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Descriptive Botanical Studies of *Lepidium sativum* L. at Different Growth Stages

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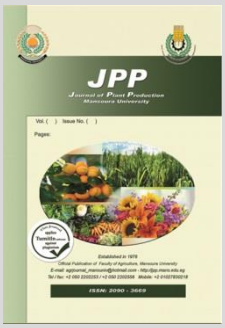

ABSTRACT

This study was focused on the morphological and histological characters of *Lepidium sativum* L. (Garden cress) throughout different growth stages. Eight vegetative characteristics at eight consecutive periods along sixteen weeks of plant age could be determining the behavior growth curves, which were tested by five linear regression models. The shoot system and various reproductive organs were described morphologically. Plant height, number of the main stem internodes, number of the primary and secondary branches/plant, number of silique of the main stem, number of silique/plant, number of seeds/plant, seed index and seed yield/plant was recorded at harvesting time. The interrelationships among these characters were explained based on the correlation coefficient, which revealed both positive and negative associations with varying levels of significance. The histological studies showed root secondary growth. The leaflets have anomocytic stomata. The section in leaf petiole represents three large vascular bundles located in the center and two small in the corners. Also, a complete hermaphrodite flower and two seeds inside the fruit surrounded by pericarp were present. The results of chemical composition *L. sativum* L. seeds showed that, the seeds contain 24% protein, 17% lipids, 35% carbohydrates, 24% crude fibers and 5% ash. The major oil components were α –Linolenic acid (31.50%), oleic acid (19.03%), gadoleic (12.89%), and linoleic (11.62%).

Keywords: Chemical, Correlation coefficient, Histological, *Lepidium sativum* L., Linear regression models and Morphological.

INTRODUCTION

Lepidium sativum L. (Garden cress) belongs to the family Brassicaceae. It is an annual herb, 10-60 cm in height, glabrous or sparsely pilose. Stem is erect, branched mainly in the upper part. Leaves 4-15 cm, the basal 2 pinnatisect, the uppermost oblong - linear; racemes and axillary, elongate in fruit. Sepals shorter than petals; petals 2mm, white or lilac, elliptic- oblong, distinctly winged, the apex notched; style projecting or included within the notch and seed 1 per locule.

The genus *Lepidium* L. comprises about 232 species distributed worldwide (Warwick *et al.*, 2019). Boulos (1999) stated that the accepted scientific name is *L. sativum* L., published in Sp. Pl., ed. 1, 644 (1753). Classification of *L. sativum* L. and their synonyms was recorded in Table (1) according to Warwick *et al.*, (2019).

Table 1. Accepted scientific name, classification, and synonyms of *L. sativum* L.

Accepted scientific name		Classification	Synonyms
Lepidium sativum L.	Kingdom	Planta- Plants	*Cardamon sativum* (L.) Fourr.
	Phylum	Tracheophyta (Vascular plants)	*Lepia sativa* (L.) Desv.
	Division	Magnoliophyta (Flowering plants)	*Lepidium hortense* Forssk.
	Class	Magnoliopsida (Dicotyledons)	*Lepidium sativum* var. *crispum* (Medik.) DC.
	Order	Brassicales	*Lepidium sativum* subsp. *sativum.*
	Family	Brassicaceae/ Cruciferae – Mustard family	*Lepidium sativum* var. *spinescens* (DC.) Jafri.
			Lepidium sativum subsp. *spinescens* (DC.) Thell.
	Genus	*Lepidium* L. (pepperweed)	*Lepidium spinescens* DC.
	Species	*sativum* L.	*Nasturtium crispum* Medik.
		garden cress pepperweed	*Nasturtium sativum* (L.) Medik.
			Nasturtium spinescens (DC.) Kuntze.
			Thlaspi sativum (L.) Crantz.
			Thlaspidium sativum (L.) Spach.

The *L. sativum* L. is known as an important medicinal crop in India. It is native to Egypt and south west Asia and was referred to over many centuries ago in Western Europe (Zhan *et al.*, 2009; Sharma and Agarwal, 2011; Doke and Guha, 2014). It can grow in any type of climate and soil condition with few requirements (Balasubramanian, 2009). *L. sativum* L. seeds were sown in the winter season, the optimal month of sowing are the cool months of November, January, and February in the Mediterranean climate (Tuncay *et al.*, 2011).

The plant has been cultivated for food since before the ancient Egyptians and is still widely used. It is most commonly eaten in the seedling form. The fresh herb of *Lepidium* has a radish-like taste, and it's used for coughs, vitamin c deficiency and diuretic (Fleming, 1998). The

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young leaves are used as salad and cooked with vegetables (Moser *et al*., 2009; Patel *et al*., 2009; Rehman *et al.,* 2012). Also, the roots, leaves and seeds have been used as a spicy condiment. Seeds become slimy when soaked in water and are used in dysentery, muscular pain, blood and skin disease, tumors, and asthma. (Saxena *et al*., 2015). Leaves and seeds extracts have an anti-inflammatory effect. The presence of flavonoids, alkaloids, tannins, glucosinolates, sterols, and triterpenes contribute to this effect (Al-Snafi, 2019).

Commonly, the seeds of *L. sativum* L. are categorized under oil seeds and are rich in minerals and vitamins but limited in protein and fat content. The seeds have 25 g protein, 24 g fat, 3 g fiber, and 33g of carbohydrates per 100gm and have good amount of a minerals, 377 mg of calcium, 430 mg magnesium and 723 mg of phosphorous and a sufficient amount of vitamins, mainly niacin (14.3 mg), riboflavin (0.61 mg) and thiamine (0.59 mg) and per 100g seeds (Gopalan *et al.,* 2010; Chaudhary and Gupta, 2017). It is a good source of iron (Nadkarni, 2005). Also, the seeds contain essential fatty acids such as linolenic (26–34 %), linoleic (7.5– 11.8 %), and arachidic (2–3.5 %) acid (Jain *et al.,* 2016).

This investigation aimed to introduce a detailed botanical study including morphological, histological characteristics, and seed chemical composition of *L. sativum* L. throughout the consecutive period of its whole life span.

