

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Comparative botanical studies of some *Salvia* species (Lamiaceae) grown in Egypt. I Morphological characteristics.

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ABSTRACT

A series of botanical studies of four species of the genus *Salvia* L. grown in Egypt; namely, *Salvia coccinea* Buc'hoz ex Etl., *Salvia farinacea* Benth., *Salvia officinalis* L. and *Salvia splendens* Sellow ex Roem. & Schult was carried out. The present study introduce a detailed botanical information about germination of seeds and the morphology of vegetative and reproductive growth of the four investigated species of *Salvia* throughout the consecutive stages of their whole life span. The vegetative characters include: plant height, number of lateral branches / plant, number of leaves/ plant, total leaf area/ plant and fresh and dry weights of leaves/ plant. In addition, various parameters of the reproductive growth at flowering stage and harvest time were recorded including: number of inflorescences/ plant, number of flowers of the main inflorescence, number of flowers/ plant, number of seeds/ plant, specific weight of seeds and yield of seeds/ plant. Moreover, keen observations and descriptive morphology of the root and the shoot system were under consideration. Such knowledge would be useful to specialists in various aspects of biology of such plants.

Keywords: *Salvia*, seed germination, morphology, vegetative and reproductive growth.

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INTRODUCTION

The family Lamiaceae (Labiatae) or mint family consists of about 250 genera and 7.756 species, cosmopolitan in distribution mainly in warmer and temperate parts, but especially abundant in Mediterranean regions and Asia. Lamiaceae plants are mostly herbs or shrubs, sometimes trees and rarely twinnings or climbers. Many species of this family are strongly aromatic due to essential oils which consist of monoterpenes, sesquiterpenes and phenylpropanoids. They have a very wide range of uses as culinary herbs, medicinal plants, ornamentals, in food flavouring, perfumery and pharmaceutical industries. Moreover, few species are edible (Dahiya, 1979; Shukla and Misra, 1979; Harley *et al.*, 2004; Singh, 2004; Simpson, 2010; Nahak *et al.*, 2011 and Roskov *et al.*, 2015).

The genus *Salvia* L. is one of the largest Lamiaceae genera with about 1000 species spreads in the warm and temperate regions of both North and South hemisphere. The greatest number of species 500 is found in Central and South America, 250 species in Western Asia and 100 species in Eastern Asia (Walker and Sytsma, 2007). In the flora of Egypt, it is represented by 9 wild species, in addition to few cultivated species which are grown as ornamentals and medicinal plants (Boulos, 2002).

Harley *et al.* (2004) described the genus *Salvia* as annual or perennial herbs or shrubs, often aromatic, often viscid with hairs, rarely dendroid; leaves simple, toothed, lobed, pinnatifid or pinnatisect; inflorescence terminal and axillary, often a paniculate, spiciform thyrse of distant or congested 1 to many flowered verticillasters; bracts inconspicuous or larger and sometimes coloured, caduceous or persistent, rarely spinulose, bracteoles present or not; calyx 3-5 lobed, 2-lipped (3/2), lobes rarely spinescent, tube cylindrical to campanulate, corolla strongly 2-lipped 4-5 lobed, white to yellow, or purple to bright red or blue, posterior lip often longer, strongly falcate, to almost straight or flattened, entire or emarginate, anterior lip often with broader median lobe, tube sometimes invaginate or ventricose below, annulate or not; fertile stamens 2, with posterior pair vestigial or absent, anterior pair included two long exserted, filaments usually short, thecae usually 1 by abortion, sometimes 2, connective elongate, often longer than filament, usually articulated at junction of filament, sometimes toothed, posterior arm ascending under corolla lip, sometimes curved, bearing fertile theca, anterior arm bearing reduced subfertile theca, or this replaced by dolabriform or flattened callus, these sometimes connate; stigma lobes usually unequal; disc 4-lobed, anterior lobe often larger; nutlets trigonous, ovoid or suborbicular, abscission scar small, mucilaginous or not.

