97 \pm 1.55	A
20	59.5 - 73.2	66.82 \pm 1.44	A
L.S.D. (0.05)		9.13 cm	

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

Fig. (6): Graph of regression of plant height on plant age in *Coriandrum sativum* L.Fig. (7): Graph of regression of main stem length on plant age in *Coriandrum sativum* L.

It was mentioned earlier that the basal portion of the main stem composed of a few number of compressed internodes which remain compact and are not distinguished throughout the whole life of plant. They were here excluded when internodes were counted. Worthy to note that the growth rate in number of internodes of the main stem conformed to those of main stem length and plant height, previously mentioned. It was found that no substantial increase in these characters was recorded after the age of 14 weeks. This also proves the determinate pattern of growth in the main stem of Coriander plant.

e- Length and diameter of successive internodes of the main stem:

Results in Table (4) and Figure (9) represent range and average of length and diameter of successive internodes of the main stem 20 weeks old. Plants were in full fruiting stage.

It is clear from Table (4) that the compact internodes of the basal portion of the main stem averaged 1.8 cm in length as a whole. The average length of the first measurable internode just above the basal portion of the main stem was 1.5 cm. The length increased gradually reaching 11.8 cm for the fifth internode. Average length of internodes then decreased steadily reaching 5.8 cm for the ninth internode (the uppermost internode which terminated in an inflorescence).

With respect to the main stem diameter, internodes were relatively thick at base and tapering toward top, being 7.8, 11.1 and 4.8 mm in diameter for internode number 1, 5 and 9; respectively.

f- Number of secondary branches:

Data pertaining to number of secondary branches of Coriander 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 equation and line of periods and number of secondary branches at successive sampling dates are illustrated in Figure (10).

Up to the age of 10 weeks Coriander plant formed 7.1 secondary branches. This number was almost double throughout the following 4 weeks recording 14.6 secondary branches. No substantial increment was achieved after this sampling date (14 weeks old); i.e., the developing secondary branches were the same till the end of the growing season. Worthy to state that lateral branches play a vital role in yield production. They are mainly responsible of flowering.

g- Length of secondary branches:

Results belonging to range and length of secondary branches of Coriander plant toward the end of the growing season (20 weeks old) are given in Table (6) and Figure (11). It is clear that the main stem of Coriander plant is monochasial-branched and usually with several side branches at its basal portion. Lateral shoot of Coriander plant developed in an acropetal succession; i.e., developing upward from the base toward the apex. The first six to eight branches developed on the basal portion of the main stem were the longest branches and averages from 91.3 to 103.5 cm. The average length of secondary branches then decreased gradually reaching a minimum of 38.5 cm for the uppermost one, sixteenth branch. This branch ranged from 33.8 to 46.2 cm.

Table (3): The periodic growth and statistical parameters of number of internodes of the main stem of *Coriandrum sativum* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.
8	1 - 2	1.3 ± 0.15 C
10	6 - 8	6.6 ± 0.26 B
12	7 - 9	8.4 ± 0.26 A
14	7 - 9	8.5 ± 0.22 A
16	8 - 10	8.7 ± 0.21 A
18	7 - 9	8.4 ± 0.22 A
20	8 - 9	8.6 ± 0.16 A
L.S.D. (0.05)	1.50 internode	

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

Table (4): Length (cm) and diameter (mm) of successive internodes of the main stem of *Coriandrum sativum* L. at the age of 20 weeks (full fruiting stage)

Internode number	Range	Mean ± S.E.
First internode	1.4 - 1.7	1.5 ± 0.13
Second internode	2.3 - 3.1	2.7 ± 0.11
Third internode	7.6 - 10.2	8.4 ± 0.96
Fourth internode	9.2 - 11.5	10.3 ± 0.75
Fifth internode	10.4 - 13.1	11.8 ± 0.84
Sixth internode	8.2 - 10.5	9.5 ± 0.56
Seventh internode	7.6 - 9.8	8.2 ± 0.62
Eighth internode	6.6 - 8.4	7.4 ± 0.48
Ninth internode	5.1 - 6.9	5.8 ± 0.29