MATERIALS AND METHODS

• Field Experiment

Two field trials were conducted during two successive seasons of 2017/ 2018 and 2018/ 2019 at the Agricultural Experiments and Researchers Station, Faculty of Agriculture, Cairo University, Giza, Egypt. The date of sowing was November 9th in two seasons. Plants are grown within the plot; (3 × 4) m with five ridges 60 cm apart. Seeds were sown in hills spaced 30 cm; the plants were thinned later to two plants per hill. Fertilization by calcium super phosphate (15.5% P_2O_5) at the rate of 20kg/ faddan during the field preparation, ammonium nitrate (33.5%N) was added in two doses of the rate of 50 kg/ faddan; the first dose was added after three weeks from planting and the second dose applied at flowering stage. Potassium sulphate (50%K_2O) at the rate of 25kg / faddan at flowering stage.

Data record

• Morphological characteristics

a.Vegetative growth

Ten plants were taken randomly from plots, which assigned at two weeks intervals to follow up the vegetative growth of *L. sativum* L. plant. The following measurements were recorded for the shoot; plant height (cm), number of internodes of the main stem and number of the primary branches per plant, number of leaves per plant, Fresh and dry weights of leafless shoot (g) (the main stem and lateral branches), Number of leaves per plant, Fresh and dry weights of leaves per plant (g).

b. Reproductive growth and yield components

The date of onset and end of flowering was recorded. General characteristics and detailed descriptions of various reproductive organs; the inflorescence, flower, fruit, and seed were reported. The yield characteristics include the number of silique of the main stem inflorescence, the number of silique/ plant, number of seeds/ plant, seed index (weight of 1000 seeds; g), and seed yield/ plant (g). All characters were recorded at harvest time by using assigned 30 plants

• Statistical analysis and plant growth modeling

Combined analysis over 2 seasons had been conducted as indicated of homogeneity test which based on homogeneity error variances of both seasons for each vegetative growth characters following Hartley's Fmax test (1950). The differences among eight periods of plant age at 0.05 level of probability ($p \leq 0.05$) were tested according to Duncan's multiple range test (Duncan, 1955). The following five statistical models were expressed elucidating this relationship for averages of vegetative studied characters across 2 seasons and tested was significances at 0.05 level of probability either, by regression variance ratio which was analyzed using analysis of variance (ANOVA). Whereas Y: is the study character as dependent variables, x: is the time (eight periods of plant age) as independent variables.

Linear model:

$$Y = a + b\,x \qquad \text{[Eq.1]}$$

a: is the Y intercept.
b: is the linear coefficient of regression.

Quadratic polynomial:

$$Y = a + bx + cx^2 \qquad \text{[Eq.2]}$$

a: is the Y intercept.
b: is the linear coefficient of regression.
c: is the quadratic coefficient of regression

Cubic polynomial model

$$Y = a + bx + cx^2 + dx^3 \qquad \text{[Eq.3]}$$

a: is the Y intercept.
b: is the linear coefficient of regression.
c: is the quadratic coefficient of regression.
d: is the cubic coefficient of regression.

Power Functions

$$Y = x^n \qquad \text{[Eq.4]}$$

n: any real constant number

Exponential Function

$$Y = a^{bx}. \qquad b>0 \qquad \text{[Eq.5]}$$

a: is constant also b: is coefficient of inverse of logarithmic curve

In addition to the yield and its components computed by descriptive statistical methods such as means, and the standard error was calculated using the method suggested by Goulden (1952). Interrelationships among seed yield/ plant and vegetative growth traits were determined according to Gomez and Gomez (1984). All collected data were processed subsequently by SPSS V.18 SPAW software package program.

• Histological studies

The samples of different plant organs for histological studies were collected, including the main root through its median portion, the apical and the median internodes of the main stem, leaflet blade and petiole of the compound leaf, and flower bud, at the age of ten weeks. In addition to, the mature fruit at the age of sixteen weeks in the second season. Specimens were killed and fixed in FAA (85 ml ethyl alcohol 70%, 10 ml formalin, and 5 ml glacial acetic acid), then dehydrated in butyl alcohol series and embedded in paraffin wax. Double stained with crystal violet- erythrosine was used. Samples were cleared and mounted in Canada balsam following the technique of Nassar and El-Sahhar, (1998).

• Seed chemical composition

a. Determination of total protein, lipids, carbohydrates, fibers, and ash.

Crude protein in *L. sativum* L. seeds was determined according to the method of AOAC (2016) by using Kjeldahl method, total lipids and crude fiber content of seeds were

determined according to AOAC (2000) while ash was determined according to AOAC (1986).

b. Determination of mineral content

Mature seeds of *L. sativum* L. were collected at harvesting time and digested according to Piper (1947). Nitrogen, Phosphorus, Potassium, Sodium, Calcium, Magnesium, Iron, Manganese, Copper and Zinc were determined in the digested samples. Total nitrogen estimated by using Kjeldahi methods (1883). The phosphorus was determined using spectrophotometer (Chen *et al*., 1956). Potassium and sodium concentrations were determined by using the flame photometer apparatus (BWB-I). Calcium, magnesium, iron, manganese, copper and zinc were determined using atomic absorption spectrometer according to AOAC (1995) at the Laboratory of Cairo University Research Park, CURP-Faculty of Agriculture.

c. Seed fixed oil

The seed oil of *L. sativum* L. was extracted by using soxhlet apparatus at the Cairo University Research Park (CURP), Cairo University, Giza, and expressed as percentage. The fatty acid profile of *L. sativum* L. oil was analyzed using GC analysis was done according to Farag *et al.* (1986).

RESULTS AND DISCUSSION

- **Morphological studies**

a. Vegetative growth

- Shoot system

Commonly, *L. sativum* L. is an annual herb about 60 cm high, with many branches on the upper part of the plant and edible shoots; it can be harvested at the age of ten days after planting (5-8 cm in length). The stems are erect, glabrous, bright green, and slender (Fig.1B). At the age of three weeks, the internodes of the main stem are very short and are surrounded by crowded foliage leaves, throughout the following ages, the internodes elongate and become distinct (Fig. 1, C &D). When the internodes were 5.3cm at four weeks, the stem remained unbranched. Leaves are alternate with long petioles, irregularly pinnate, classified into leaflets, leaves gradually become simple and linear in the upper part of the plant. The inflorescence is a raceme with a small white flower, develops in the axils of uppermost leaves on the main stem and lateral branches.