Four species of *Salvia* growing in Egypt were chosen to be the subjects of the present investigation; namely, *Salvia coccinea* Buc'hoz ex Etl., *Salvia farinacea* Benth., *Salvia officinalis* L. and *Salvia splendens* Sellow ex Roem. & Schult because of their economic importance as ornamentals and medicinal herbs.

The present study aimed at comparing the differences in morphological characters of vegetative and reproductive growth of four investigated species of *Salvia* grown under local conditions throughout the consecutive periods of their whole life span. Such knowledge would be useful to specialists in various aspects of biology of such plant species.

MATERIALS AND METHODS

Plant material

The current investigation was carried out on four species of genus *Salvia* (Lamiaceae); namely: *Salvia coccinea* Buc'hoz ex Etl., *Salvia farinacea* Benth., *Salvia officinalis* L. and *Salvia splendens* Sellow ex Roem. & Schult.

Source of seeds

Seeds of *Salvia coccinea* Buc'hoz ex Etl. and *Salvia farinacea* Benth. were procured from Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt, while seeds of *Salvia officinalis* L. were obtained from the Experimental Station of Medicinal Plants, Faculty of Pharmacy, Cairo University, Giza, Egypt and seeds of *Salvia splendens* Sellow ex Roem & Schult. were collected from Orman Botanical Garden, Giza, Egypt.

Test of germination

A germination test of the four investigated species was carried out to determine the speed (first count, 7 days) and the capacity (final count, 14 days) of germination according to the Rules for Seed Testing Association (Anon., 1979). The recommended conditions of germination are summarized as follows:

Substrate : Between blotters or in sand
Temperature °C : 20-30
First count (days) : 7
Final count (days) : 14

Preparation of transplants

In order to obtain transplants of investigated *Salvia* species, the seeds were sown promptly in divided foam seedling trays in open air, filled with a mixture of peat moss and vermiculite (1:1 volume), one seed / hole, irrigation soon, then irrigated regularly every 3 days. This work was carried out in the wire greenhouse of the Experimental Station of Medicinal Plants, Faculty of Pharmacy, Cairo University, Giza, Egypt. Date of cultivation was October 30th, 2012 for the four studied plant species of genus *Salvia*.

Field work procedure

The field trial was carried out in the Agricultural Experiments and Researches Station, Faculty of Agriculture, Cairo University, Giza, Egypt. Date of transplantation was November 30th, 2012 for the four studied plant species of genus *Salvia*, aged a month. The field work continued to July 2014 (two consecutive growing seasons).

Due to withering and defoliation associated with aging at the end of the first growing season, terminal branches of three plant species; namely, *S.coccinea*, *S.farinacea* and *S. splendens* were cut in September 2013 to renew the plant growth for the second season. However, *S.officinalis* continued growth and no cutting was needed throughout the whole period of the experiment.

The experimental field layout was a randomized complete block design with four replicates per each plant species. Plot dimensions were 3 × 4 m. with five ridges 60 cm apart. Transplants were inserted at 50 cm distance between plants. Irrigation was carried out immediately after cultivation to encourage root development. All field practices were then performed as recommended for the investigated plants in the vicinity.

Plant authentication

Mature plant specimens of each of the four investigated plant species were collected from the experimental site and subjected to identification at the Herbarium, Flora & Phyto-Taxonomy Researches, Horticulture Research Institute, Agricultural Research Center, Dokki, Giza, Egypt (CAIM). Authentication of the four investigated plant species was carried out. Plant samples were identified using botanical keys before being compared with reference herbarium specimens from CAIM collection for each of the four investigated plant species.

Comparison with voucher specimens and standard description proved that investigated plant species are authentic materials for: *Salvia coccinea* Buc'hoz ex Etl., *Salvia farinacea* Benth., *Salvia officinalis* L. and *Salvia splendens* Sellow ex Roem. & Schult. The identified plants were prepared in form of herbarium specimens and deposited in Department of Agricultural Botany, Faculty of Agriculture, Cairo University, Giza, Egypt and CAIM. Scientific names of investigated plant species were revised according to the Catalogue of Life Annual Checklist (Roskov *et al.*, 2015).