Character	Range	Mean ± S.E.
Length of the basal portion	1.6 - 2.0	1.8 ± 0.09
Diameter of the first internode (basal one)	15.9 - 19.6	17.8 ± 0.64
Diameter of the fifth internode (median one)	9.4 - 12.3	11.1 ± 0.52
Diameter of the ninth internode (apical one)	4.6 - 5.2	4.8 ± 0.27

$$\hat{Y}_C = -60.881 + 13.555X - 0.8649X^2 - 0.0181X^3 \quad (R^2=0.9906)$$

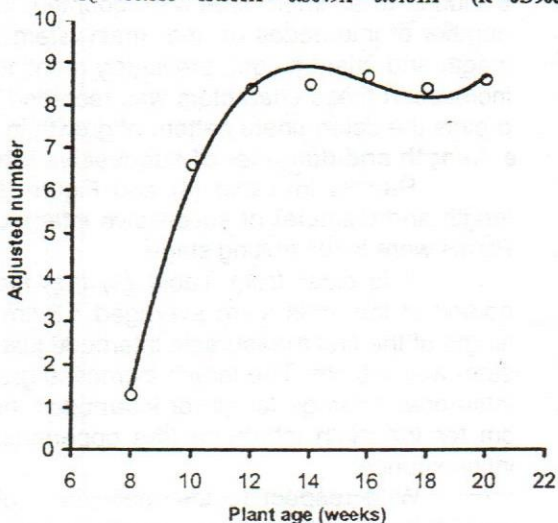


Fig.(8): Graph of regression of number of internodes of the main stem on plant age in *Coriandrum sativum* L.

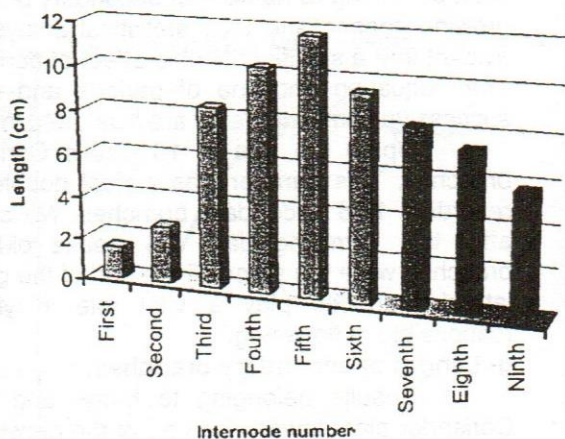


Fig. (9): Histogramme representing length of successive internodes of the main stem of *Coriandrum sativum* L. at the age of 20 weeks

Table (5): The periodic growth and statistical parameters of total number of secondary branches of *Coriandrum sativum* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.
10	6 - 8	7.1 ± 0.27 C
12	10 - 12	11.2 ± 0.29 B
14	14 - 15	14.6 ± 0.23 A
16	13 - 16	14.7 ± 0.58 A
18	14 - 15	14.5 ± 0.26 A
20	13 - 16	14.6 ± 0.47 A
L.S.D. (0.05)	1.47 branch	

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

Table (6): Range and average of length of secondary branches (cm) of *Coriandrum sativum* L. at the age of 20 weeks (full fruiting stage)

Branch number	Range	Mean ± S.E.
First branch	73.9 - 107.5	91.3 ± 4.2
Second branch	77.5 - 108.3	95.4 ± 6.3
Third branch	83.7 - 112.9	100.6 ± 5.8
Fourth branch	93.0 - 114.5	101.8 ± 4.9
Fifth branch	88.5 - 116.2	103.4 ± 6.8
Sixth branch	89.7 - 120.5	103.5 ± 9.5
Seventh branch	91.6 - 110.8	98.4 ± 4.6
Eighth branch	89.2 - 105.8	96.2 ± 5.3
Ninth branch	77.9 - 115.6	95.8 ± 9.7
Tenth branch	67.0 - 110.5	90.8 ± 9.1
Eleventh branch	65.8 - 107.4	84.6 ± 7.2
Twelfth branch	61.5 - 92.7	72.4 ± 4.8
Thirteenth branch	56.5 - 75.5	66.8 ± 6.9
Fourteenth branch	46.5 - 67.0	56.3 ± 5.4
Fifteenth branch	32.4 - 58.9	45.6 ± 3.7
Sixteenth branch	33.8 - 46.2	38.5 ± 1.6

$$\hat{Y}_C = -79.935 + 15.896X - 0.8827X^2 + 0.0162X^3 \quad (R^2 = 0.9871)$$

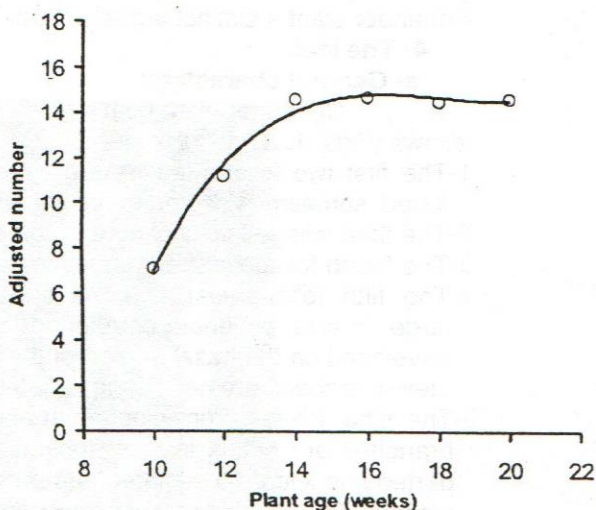


Fig.(10): Graph of regression of total number of secondary branches on plant age in *Coriandrum sativum* L.