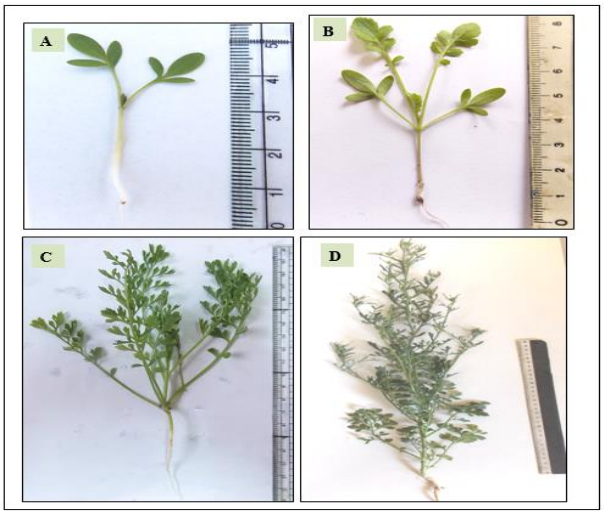

Fig. 1. Different growth stages of *L. sativum* L.

A. Plant at the age of three days from sowing date (seedling stage)
B. Plant at the age of ten days from sowing date (the first two foliage leaves are formed).
C. Plant at the age of three weeks from sowing date (Crowded foliage leaves and the internodes are very short).
D. Plant at the age of eight weeks from sowing date (the beginning of the flowering stage).

- **Growth behavior of shoot**

Five common linear regression models and their efficiency for elucidating vegetative growth traits were presented in (Table 2). The assumptions detected among these modeling based on the coefficient of determination (R^2) and standard error (SE) of fitting linear estimate in addition to testing the significance of each model.

Table 2. Significances of five curve fitting models linear regression and its standard error due to estimate the studied characters along different 8 period of plant age of *L. sativum* L. vegetative growth across two seasons.

Traits	Statistical Expression	Linear	Quadratic	Cubic	Power	Exponential
Plant height cm	Model	y =4.01 x -1.35	y =-0.07 x ^{2} +5.28x -5.58	y= -0.03x^3+0.76x^2-1.05 x+ 6.58	y= 6.9$x^{1.06}$	y=7.47$e^{0.3x}$
	R^2	0.97**	0.97**	0.99**	0.97**	0.91**
	SE±	3.61	3.6	2.62	0.15	0.24
No. of Internodes	Model	y =1.16x +0.77	y =-0.07 x ^{2} +2.41x -3.37	y= 0.01x^3-0.17x^2-3.2x -4.94	y= 1.53$x^{1.31}$	y=1.96$e^{0.33x}$
	R^2	0.94**	0.99**	0.99**	0.92**	0.71*
	SE±	1.61	0.74	2.62	0.3	0.56
Number of primary branches	Model	y =1.16x -4.43	y =-0.05 x ^{2} +0.35x -1.71	y=- 0.13x^3+0.4x^2-2.37x +3.53		
	R^2	0.94**	0.96**	0.99**	DNE	DNE
	SE±	1.56	1.35	2.62		
Fresh weight of leafless shoot (g)	Model	y =1.38x -5.6	y =0.1 x ^{2} -0.45x + 0.39	y=- 0.01x^3+0.26x^2-1.71x +2.8	y= 0.02$x^{3.26}$	y=0.03$e^{0.88x}$
	R^2	0.89**	0.97**	0.98**	0.98**	0.88**
	SE±	2.42	1.3	1.3	0.33	0.83
Dry weight of leafless shoot (g)	Model	y =0.34x -1.48	y =0.03 x ^{2} -0.20x + 0.34	y=- 0.001x^3+0.04x^2-0.31x +0.5	y=0.012$x^{2.85}$	y=0.015$e^{0.79x}$
	R^2	0.87**	0.98**	0.98**	0.99**	0.93**
	SE±	0.69	0.27	0.31	0.24	0.5
Number of leaves	Model	y =9.42x -38.8	y =-0.87 x ^{2} -6.4x + 13.87	y=- 0.03x^3+1.61x^2-11.9x +24.5	y= 1.69$x^{1.94}$	y=1.7$e^{0.57x}$
	R^2	0.85**	0.97**	0.97**	0.93**	0.98**
	SE±	20.9	10.63	11.5	0.4	0.24
Fresh weight of leaves (g)	Model	y =0.58x -1.95	y =0.03 x ^{2} +0.04x - 0.14	y=- 0.004x^3+0.14x^2-0.78x +1.4	y=0. 04$x^{1.91}$	y=1.69$e^{0.53x}$
	R^2	0.91**	0.95**	0.96**	0.98**	0.92**
	SE±	0.96	0.78	0.78	0.2	0.41
Dry weight of leaves (g)	Model	y =0.12x -0.40	y =0.007 x ^{2} -0.005	y=- 0.001x^3+0.03x^2-0.15x +0.3	y=0.032$x^{1.85}$	y=0.036$e^{0.52x}$
	R^2	0.92**	0.97**	0.98**	0.97**	0.92**
	SE±	0.18	0.13	0.12	0.23	0.41

***, ** indicated significant regression at 0.01 and 0.05 level of probability respectively, DNE: Does Not Exist output values of models**

The significant model which had the highest R^2 and lowest SE was the best model fitted to the growth habit. Generally, all models were significant effects along with studied traits except the number of primary branches, which doesn't has operated mathematically efficient for both power and exponential models due to zeros value of obtained data at beginning stages or juvenile growth phase of the plant during 2 - 4 week intervals (Fig. 2).