Observations and recording of data

Vegetative growth

Eight plants were assigned to follow up the vegetative growth for each plant species at monthly intervals. At each sampling date the shoot system was described morphologically. Measurements recorded for the shoot system were plant height (cm), number of the lateral branches / plant, number of leaves / plant and total leaf area / plant (cm²). Fresh and dry weights (70°C) of leaves (g) were determined.

Reproductive growth

General characters and detailed description of various reproductive organs were reported. Flowering period was determined; *i.e.*, date of onset and end of flowering was recorded.

The recorded characters were total number of inflorescences / plant, number of flowers of the main inflorescence, total number of flowers / plant, total number of seeds / plant, specific weight of seeds (weight of 1000 seeds, g) and yield of seeds / plant (g).

Data were subjected to conventional methods of analysis of variance according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Germination of seeds and seedling growth

The seeds of *Salvia* species occur usually as entire nutlets. After sowing of seeds, germination takes place. Nutlet with the seed imbibes water as a first step leading to germination. As a result, the seed and nutlet coats soften and swell and burst at the basal end of the seed. As germination proceeds, the structure of the seedling soon becomes evident. The radical emerges from the lower end where the seed has been bursted. This takes place in about two days. Seed germination of *Salvia* species is epigeal; the hypocotyl elongates and raises the two cotyledons above the ground accompanied by the partially enveloping remains of the seed. The hypocotyl is somewhat bent in its growth before emergence above the soil, and then becomes straight. This almost takes place six days after sowing. The hypocotyl is slenderical in shape and green in color. The cotyledons are small in size, fleshy, green in colour and fan in shape in *S. coccinea* and *S. farinacea* while reniform shape in *S. officinalis* and *S. splendens* (Figure 1). By now, the plumule is also upward and the secondary roots develop. At the age of 10-14 days, the first two foliage leaves are formed and seedling stage comes to an end.

Using the Rules for Seed Testing Association (Anon., 1979) the germination speed (after 7 days) being 90, 85, 35 and 80% and the germination capacity (after 14 days) was 92, 90, 45 and 85% for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively. These values indicate that seeds of *S. coccinea*, *S. farinacea* and *S. splendens* are highly viable compared to *S. officinalis* seeds.

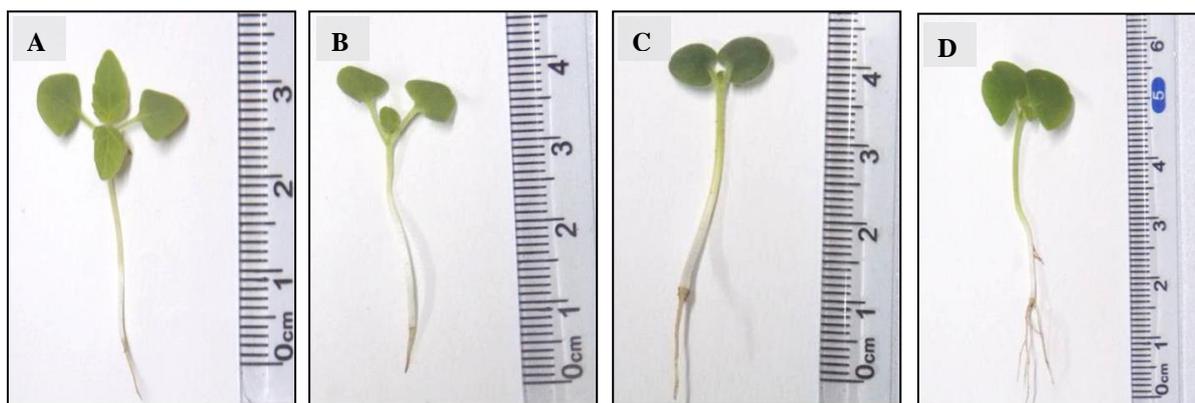


Fig.1. Photographs of the four studied plant species of *Salvia* seedlings at the age of 10 days. The cotyledons are small in size, fleshy, green in colour and fan in shape in A. (*S. coccinea*) and B. (*S. farinacea*) and reniform in shape in C. (*S. officinalis*) and D. (*S. splendens*).