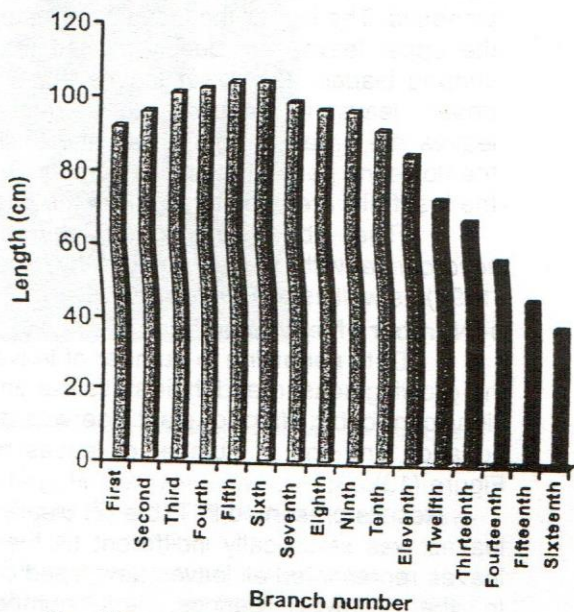


Fig. (11): Histogramme representing length of secondary branches of *Coriandrum sativum* L. at the age of 20 weeks.

It is important to note that the growth pattern of the lateral shoot where a gradual decrease in branches length was achieved upward gave the shoot of Coriander plant a distinct umbel shape. This is shown in Figure (4).

4- The leaf:

a- General characters:

Coriander plant bears different foliage leaf types. These types are as follows (Figs. 1, 3 and 12).

- 1-The first two foliage leaves are simple and the lamina of each is pinnately lobed, sometimes seems to be pinnatifid.
- 2-The third foliage leaf is pinnately compound with leaflets three.
- 3-The fourth foliage leaf is imparipinnately compound with leaflets five.
- 4-The fifth foliage leaf and the subsequent leaves till the eighteenth are large, in size, bipinnate compound leaves. All these leaves are stalked and developed on the basal portion of the main stem, which remain compact and their internodes are not distinguished throughout the whole life of plant.
- 5-The other leaves, from nineteenth and upward including those on the lateral branches are small, in size, tripinnately compound leaves and leaflets are parted into linear-lanceolate segments. The leaf being finely divided feathery pinnate. The petiole is reduced to a small, nearly amplexicaul leaf sheath.

Generally, it could be stated that Coriander plant is diversifolious. The leaves alternate, and the first ones are often gathered in a rosette. The blade shape of the basal leaves is usually either undivided with three lobes, or tripinnatifid, while the leaves of the nodes following are to a higher degree pinnatifid. The higher the leaves are inserted, the more pinnate they are. Thus, the upper leaves are deeply incised with narrow lanceolate or even filiform-shaped blades. The lower leaves are stalked, while the petiole of the upper leaves is reduced to a small, nearly amplexicaul leaf sheath. The leaves are green or light green and their underside often shiny waxy. During the flowering period the leaves sometimes turn red or violet. They wither before the first fruits are ripe starting from the basal leaves.

The above mentioned characters of Coriander leaves are in accordance with those reported by Shukla and Misra (1979) and Bunney (1992) as well as by Pandey (2003).

b- Number of leaves per plant:

Data pertaining to number of leaves per plant of Coriander throughout the growing season and their statistical analysis are represented in table (7). A significant cubic effect of plant age was detected on this character. The cubic equation and line of number of leaves per plant and ages are illustrated in Figure (13).

Results presented in Table (7) clearly show that the increase in number of leaves was statistically indifferent till the age of eight weeks, reaching 17.5 leaves represented all leaves developed on the basal portion of the main stem. In the following periods, leaf number recorded significant prominent increments, being 139.9, 362.8 and 529.5 leaves at 10, 12 and 14 weeks old, respectively. The maximum number of leaves per Coriander plant (529.5) was detected at the age of 14 weeks which being statistically indifferent with that recorded at the age of 16 weeks (509.9 leaves) or with that recorded at the age of 18 weeks (501.7 leaves).