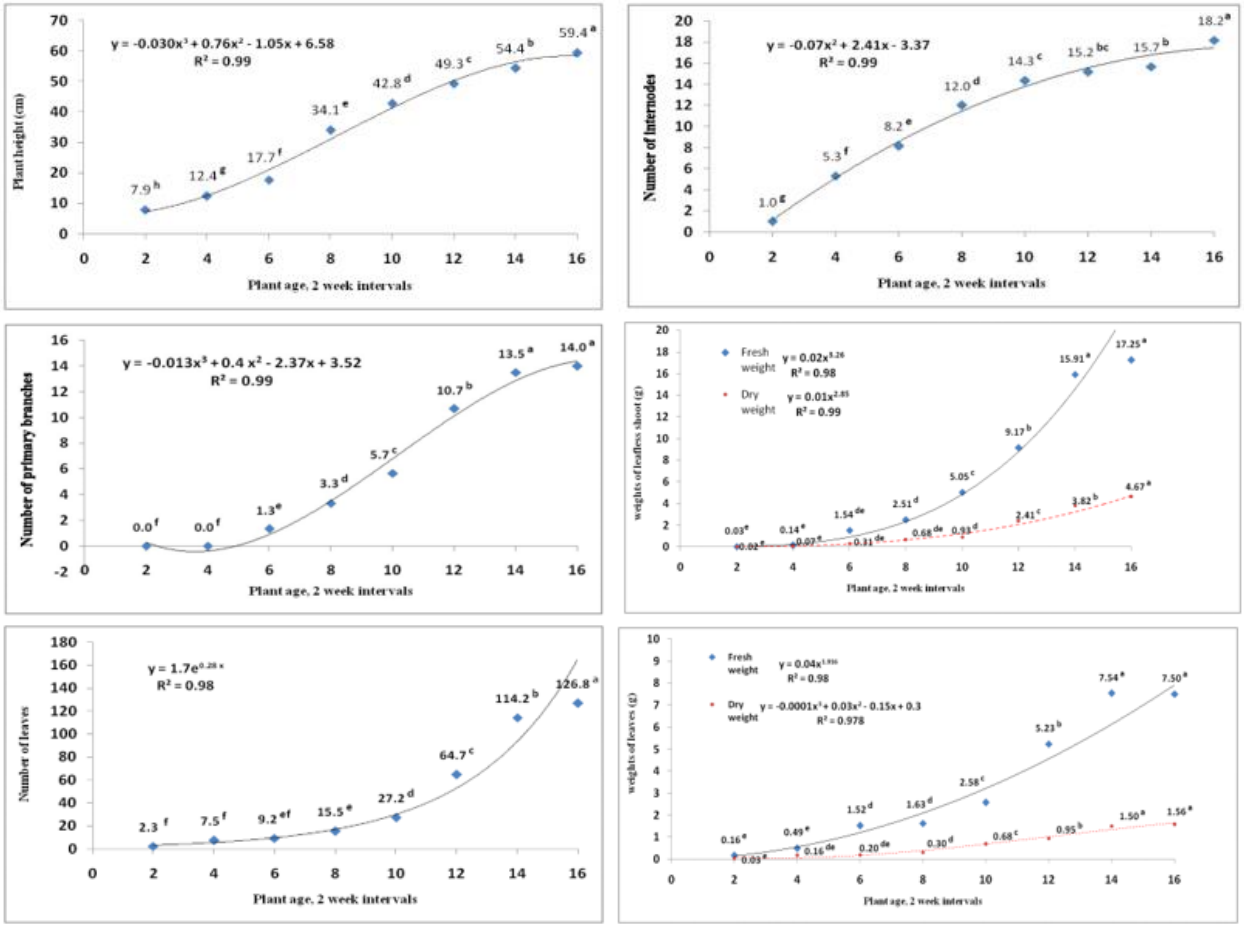

Fig. 2. Graphs showing trend lines of studied characters and fitting by R^2 (coefficient of determinations) of plant age during vegetative growth of L. *sativum* L. and their statistical analysis in two successive growing seasons.

Accordingly, significances models for studied traits indicated that linear regression models expressed a precise interrelationship between week intervals (time factor) as independent variables corresponding to studied characters (each vegetative trait) as dependent variables. Although many equations have been suggested to describe sigmoid plant growth habits (Zeide, 1993), and empirical models are still being improved (Birch, 1999). The significance cubic model showed the best performance fitting estimation of several studied characters such as plant height, no. internodes and the number of primary branches with 0.99 of coefficient determinants (R^2) beside that the dry weight of leaves which recorded 0.98 of R^2. Two models cubic and power were showed the equivalent value of R^2 for the fresh weight of leaflets shoot (0.98), but the power model was more efficient than cubic due to the observed value of SE with 0.33 that it had smaller four-folds compared than a cubic model with SE 1.33. Moreover, the power curve model has investigated the relation between dry weight of leafless shoots and fresh weight of leaves with 0.99 and 0.98, respectively of R^2 values. Obviously trending both exponential and power models of studied traits showed no sigmoid curve, the similar findings were also reported by Diepenbrock (2000) of *Brassica napus.* On other words, Yin *et al.*, (2003) mentionedthere is no existing sigmoid equation suitable for exact estimation of biomass or either dry matters accumulation of plant and duration of determinate growth. The using truncated power is more efficient than linear and quadratic functions, also seem to be useful than cubic because it can smoothly predict maximum weights (fresh and or dry) at the final weight at the end of growth habit.

1. Plant height

Plant height of *L. sativum* L. increased significantly from sowing date up to 16 weeks at full blooming stage being 59.4 cm. Elongation of the plant progressed consistently throughout the consecutive periods. Boulos (1999) stated that the plant ranged from 10-60 cm in height. In the present study, the plant height reached about 60 cm, being within the same range.

2.The stem

• Number of internodes of the main stem

Results reveal that a significant increment in several numbers of internodes of *L. sativum* L. occurred from the age of 2 weeks till the age of 10 weeks where the average number of internodes was 14.3. Thereafter, no significant increments were observed in a number of internodes at 12

and 14 weeks being 15.2 and 15.7. The maximum number was recorded at the age of 16 weeks, being 18.2 internodes.

- **Number of the primary branches**

The primary branches of *L. sativum* L. started their development at 6 weeks in the two growing seasons, where their number was 1.3. Thereafter, significant increments in the number of primary branches occurred reaching 13.5. However, no further substantial increments were achieved in the number of primary branches at 16 weeks old, being 14.0 branches.

- **The fresh and dry weight of leafless shoot**

Average fresh weight of leafless shoot of *L. sativum* L. was small till the age of 8 weeks, being 2.51g. Thereafter, a significant increase in weight was achieved reaching 17.25 g when the plant aged 16 weeks old. Concerning the dry weight of leafless shoot, no significant increment was achieved till the age of 10 weeks (0.93 g), throughout the following ages the weights increased significantly to reach the maximum dry weight (4.67 g) at 16 weeks.

3.The leaf

Cotyledons of *L. sativum* L. at the seedling stage are Tri-foliolate with three leaflets, the central one bigger than the lateral one. After two weeks from germination, the seedling leaves are ready for consumption. The young leaves were used for salads, cooked with other vegetables, and used to garnish food.