The tap (primary) root, of studied species of *Salvia* develops directly below the hypocotyl and both are similar in thickness then tapering towards the root apex. Lateral roots develop acropetally in two longitudinal rows. The root system is mainly composed of a stout tap root developing a large number of lateral roots of different branching degrees. Due to difficulty in taking intact underground samples which were easily ruptured when pulled out no measurements of the root system could be recorded.

The shoot system

By the end of seedling stage (age of two weeks), the plumule starts a prominent development to produce the shoot. At the age of one month (Nov. 2012), three internodes are developed, stem erect and plant height reaches 7.0, 7.2, 8.0 and 9.3 cm for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively. About six foliage leaves are developed in three pairs. Worthy to note that the two cotyledons are still intact at this age (Figure 2).

At the age of three months (Jan.2013), the primary branches of *S. coccinea* and *S. officinalis* are developed, while the other two species (*S. farinacea* and *S. splendens*) are developed at the age of four months (Feb.2013). Lateral shoot develops in an acropetal succession; *i.e.*, developing upward from the base toward the apex.

When plants are five months old (March 2013), the internodes elongate and their number records 12.0, 10.7, 10.5 and 12.0, plant height reaches 50.8, 43.8, 27.6 and 31.3 cm and total number of leaves per plant averages 184.3, 135.8, 88.5 and 59.5 for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively. At this age, racemes emergence starts and onest of flowering is observed for three species of the studied plants excluding *S. officinalis* (Figure 3).

Flowering stage of *S. coccinea*, *S. farinacea* and *S. splendens* started in March 2013 and continued up to August during the first season, while in the second season flowering started from January 2014 to July 2014. However, *S. officinalis* started flowering for the first time late at the end of January 2014 up to April in the second season. Flowers are arranged in whorls of terminal racemes on the main stem and lateral branches. Fruiting stage starts when all inflorescences developed where some inflorescences formed fruits with mature seeds. The fruit consists of four nutlets, each nutlet comprised one seed.

Worthy to state that, at the end of the first growing season the upper part of three of the studied plant species; namely, *S. coccinea*, *S. farinacea* and *S. splendens* were cut to encourage the growth and to produce more flowers in the second season.

Salvia species are herbaceous perennial plants, tomentose and branched. Stem is erect, glabrous and hexangular in case of *S. splendens* while other plant species are quadrangular. Stem colour varies depending upon variation of species; *e.g.* stem of *S. coccinea* is crimson in colour, while stem of *S. farinacea* and *S. splendens* is green in colour but the nodes of the main stem and leaf petiole of *S. splendens* are reddish in colour, however in case of *S. officinalis*, white wooly hairs cover all parts of the plant so that shoots turn greyish- green in colour (Figures 3). The leaves of *Salvia* species are simple, opposite, petioled, exstipulate, glabrous on both surfaces and have reticulate venation. The stalked leaves are arranged in a decussate manner, where the arrangement of a pair of opposite leaves intersects the next to form a cross and so on. Flowers are arranged in terminal racemes of the main stem and lateral branches. The fruit consists of four nutlets enclosed in the mature calyx.

The aforementioned description of the shoot system agrees with those stated by Bailey (1969), Bown (1998), Edward and Teresa (1999), Betsy and Barner (2003), Christopher (2003), Harley *et al.* (2004), Singh and Panda (2005) and Mckenney and Sandra (2008).