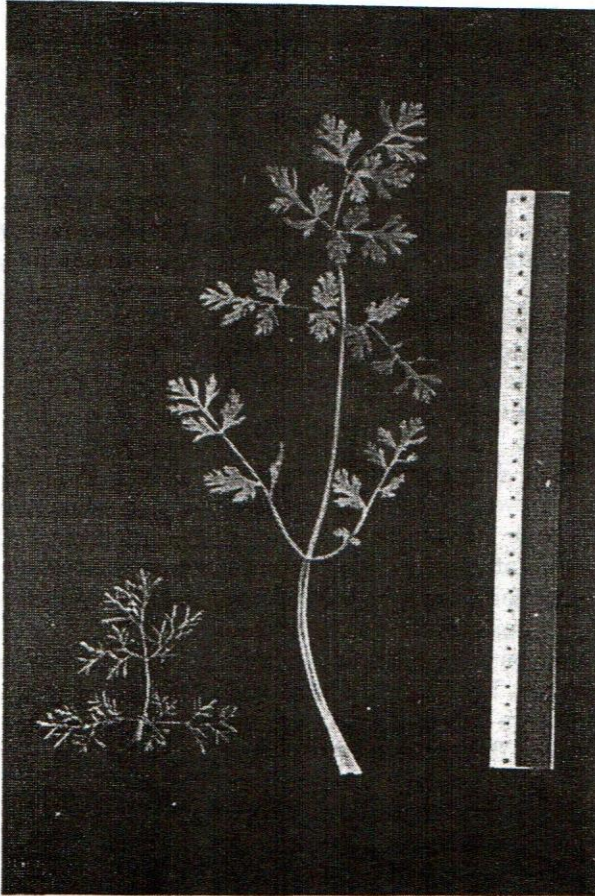


Fig. (12): A photograph of some leaf types formed by *Coriandrum sativum* L. plant, ten weeks old.

Right: Bipinnate compound leaf, large in size, represents most leaves formed on the basal portion of the main stem from the fifth foliage leaf till the eighteenth leaf.

Left: Tripinnately compound leaf, represents upper leaves, small in size, leaflets are parted into linear lanceolate segments, the leaf being finely divided feathery pinnate.

The number of leaves than decreased towards the end of the growing season reaching 448.9 leaves at the age of 20 weeks old due to normal shrivel and defoliation.

It is worthy to note that the leaf number was statistically indifferent during the period prior to formation of the lateral branches, where leaves developed on the main stem. But, when main stem elongated and secondary branches formed (beginning at 10 weeks old) number of leaves increased significantly; i.e., the lateral branches played the main role in bearing the leaves.

c- Fresh weight of leaves per plant:

Data in Table (8) exhibit fresh weight of the leaves per plant of Coriander throughout the growing season and their statistical analysis. A significant cubic effect of plant age was recorded on this character. Figure (14) depicts the cubic equation and line of fresh weight of leaves and ages.

It is realized from Table (8) that up to four weeks old, average fresh weight of leaves was 1.53 g. A steady significant increase occurred thereafter reaching 217.06 g when plants aged 14 weeks. Then the weight showed a significant decline towards the end of the growing season reaching 67.48 g at the age of 20 weeks due to normal shrivel and abscission of basal leaves.

5- The inflorescence and flowers:

a- General characters:

Flowering stage starts at plant age of 12 weeks. Most of developing inflorescences bear flowers in form of flower buds. Anthesis, however, takes place when plants are 14 weeks old. Full blooming and start of fruiting formation take place at the age of 16 weeks. When plants are 20 weeks old all inflorescences develop into fruits. Fruits are completely matured and ready for being harvested at the age of 22 weeks.

The inflorescence (Fig. 15) is a compound umbel. Sometimes there are one or two linear bracts. The umbel has two to eight primary rays, which are of different length, in such a way that the umbellets are located at the same level. Two, three or more bracteols carry the umbellets with five to twenty secondary rays. Flowering starts with the primary umbel. In every umbel the peripheral umbellets, and in every umbellet the peripheral flowers are the first ones to flowers. These flowers are protandrous. The central flowers of the umbellets are sometimes staminiferous or sterile.

Coriander flower has an inferior ovary and the five calyx teeth surrounding the stylopodium are still visible in the ripe fruit. The five calyx teeth are of different length, as are the petals in peripherally situated flowers. The flowers have five petals. The peripheral flowers of every umbellet are asymmetric, as the petals toward the outside of the umbellets are lengthened. The central flowers are circular, with small inflexed petals. The colour of petals is pale pink or sometimes white. The five filaments of the stamens are located between the five petals. After the flower opens, the white filaments are visible between the petals, because they are bent and the pollen sacs at their top are bent and hidden in the center of the flower.