Mature leaves are alternately arranged on the stem, exstipulate, glabrous, 4-12 cm in length and have economic importance. Leaves are stimulant and diuretic (Maghrani *et al.*, 2005; Wright *et al.*, 2007). There are two types of leaves on the same plant at maturity; the lower leaves have long petioles about 1-4 cm, pinnatifid, the leaf is divided into 5-11 leaflets and margin irregularly toothed, while the upper leaves are sessile or subsessile, much smaller than the lower leaves, less divided, linear in shape and margins entire (Fig. 3 & 4).

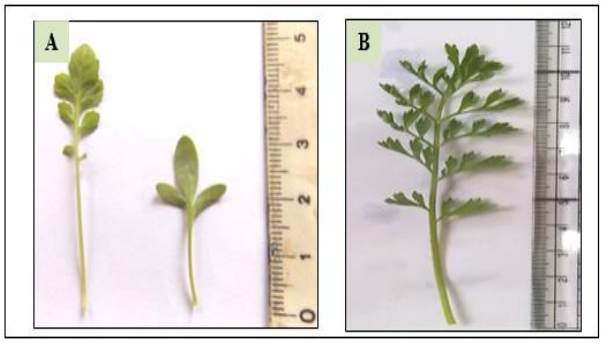

Fig. 3. Leaf forms of *L. sativum* L.

A. Tri-foliolate cotyledons and the first foliage leaf.
B. Pinnatifid leaf at the basal portion of the plant.

- **Number of leaves**

It is obvious that the increase in the number of leaves was statistically indifferent till the age of 8 weeks, being 15.5 leaves. In the following ages, leaf number recorded significant increments to reach a maximum number of 126.8 at the age of 16 weeks from sowing.

- **The fresh and dry weight of leaves per plant**

It is clear that, fresh and dry weight of leaves per plant of *L. sativum* L., following the same trend of the growth pattern. The fresh and dry weight of leaves per plant increased slightly from sowing date up to the age 8 weeks, *i.e.*, values were statistically indifferent reaching 1.63 g and 0.30 g for leaves fresh and dry weight; respectively. A significant increment was observed from 10 to 14 weeks where the fresh and dry weight of leaves reached the maximum being 7.54 g and 1.50 g; respectively.

b. Reproductive growth and its components

1. The inflorescence and the flower

The inflorescence of *L. sativum* L. (Fig. 4) is a raceme, with white flowers which had a small pedicel (stalk). The flower is a perfect bisexual hermaphrodite, actinomorphic and hypogenous. The calyx is composed of four sepals free, in two decussate pairs. The corolla contains four white petals free and alternate with the sepals. Androecium consist of six stamens. Gynoecium is two carpels. Ovary superior, with 2-locular and parietal placentation. This agrees with the flower structure of *L. sativum* L. given by Boulos (1999), Sharma and Agarwal (2011).

Fig. 4. A photograph showing the upper portion of *L. sativum* L., plant at full flowering stage at the age of 12 weeks (3 months) after the sowing date (The plant developed many branches, each branch ending with an inflorescence).

Not: leaves at the upper portion of the plant are sessile, less divided, and linear in shape and entire margins.

2.The fruit and seed

The fruiting stage of ***L. sativum*** L. occurred when all inflorescence was developed and turned into fruits with mature seeds at the age of 16 weeks, after two weeks green fruits turned into yellow fruits at harvest time 18 weeks, (Fig. 5 & 6). Fruits are silique, pale green to yellow, base round, margins wing-like glabrous, dehiscent (dehiscing by 2 valves), with 2-seeds/ silique. Seeds are small, oval-shaped, smooth, about 2-3 mm long, reddish-brown in colure (Figure, 7), and mucilaginous when soaked.

Fig. 5. Photographs showing the inflorescence of *L. sativum* L.at fruit formation.

A. Much branched of raceme B. Fruiting branch at the green stage.

Data of the seed yield characters and its components of *L. sativum* L. plant at harvest time are shown in Table (3). The average number of silique (mature fruits) per plant was 634.8. Worthy to mention that each silique is comprised of two seeds. So, the average number of seeds per plant recorded 1186.50 which weight 2.10 g. whereas, seed index (weight of 1000 seeds) was 1.70 g. However, both seed index (g) and seed yield per plant (g) showed narrow values of dispersion calculation of standard error (SE±) with 0.06 and 0.11; respectively.

Fig. 6. *L. sativum* L. at harvest time. Plant bearing mature fruits at the age of 18 weeks.

Fig. 7. General view of mature seeds of *L. sativum* L. with reddish- brown in colure.

Table 3. Descriptive statistics of 9 studied characters of reproductive growth of *L. sativum* L. for yield and its components (the age of 18 weeks) across the two seasons.

Descriptive Statistics	Plant height (cm)	No. of internodes /plant	No. of primary branches	No. of secondary Branch	No. of silique of main stem Infl.	No. of silique/ plant	No. of seeds / plant	Seed Index (g)	Seed yield / plant (g)
Mean	60.30	18.70	14.50	51.50	36.30	634.8	1186.50	1.70	2.10
Minimum	57.00	17.00	13.00	40.00	30.00	571.00	1074.00	1.48	1.85
Maximum	65.00	20.00	17.00	66.00	40.00	733.00	1378.00	1.91	2.62
SE±	1.09 ±	0.42 ±	0.67 ±	3.95 ±	1.43 ±	25.47 ±	45.15 ±	0.06 ±	0.11 ±

The correlation coefficient for the different yield parameters of *L. sativum* L. is shown in Table (4). Highly positive significance ($p<0.01$) relationship was observed between plant height and a number of internodes per plant with correlation value r=0.85, and it was exceeded to r = 0.98 between two variables for a total number of silique and number seeds per plant as considering the largest relation, beside that there was the most important of relationship occurred between seed yield per plant and a total number of seed with the value of r = 0.88. In addition to, seed yield per plant showed positive significant effects ($p<0.05$) with a total number of silique per plant r=0.80. Whereas, the number of secondary branches per plant recorded a negative correlation with the total number of siliques (The similar finding by Thondaiman *et al*., 2018), the total number of seed and seed yield per plant with r = -0.13, -0.31, and -0.54; respectively.

Table 4. Matrix simple Person correlation coefficients among reproductive growth studied characters (yield and its components) calculated from averages of L. *sativum* L.