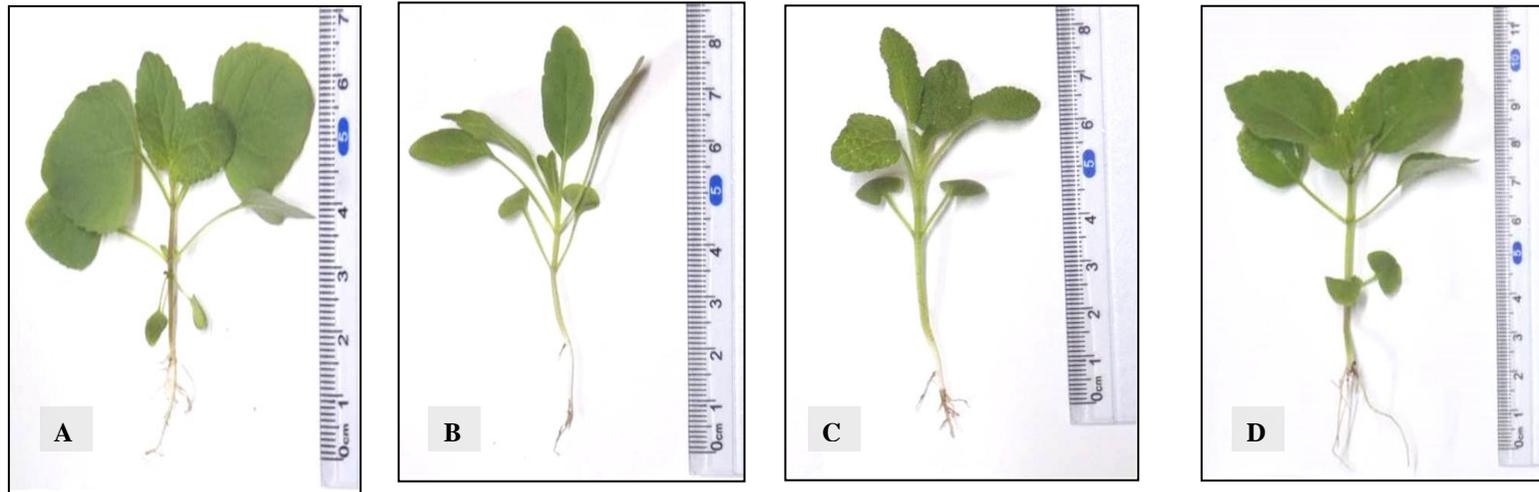


Fig .2. Photographs of the four studied species of *Salvia* plants at the age of one month. The two cotyledons still intact.
 A. *S. coccinea*, B. *S. farinacea*, C. *S.officinalis* and D. *S.splendens*.

Fig .3. Photographs of the four studied species of *Salvia* plants at the age of five months (March 2013), showing the flowering onset for three species of the studied plants excepting *S.officinalis*. A. *S. coccinea*, B. *S. farinacea*, C. *S.officinalis* and D. *S.splendens*.



Plant height

The increase in plant height continued during most of the entire life span of the plants (Table 1). In the first season, plant height of *S.officinalis* increased continuously to reach 58.6 cm in August 2013. In case of other species of *Salvia*, increments were observed from March 2013 (flowering onset) being 50.8, 43.8 and 31.3cm up to June 2013 (full blooming stage) to record a plant height of 95.4, 87.3 and 70.3 cm. for *S.coccinea*, *S. farinacea* and *S. splendens*; respectively.

At the end of the first growing season (September 2013), the upper parts of the three plant species; *S.coccinea*, *S. farinacea* and *S. splendens* were cut to renew the plant growth of the second season. But *S.officinalis* continued growing and no cutting was needed for this species throughout the whole period of the experiment.

The maximum heights of the four plant species were recorded in the second season (May 2014) being 150.1, 110.3, 75.7 and 85.4 cm for *S.coccinea*, *S. farinacea*, *S.officinalis* and *S. splendens*; respectively. It is obvious that, *S.coccinea* recorded the highest values of plant height compared to other studied species.