Table (7): The periodic growth and statistical parameters of total number of leaves per plant of *Coriandrum sativum* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.	
2	2 - 3	2.2 ± 0.13	E
4	4 - 6	4.3 ± 0.21	E
6	9 - 14	12.5 ± 0.67	E
8	15 - 18	17.5 ± 0.94	E
10	110 - 172	139.9 ± 8.04	D
12	314 - 408	362.8 ± 19.92	C
14	482 - 586	529.5 ± 23.28	A
16	466 - 547	508.9 ± 21.82	A
18	462 - 537	501.7 ± 22.73	AB
20	418 - 493	448.9 ± 17.46	B
L.S.D. (0.05)	53.7 leaves		

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

Table (8): The periodic growth and statistical parameters of fresh weight of leaves (g) of *Coriandrum sativum* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.	
2	0.52 - 0.84	0.68 ± 0.07	G
4	1.24 - 1.82	1.53 ± 0.14	G
6	31.84 - 55.67	43.69 ± 3.22	F
8	56.77 - 97.46	79.87 ± 6.51	D F
10	91.68 - 152.38	121.35 ± 8.47	C
12	128.27 - 199.65	169.17 ± 9.64	B
14	175.62 - 254.93	217.06 ± 12.26	A
16	115.74 - 162.39	138.23 ± 8.93	B C
18	89.53 - 124.82	106.45 ± 6.16	C D
20	52.83 - 84.26	67.48 ± 4.95	F F
L.S.D. (0.05)	32.84 g		

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

$$\hat{Y}_C = 225.55 - 133.24X + 18.899X^2 - 0.585X^3 \quad (R^2 = 0.9642)$$

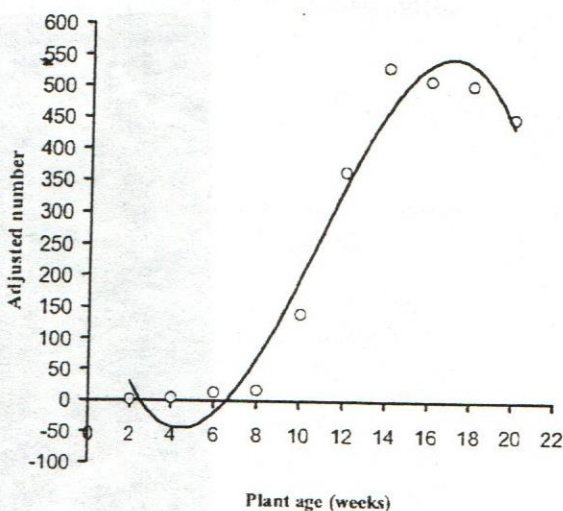


Fig. (13): Graph of regression of total number of leaves on plant age in *Coriandrum sativum* L.

$$\hat{Y}_C = 1.8807 - 9.8414X + 3.9233X^2 - 0.1651X^3 \quad (R^2 = 0.9157)$$

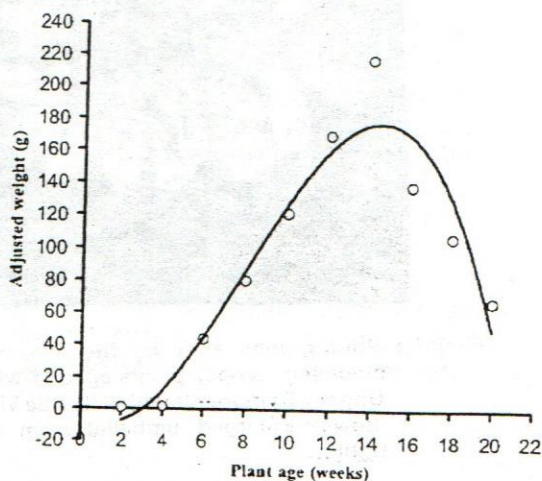


Fig. (14): Graph of regression of fresh weight of leaves on plant age in *Coriandrum sativum* L.