Studied Characters	Plant height (cm)	No. of internodes / Plant	No. of primary branches	No. of secondary branches	No. of silique of main stem Infl.	No. of silique / plant	No. of seeds / plant	Seed Index (g)	Seed yield / plant (g)
Plant height (cm)	1	0.85**	0.78*	0.61 ns	0.74*	0.50 ns	0.35 ns	0.27 ns	0.11 ns
No. of internodes / Plant		1	0.58 ns	0.58 ns	0.81*	0.56 ns	0.45 ns	0.69 ns	0.17 ns
No. of primary branches			1	0.76*	0.17 ns	0.16 ns	0.00 ns	-0.14 ns	-0.02 ns
No. of secondary branches				1	0.22 ns	-0.13 ns	-0.31 ns	0.00 ns	-0.54 ns
No. of silique of main stem Infl.					1	0.60 ns	0.55 ns	0.71 ns	0.17 ns
No. of silique/ plant						1	0.98**	0.54 ns	0.80*
No. of seeds / plant							1	0.57 ns	0.88**
Seed Index (g)								1	0.33 ns
Seed yield/plant(g)									1

ns, * and ** indicate insignificance, significance at 5% level and at 1% level of probability, respectively.

- **Histological studies**

a.The root

In a cross-section of *L. sativum* L. root at the age of ten weeks, show the secondary structure as a result of the activity of the secondary meristems (Fig. 8). The periderm is the outermost layer covered by the root. There were multilayers of parenchymatous cortex cells beneath the periderm tissue. Groups of thick-walled cells appeared above the phloemic region. The cambium region is a very clear and distinguished between secondary phloem and xylem. The central xylemic region occupying two-third of the root thickness. The secondary xylem vessels were different in diameter with thick-walled distributed in radial distribution continuously or discontinuously. This description is somewhat similar to the root description of *Lepidium perfoliatum* given by Grigore and Toma (2008). The primary xylem is located in central regions.

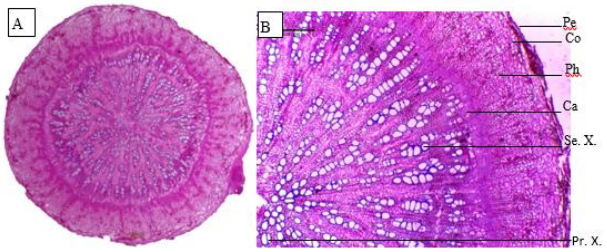

Fig .8. Cross sections of *L. sativum* L. root at the age of ten weeks from sowing date.

A. Whole root section. (40x) B. A magnified portion of A. Details: Ca; Cambium; Co: Cortex; Pe: Periderm; Ph: Phloem; Pr. X.: Primary xylem; Se. X., Secondary xylem.

b. The main stem

- **The apical internode**

The epidermis is consisting of small, thick-walled cells with a few stomata. Cortex is present just below the epidermis. More than twenty collateral vascular bundles were arranged in

a ring separated with thick-walled cells. The vascular bundles were varying in size. Group of sclerenchyma tissue located at both vascular bundles poles (Fig. 9 A & B).

• The median internode

The median internode in cross-section showed a secondary structure, oval in shape, covered with a uniseriate epidermal layer containing a few stomata. The cortex includes many layers of parenchymatic cells. The vascular bundles were arranged in a ring; represent about 35 bundles separated with medullary rays. There was a sclerenchyma cap above every vascular bundle which was distinct in the biggest bundles. The big vascular bundles have 10 rows of xylem while the smallest one has 5 rows. Vascular cambium appeared between xylem and phloem formed a ring with multiple layers appear in a continuous ring. Pith tissue occupies most of the stem sections (Fig. 9 C & D).

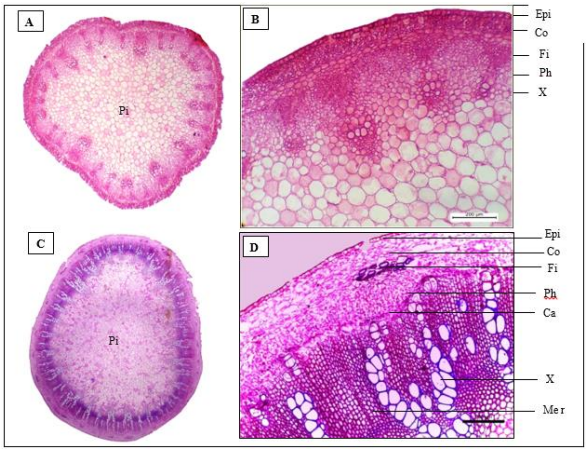

Fig. 9. Cross sections of L. *sativum* L. stem at the age of ten weeks from sowing date.

A. Whole section of the apical internode. (64x)
B. Details of a magnified portion of (Fig. 9A).
C. Whole section of median internode. (40x)
D. Details of a magnified portion of (Fig.9 C).
Details: Ca: Cambium; Co: Cortex; Epi: Epidermis; Fi: Fiber; Me r: Medullary ray; Ph: Phloem; Pi: Pith; X: Xylem.

c.The leaf

• The leaflet blade

The anatomical observation about *L. sativum* L. (Fig. 10 A) leaflets at the age of ten weeks after sowing exhibited that the leaflets consist of a bi-layer of epidermis, the upper (adaxial) and the lower epidermis (abaxial). Every layer consists of a uniseriate layer of compacted epidermal cells with a cuticle layer. Just below the upper epidermis in the lamina region the mesophyll tissue is differentiated into two regions. The external zone is represented by vertically elongated cylindrical cells and stretched along with the leaflets. The palisade layer is formed by two layers of parenchyma cells and occupies about one-third of the whole thickness of the mesophyll followed by spongy tissue. The spongy layer is composed of four layers of loosely arranged paranchymatuse cells with many wide intercellular spaces and occupied two-third of the thickening of the blade. The main vascular bundle is located at the center of the midrib consist of xylem and phloem elements. Xylem tissue consists of about four or five rows and each row has four to six xylem vessels. The epidermal peel of leaf lower surfaces of *L. sativum* L. leaflets show undulate epidermal walls and anomocytic stomata type and its density is increased in the lower epidermis one (Fig. 10 B). These results are in agreement with Kadhem and Alnmani (2017).

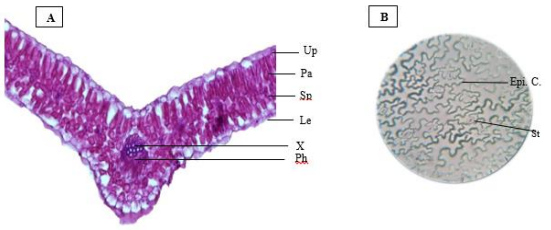

Fig. 10. Light micrograph of *L. sativum* L. plants showing (the leaflet and epidermal peel of leaf blade at the age of ten weeks).