Noteworthy that, elongation of plants progressed consistently throughout the consecutive periods of plant life.

The lateral branches

Number of the primary branches

It was found that the primary branches of *S.coccinea* and *S.officinalis* started their development at January 2013 (Table 1). Whereas the primary branches of *S.farinacea* and *S.splendens* were observed a month later (February 2013). The number continued to increase up to the end of the first season (August 2013) being 18.25, 16.75, 20.0 and 14.25 for *S.coccinea*, *S. farinacea*, *S.officinalis* and *S.splendens*; respectively. However, no further substantial increments were observed in number of the primary branches from August until December 2013.

In the second season, a slight increase in number of branches was then recorded reaching a maximum of 22.5, 18.5, 28.0 and 18.75 branches; respectively in June 2014. No further increments were achieved thereafter.

Number of the secondary branches

The secondary branches of *S.coccinea* and *S. splendens* started their development at January 2014 in the second growing season. In case of *S. farinacea* and *S.officinalis*, no secondary branches were formed. Total number of secondary branches recorded in July 2014 was 15.3 and 9.8 branches for *S.coccinea* and *S.splendens*; respectively. These branches behaved in their growth in a similar manner to that of the main stem. Worthy to mention that secondary branches of *S.coccinea* plant play a vital role in yield production.

The leaf

Mature leaves of the four investigated plant species of *Salvia* are simple, petiolate, opposite, exstipulate, glabrous on both surfaces in case of *S.coccinea*, *S. farinacea* and *S. splendens* and densely covered with trichomes in case of *S.officinalis*, venation reticulate. The leaves are arranged in decussate manner, where the arrangement of a pair of opposite leaves intersects the next to form a cross and so on.

Leaves of *S. coccinea* are dark green in colour, 5-9 cm in length, ovate to cordate (cordiform) in shape, crenate margin, apex acute and base cordiform.

Leaves of *S. farinacea* are green in colour, 10-12 cm in length, lance-ovate in shape, acute at apex and base and serrate margin.

Table.1. The periodic growth and statistical analysis of plant height (cm) and total number of primary branches of investigated plant species of *Salvia* throughout two consecutive seasons.

Date	Plant height (cm)					Total number of primary branches				
	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	Mean (A)	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	Mean (A)
Nov. 2012	7.0	7.2	8.0	9.3	7.9	0.00	0.00	0.00	0.00	0.00
Dec.	9.3	10.8	11.3	13.8	11.3	0.00	0.00	0.00	0.00	0.00
Jan. 2013	10.9	11.4	14.2	17.2	13.4	3.50	0.00	4.00	0.00	1.88
Feb.	15.4	16.8	20.3	23.5	19.0	6.00	2.00	8.00	3.00	4.75
March	50.8	43.8	27.6	31.3	38.3	10.75	7.00	11.25	8.50	9.38
April	87.0	72.0	44.5	55.0	64.6	16.25	12.25	14.75	12.50	13.94
May	93.1	84.4	50.4	63.3	72.8	17.00	14.50	16.00	13.50	15.25
June	95.4	87.3	54.6	70.3	76.9	17.25	15.75	17.50	14.00	16.13
July	95.0	85.9	55.9	70.0	76.7	18.00	16.50	19.75	14.00	17.06
August	90.0	81.0	58.6	66.4	74.0	18.25	16.75	20.00	14.25	17.31
Dec.2013	77.1	69.0	60.1	57.4	65.9	18.75	16.75	20.50	15.00	17.75
Jan. 2014	85.9	77.0	66.8	64.5	73.5	19.50	16.00	21.75	15.25	18.13
Feb.	100.5	81.3	71.3	69.9	80.7	19.75	17.00	24.25	16.00	19.25
March	122.2	94.3	74.5	79.1	92.5	20.25	17.25	26.00	16.50	20.00
April	145.8	107.5	75.1	83.0	101.3	21.00	17.75	27.50	17.10	20.84
May	150.1	110.3	75.7	85.4	109.1	22.25	18.25	27.75	17.50	21.44
June	148.0	100.0	70.3	81.1	99.9	22.50	18.50	28.00	18.75	21.94
July	145.3	98.0	70.1	80.8	98.6	22.50	18.50	28.00	18.50	21.88
Mean (B)	84.9	68.8	50.5	56.7		15.19	12.49	17.50	11.91	
L.S.D. _{0.05} (A)	2.5					1.23				
L.S.D. _{0.05} (B)	1.2					0.57				
L.S.D. _{0.05} A x B	3.6					2.41				