F15

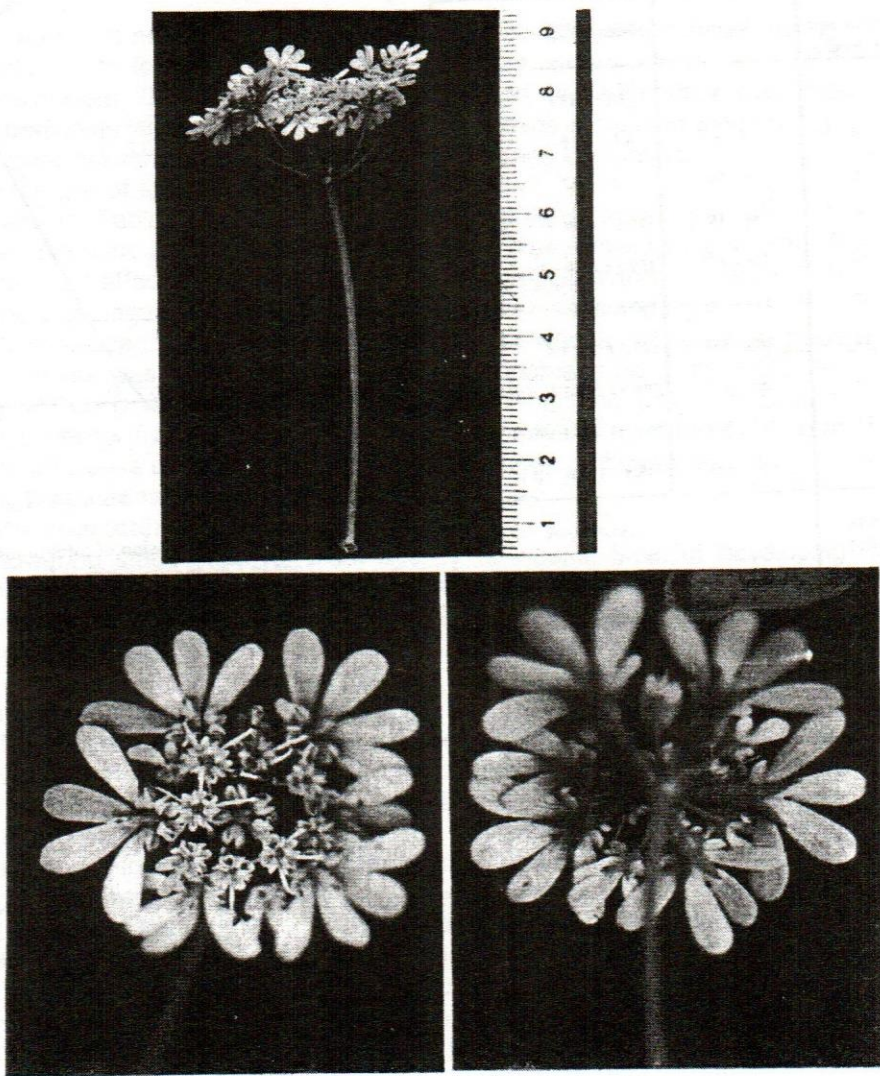


Fig.(15): Photographs showing the inflorescence of *Coriandrum sativum* L. at full blooming stage, plants aged 16 weeks.
Upper : Compound umbel in side view .
Lower: Enlarged umbellet from top (front view) at left and from bottom at right .

Gynoecium is comprised of two united carpels. Pistil syncarpous, the ovary is inferior, bilocular, each locule with a single pendulous ovule, ovary placed antero-posteriorly. Styles two, terminating the stylopodium, a bilobed nectar secreting disc lying at the base of style, stigma capitate.

Floral formula for Coriander flower:

Outer flowers: $\% , \text{♀} , K_{(5)} , C_5 , A_5 , \overline{G_{(2)}}$

Inner flowers: $\oplus , \text{♀} , K_{(5)} , C_5 , A_5 , \overline{G_{(2)}}$

The aforementioned characters of Coriander flower are in conformity with those described by Shukla and Misra (1979) and by Bunney (1992).

b- Number of compound umbels per plant:

Results belonging to total number of compound umbels per plant of Coriander throughout the growing season and their statistical analysis are given in Table (9). It is obvious that a significant cubic effect of periods was achieved for this character. The cubic equation and line of periods and number of compound umbels at successive ages are shown in Figure (16).

As inferred earlier, flowering started when plants were 12 weeks old. Counting of developing inflorescences was made at two-week intervals up to the end of the growing season. Average number of compound umbels was 35.2 per plant at 12 weeks old. This number increased significantly at both 14 and 16 weeks old, being 181.8 and 405.6 compound umbels; respectively. No substantial increment in number of compound umbels was recorded up to the end of the growing season.

It could be concluded that Coriander plant developed all its inflorescences throughout the period from 12 to 16 weeks old. No further inflorescence was formed, thereafter. Fruits started, then, their development.

c- Components of compound umbels per plant:

Data presented in Table (10) depict a detailed count for different reproductive organs of Coriander plant at full blooming stage (16 weeks old).

It is clear that Coriander plant at full blooming stage developed an average number of 405.6 compound umbel. Each compound umbel formed an average number of 4.85 umbellet. Thus, the average number of umbellets per plant was 1967.2. It was found that the average number of flowers per umbellet was 10.98. Consequently, Coriander plant developed a total number of 21599.8 flowers of which 9861 flowers were fertile and the remainder flowers were sterile.