A. Cross sections of leaf (200x)
B. Epidermal peel of the abaxial leaf blade(600x)
Details: Epi. C.: Epidermal cells; Pa: palisade tissue; Le: Lower epidermis; Ph: Phloem; Sp: Spongy tissue; St :Stomata; Up: Upper epidermis; X: Xylem.

• The leaf petiole

Transition sections made in *L. sativum* L. petiole (Fig. 11). The petiole appeared heart-shaped and surrounded by the uniseriate epidermis, beneath the epidermis, there were two or three collenchyma tissue layers. Underneath, the collenchyma multi- layered parenchyma is formed. Five collateral vascular bundles embedded in ground tissue are present. There were three large vascular bundles in the center and two small in the corners.

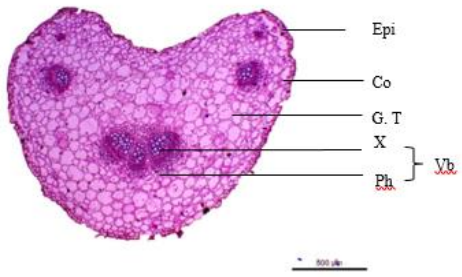

Fig. 11. Transverse section of *L. sativum* L. leaf petiole at the age of ten weeks.

Details: Co: Cortex; Epi: Epidermis; G.T: Ground tissue; Ph: Phloem; Vb: Vascular bundle; X: Xylem.

d. The floral bud

The result of *L. sativum* L. bud anatomical structure showed that the flower is complete and hermaphrodite (Fig 12 A). The calyx is consisting of four separated sepals followed by four distinct, diagonally placed petals (corolla). The androecium has six stamens, tetradynamous with four longer than the other two. The anther showed original four pollen sac merged into two and only one vascular bundle in the central connective. The four mature sacs are filled with spherical pollen grain. The gynoecium is formed of bicarpellary, syncarps, superior ovary (Fig. 12 B).

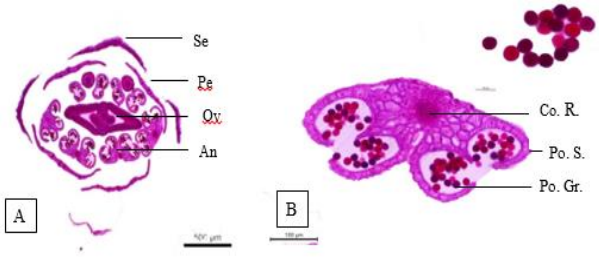

Fig. 12. Transverse section of *L. sativum* L. floral bud at the age of ten weeks.

A. Whole section of bud B. Section of anther
Details: An: Anther; Co.R.: Connective region; Ov: Ovary; Pe: Petals; Po. Gr.: Pollen Grain; Po. S.: Pollen Sac; Se: Sepal.

e.The fruit

The *L. sativum* L. fruit in cross-section consists of two seeds inside the fruit surrounding by pericarp (Fig. 13 A). The pericarp is divided into three layers; the outer part (exocarp), the median part (mesocarp), and the inner part (endocarp) (Fig 13 B). The exocarp; the outer part consist of one layer of cells covered with a thick cuticle layer. The mesocarp; the medium layer consist of many layers of parenchmatious cells. The inner layer; the endocarp has a single layer of tubular or pillar-like cells (Fig. 13).

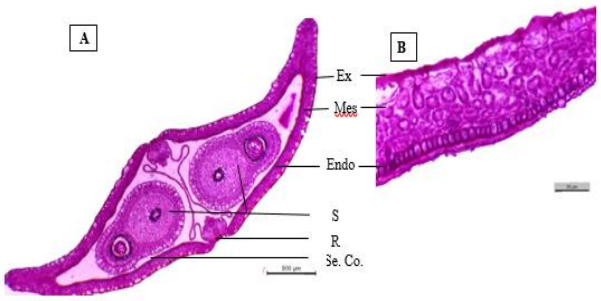

Fig. 13. Transverse section of *L. sativum* L. fruit at fruiting stage (sixteen weeks).

A. Whole fruit structure B. Pericarp structure (magnified portion of (Fig. 13 A)

Details: Endo; Endocarp; Ex: Exocarp; Mes: Mesocarp; R: Replum; S: Seeds; Se. Co.: Seed coat.

• Seed chemical concentration

a.Total protein, lipids, carbohydrates, fibers, and ash.

In this investigation, seeds have 24% protein, 17% lipids, 35% carbohydrates, 24% crude fibers, and 5% ash; this means that seeds of *L. sativum* L. are a good source of protein and total carbohydrates (Fig. 14). Several other studies showed almost similar results to those given in the present study; *e.g.*, Zia-Ul-Haq *et al*. (2012), Agarwal and Sharma (2013), Chaudhary and Gupta (2017) they found that the seeds of L. *sativum* L. contained protein (24-27%), lipids (23-25%), carbohydrates (30-38%), fiber (3-15%), ash (5-7%) .

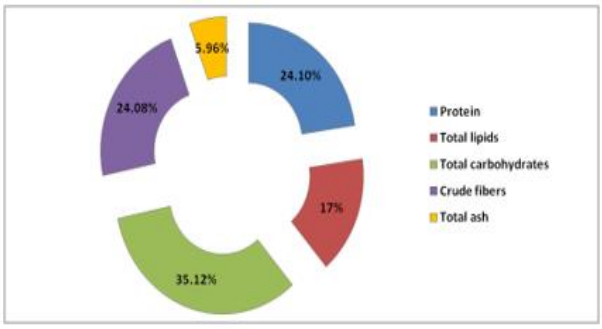

Fig. 14. Illustrated the percentage of nutrients as major chemical composition of *L. sativum* L. seeds.

b. Minerals concentration

Seeds of *L. sativum* L. contained a high level of Sodium 27400 followed by Phosphorus 87500, nitrogen 14000, magnesium 3011.70, zinc 1212.09 and, calcium 901.84 mg/kg, while the rest of the mineral like- potassium, iron, manganese, and copper were found in low concentrations in the seeds (Table 5).

L. sativum L. seeds were found to be a rich source of nitrogen and Phosphorus along with being a good source of zinc and calcium thus can be used as a viable supplement, as medicinal formulations, and inhuman food as a ready source of dietary minerals to fight various diseases Agarwal and Sharma (2011).