Leaves of *S. officinalis* are greyish-green in colour since they are densely covered with white wooly hairs, 5-10 cm in length, leaf blade is corrugated, lance-ovate to auriculiform in shape, apex acute to rounded, base rounded to auriculate and crenulate margin. The leaves are strongly aromatic due to volatile oils located in the glandular hairs.

Leaves of *S. splendens* are dark green in colour with red petiole, 8-10cm long, ovate in shape, apex acuminate, base obtuse and margin dentate. (Table 2 and Figure 4).

The previously given morphology of leaf of the four studied *Salvia* species is in conformity with that mentioned by Bailey (1969), Betsy and Barner (2003), Christopher (2003), Radford *et al.* (1974) and Singh and Panda (2005).

Number of leaves per plant

Total number of leaves per plant at the beginning of the growing season (November 2012), when plants aged one month, was six leaves in case of the four studied *Salvia* species (Table 3). This number increased significantly reaching 620.0,

Table 2. Morphological diagnostic characters of leaves of the four studied plant species of *Salvia*.

characters	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S.officinalis</i>	<i>S. splendens</i>
Colour	Dark green	Green	Greyish-green	Green with red petiole
Length, cm	5-9	10-12	5-10	8-10
Shape	Ovate to cordate	Lance-ovate	Lance-ovate to auriculiform	Ovate
Apex	Acute	Acute	Acute to rounded	Acuminate
Base	Cordiform	Acute	Rounded to auriculate	Obtuse
Margin	Crenate	Serrate	Crenulate	Dentate

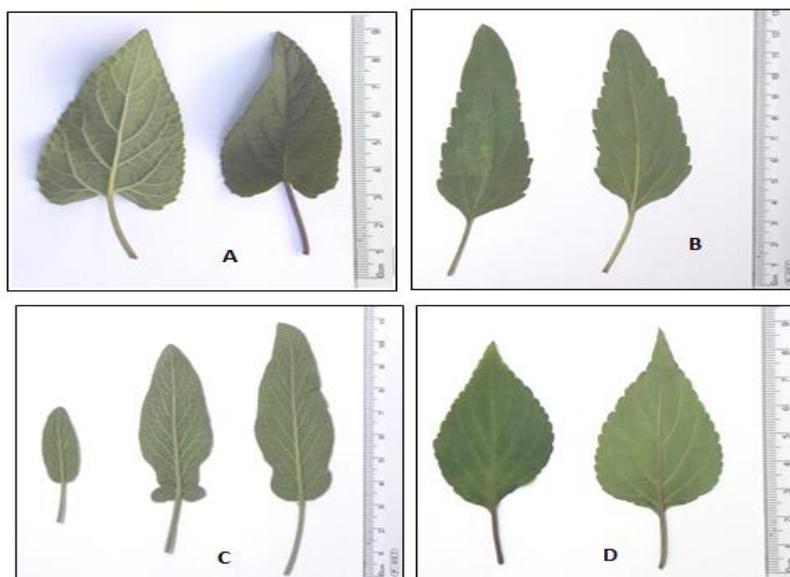


Fig .4. Photographs showing mature leaves develop on the main stem of the four investigated plant species of *Salvia*. Leaves are simple, petiolate and exstipulate. Venation reticulate, ovate to cordate shape in *S. coccinea* (A), lance-ovate shape in *S. farinacea* (B), lance-ovate to auriculiform shape in *S.officinalis* (C) and ovate shape in *S.splendens* (D).