The abovementioned results proved that Coriander plant formed enormous number of flowers (21599.8 flowers). However, about more than half of these flowers were sterile (about 11738 flowers). Moreover, not all the fertile flowers produced normal seeds.

6- The fruit and seed:

a- General characters:

Flowering of Coriander plant reached to a maximum (full blooming) at the age of 16 weeks where all inflorescences were developed and some formed seeds (start of fruiting). When plants were 20 weeks old almost all inflorescences turned to fruits (full fruiting stage). However, seeds were harvested at the age of 22-23 weeks.

Table (9): The periodic growth and statistical parameters of total number of compound umbels per plant of *Coriandrum sativum* L. throughout the growing season

Plant age in weeks	Range	Mean ± S.E.
12	28 - 42	35.2 ± 1.48 C
14	152 - 194	181.8 ± 4.30 B
16	349 - 451	405.6 ± 9.85 A
18	358 - 429	397.3 ± 8.18 A
20	354 - 450	406.8 ± 9.71 A
L.S.D. (0.05)	65.95 umbel	

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

$$\hat{Y}_C = -324.05 - 129.54X + 20.659X^2 - 0.6188X^3 \quad (R^2 = 0.9612)$$

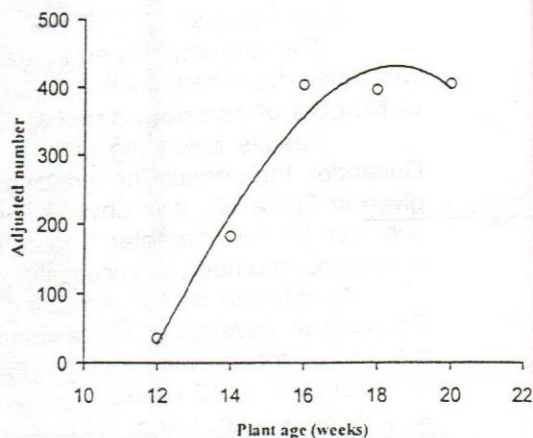


Fig. (16): Graph of regression of total number of compound umbels on plant age in *Coriandrum sativum* L.

Table (10): Count of reproductive organs of *Coriandrum sativum* L. plant in full blooming, 16 weeks old

Characters	Range	Mean ± S.E.
Number of compound umbels / plant.	349 - 451	405.6 ± 9.85
Average number of umbellets / compound umbel.	2 - 8	4.85 ± 0.099
Total number of umbellets / plant.	1692 - 2184	1967.2 ± 82.7
Average number of flowers / umbellet .	6 - 17	10.98 ± 0.38
Total number of flowers / plant.	18343 - 23976	21599.8 ± 1526.3
Average number of fertile flowers / plant = 9861 flowers		

Coriander forms seed-like fruits derived from an inferior ovary Figure(17) . The dry fruits are known as Coriander seeds and occur usually as entire cremocarps, which are sub-spherical, globular and ribbed, about 3 to 5 mm in diameter, brownish-yellow in colour, crowned by five small sepals and a styloped. When pressed, they separate into two mericarps, each containing a seed. Each mericarp has four , straight, primary ridges and five, less distinct, secondary ridges. The fruit will be noticed with a short length of stalk attached. The seed is coelosperrmous. The odour of the bruised fruit is aromatic, and the taste spicy.

The abovementioned characters of Coriander fruit and seed are in harmony with those given by Parry (1945) and Wallis (1999) as well as by Evans (2001) and Pandey (2003).

b- Yield characters:

Results of yield characters of Coriander plant at harvest time are given in Table (11).

It is realized from Table (10) that average number of fertile flowers per Coriander plant was about 9861 flowers. However, data presented in Table (11) clearly show that total number of fruits (cremocarps) per plant was 2806.8 fruits. The fruits produced per plant weight 20.61 g and the specific weight of fruits (weight of 1000 cremocarps) was 7.343g.

In essence, Coriander plant formed enormous number of flowers exceeding in average 21500 flowers per plant. However, some 11700 flowers per plant were sterile, and failed to complete their development into fruits. At the same time, not all fertile flowers (more than 9800) proceeded to fruit formation, about 2800 flowers only were able to form fruits; i.e., more than 80% of the flowers developed by Coriander plant did not form fruits.

Table (11): Yield characters of *Coriandrum sativum* L. plant at harvest time, plants aged 22 weeks.