Singh *et al*. (2015) and Bryan *et al.* (2009) reported that the seeds contained calcium 266.35, copper 5.73, iron 8.3, magnesium 339.23, manganese 2.00, phosphorus 608.63, potassium 1236.51, sodium 19.65 and zinc 6.99 mg/100 g. The difference between the reported values and the values obtained in the present study may be due to the cultivars they used and the difference in the environmental conditions.

Table 5. Minerals content of L. *sativum* L. seeds.

Minerals		Unit	Results
Nitrogen	(N)	mg/kg	14000
Phosphorus	(P)	mg/kg	87500
Potassium	(K)	mg/kg	700
Sodium	(Na)	mg/kg	27400
Calcium	(Ca)	mg/kg	901.84
Magnesium	(Mg)	mg/kg	3011.70
Iron	(Fe)	mg/kg	416.68
Manganese	(Mn)	mg/kg	28.05
Copper	(Cu)	mg/kg	6.76
Zinc	(Zn)	mg/kg	1212.09

c. Fixed oil analysis

The yield of fixed oil was 19.79 per 100g of *L. sativum* L. mature seeds. As a result of GC-MS analysis, it was found that L. *sativum* L. fixed oil was composed of 16 components of fatty acids (Table 6).

Table 6. Fatty acids of *L. sativum* L. seeds, retention time and their concentrations.

Retention time (mins)	Components name	Numerical symbol	Concentration %
12.29	Myristic acid	C14:0	0.11
15.66	Palmitic acid	C16:0	10.19
16.23	Palmitoleic acid	C16:1	0.18
17.49	Margaric acid	C17:0	0.05
18.07	Ginkgolic acid	C17:1	0.03
19.54	Stearic acid	C18:0	2.63
20.13	Oleic acid	C18:1	19.03
21.19	Linoleic acid	C18:2	11.62
22.04	Y-Linolenic acid	C18:3n6	0.12
22.67	α -Linolenic acid	C18:3n3	31.50
23.86	Arachidic acid	C20:0	3.27
24.60	Gadoleic acid	C20:1	12.90
25.91	Unknown		0.79
27.79	Unknown		0.69
29.42	Behenic acid	C22:0	0.87
30.49	Erucic acid	C22:1	6.05

Fourteen of them were identified and only two components were unknowns. The seed oil of *L. sativum* L. contains 82.29% of unsaturated fatty acids, the major constituent was α–Linolenic acid comprises 31.50% of seed total fatty acids, followed by monounsaturated fatty acids such as oleic (19.03%) and gadoleic (12.89%). In addition, linoleic is the fourth major component which scored 11.62% of seed total fatty acids. The highest content of erucic acid (C22:1, monounsaturated fatty acid) is present in the oil of Brassica rape and B. oleracea (41-46%, respectively) of the total fatty acids (Sharafi *et al.*, 2015). In this investigation, erucic acid recorded 6% of the total fatty acids of *L. sativum* L. seed, this percentage is considered safe but the high levels of erucic acid may be dangerous and harmful to health, so it is recommended to use *L. sativum* L. seed oil for short

periods and in small doses. (Paranjape and Mehta, 2006) found that one gram of *L. sativum* L. seed powder/thrice a day for four weeks in asthmatic patients produced no adverse effect in all treated patients. Worthy to mention that, saturated fatty acids consist 17.12% of the total fatty acids of *L. sativum* L. seed of which palmitic acid (C16:0), stearic acid (C18:0) and arachidic acid (C20:0) comprised 10.19, 2.63 and 3.27%; respectively. The remaining saturated fatty acids recorded less than 1%.

The aforementioned results are in agreement with Chatoui *et al.* (2020) who reported that the major components of *L. sativum* L. seed oil are oleic, linolenic, and linoleic acid as unsaturated fatty acids, and it also contains saturated fatty acids such as palmitic, stearic, and arachidic acid**.**

CONCLUSION

Investigate study was concluded that exploring for plant growth modeling based on linear regression models possess the important role in assessing plant growth at different stages, besides that both morphological and histological botanical attributes the studied of such plant description.

ACKNOWLEDGMENT

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Conflict of interest: There is no conflict of interest in this study with any associations or foundations.

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دراسة نباتية وصفية لنبات حب الرشاد اثناء مراحل نموه المختلفة

هند محمد عبد الغني فرج وشيماء عبد السلام شعبان*

قسم النبات الزراعي – كلية الزراعة – جامعة القاهرة

أجريت هذه الدراسة من أجل توضيح المزيد من التفاصيل حول الصفات المورفولوجية والتشريحية لنبات حب الرشاد خلال مراحل نموه المختلفة. حيث استخدم أثناء الدراسة ثمان صفات خضرية خلال 8 فترات زمنية متتالية على مدار 16 اسبوع من عمر النبات والتي تم اختبارها بواسطة 5 معادلات انحدار خطي لتحديد سلوك تلك الصفات اثناء المدة الزمنية لكل فترة. أيضا تم وصف المجموع الخضري والأعضاء التكاثرية المختلفة مورفولوجيا. علاوة على ذلك تم تسجيل قياسات اخرى عند حصاد النباتات الفردية وهي كالتالي: ارتفاع النبات، عدد سلاميات الساق الرئيسي، عدد الافرع الأولية والثانوية للنبات، عدد القرون (الثمار) للنورة الرئيسة، عدد القرون وعدد البذور للنبات، دليل البذرة (وزن الألف بذرة بالجرام) ومحصول النبات من البذور بالجرام. أظهرت الدراسات التشريحية النمو الثانوي في الجذر. الوريقات بها ثغور من النوع Anomocytic (بدون خلايا مساعدة). عنق الورقة به ثلاث حزم وعائية تقع في المركز واثنتان صغيرتان في الزوايا. كما أظهرت الدراسات التشريحية تركيب الزهرة الكاملة الخنثى وبذرتان داخل الثمرة المحاطة بالغلاف الثمرى. أظهرت نتائج التركيب الكيمائي ان البذرة تحتوي على 24% بروتين، 17% دهون، 35% كربوهيدرات، 24% الياف و5% رماد. يعتبر حمض الفا لينولينيك (31.5%)، الأوليك (19.03%)، الجادوليك (12.89%)، واللينوليك (11.62%) من الاحماض الدهنية الرئيسية لزيت بذور حب الرشاد.