Characters	Range	Mean \pm S.E.
Total number of cremocarps / plant.	2274 – 3488	2806.8 \pm 296.4
Yield of cremocarps (g)/plant.	17.64 – 24.19	20.61 \pm 1.47
Average weight of 1000 cremocarps (g).	6.935 – 7.757	7.343 \pm 0.28

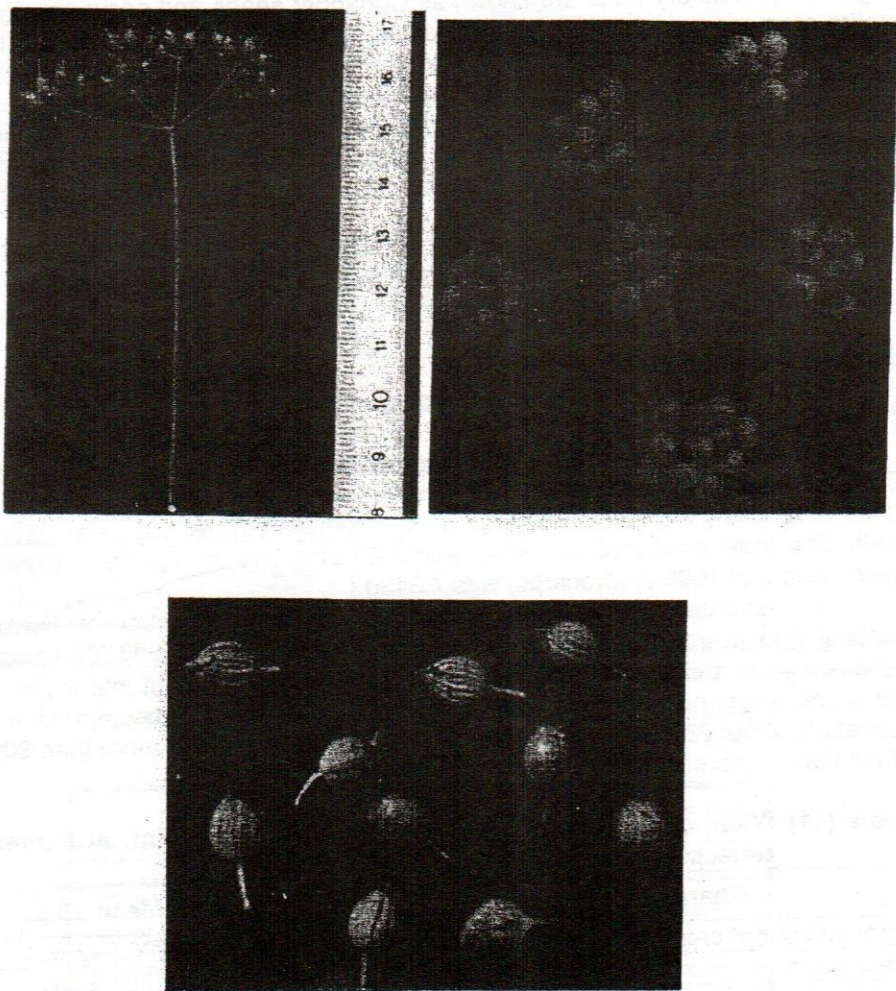


Fig. (17): Photographs of *Coriandrum sativum* L. fruit, plants aged 20 to 22 weeks.

Upper: Fruits of an intact umbel in side view at left and in front view at right.

Lower: Entire cremocarps with the pedicels attached.

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دراسات نباتية على نبات الكسبرة من الفصيلة الخيمية

محمد عبد العزيز نصار - محمد اسامة عبد المنعم السجاعي - سماح نجيب على محمد

قسم النبات الزراعي - كلية الزراعة - جامعة القاهرة - الجيزة - مصر.

يواجه علماء التقسيم صعوبات كبيرة للوصول الى تصنيف مرضى للفئات المختلفة للفصيلة الخيمية. ويرجع ذلك لنقص المعلومات المتاحة عن الصفات المورفولوجية للانواع المختلفة من الفصيلة الخيمية. ولذلك تم اختيار نبات الكسبرة لعمل دراسة متعلقة بالصفات المورفولوجية للنمو الخضري والتكاثرى للنبات خلال مراحل متتابعة من دورة حياته. مثل هذه المعلومات قد تجيب على التساؤلات في هذا الخصوص. ويشتمل النمو الخضري على: ارتفاع النبات، طول الساق الرئيسي، عدد سلاميات الساق الرئيسي، طول وقطر السلاميات المتتالية للساق الرئيسي، عدد الافرع الثانوية، طول الافرع الثانوية، عدد الاوراق علي النبات و الوزن الرطب لاوراق النبات. ويشتمل النمو التكاثرى علي عدد النورات المركبة للنبات، عدد النورات البسيطة للنورة المركبة، العدد الكلي للنورات البسيطة للنبات، عدد الازهار في النورات البسيطة، عدد الازهار الكلي للنبات، عدد الثمار الكلي للنبات، محصول الثمار للنبات والوزن النوعي للثمار (وزن ١٠٠٠ ثمرة).