357.3, 574.5 and 294.3 for *S.coccinea*, *S. farinacea*, *S.officinalis* and *S. splendens*; respectively in July 2013. At the end of the first growing season (August 2013), leaves number of *S. coccinea*, *S. farinacea* and *S. splendens* decreased as plants were in full fruiting stage, in the mean time leaves number of *S. officinalis* increased continuously to reach 592.5, then leaves number of the four studied *Salvia* species decreased toward the winter season reaching 185.8, 119.3, 500.0 and 98.1 for *S.coccinea*, *S. farinacea*, *S.officinalis* and *S. splendens*; respectively (December 2013). Significant increments were recorded thereafter.

Worthy to mention that, the maximum number of leaves of *S. coccinea*, *S.farinacea* and *S. splendens* was achieved at the end of the first growing season (July 2013). Whereas the maximum number of *S. officinalis* leaves was recorded in the second growing season (April 2014), being 720.3 leaves. Thereafter, the leaves number decreased again till the end of the second growing season (July 2014) as a result of shrivelled, normal dryness and defoliation of leaves at fruiting stage.

Leaf area per plant

As being expected, both the number of leaves and leaf area per plant behaved in a similar manner throughout the two growing seasons of the present study (Table 3).

In concern of the first season, total leaf area per plant of the four studied plant species of *Salvia* at the beginning of the growing season (transplants of one month old) was 21.9, 20.8, 14.3 and 18.4 cm² for *S.coccinea*, *S. farinacea*, *S.officinalis* and *S. splendens*; respectively, then increased gradually to reach a maximum in July 2013 being 5122.5, 2826.4 and 2518.1cm² for *S. coccinea*, *S. farinacea* and *S. splendens*; respectively. While total leaf area of *S. officinalis* continued to increase till August 2013, being 4576.7 cm². Normal decrease in total leaf area occurred thereafter in December 2013 due to normal defoliation of leaves in winter season.

Regarding the second growing season, leaf area per plant increased again from January up to April 2014 in *S. officinalis* to reach a maximum of 6971.5 cm². In case of *S. coccinea*, *S. farinacea* and *S. splendens*, increment in total leaf area continued up to May 2014, being 4984.5, 2790.6 and 2350.7 cm²; respectively.

Fresh weight of leaves per plant

It is obvious that, number of leaves, leaf area (Table 3), fresh and dry weight of leaves per plant (Table 4) of the four studied plant species of *Salvia*, as being expected, followed the same trend of growth pattern.

Fresh weight of leaves per plant of the four studied plant species of *Salvia* increased slightly from sowing date up to February 2013 (the age of four months); *i.e.*, values were statistically indifferent reaching 5.69, 2.58, 5.08 and 5.33 g for *S.coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively (Table 4). A significant increment was observed from March till July 2013 in *S. coccinea*, *S.farinacea* and *S. splendens*, where the fresh weight of leaves reached the maximum being 115.60, 75.91 and 88.73 g; respectively. Whereas the fresh weight of *S.officinalis* leaves increased till August 2013 being 92.61g, at the same time the fresh weight of leaves of other studied species decreased due to normal dryness of leaves after fruiting stage. The least fresh weight of leaves of the four studied plant species was attained throughout the winter season (December 2013) recording 40.51, 32.15, 74.61 and 37.32 g for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively.

At the beginning of January 2014, fresh weight of *S. officinalis* leaves increased again till April to reach a maximum of 175.51g. In case of *S. coccinea*, *S. farinacea* and *S. splendens*, fresh weight of leaves continued its increase until May 2014 being 94.25, 70.68, 81.31g; respectively. Thereafter, fresh weight of leaves of the four studied *Salvia* plant species decreased gradually toward the end of the second growing season.

Dry weight of leaves per plant

No appreciable increments were gained in dry weight of leaves up to March 2013 in the first season, being 9.23, 4.45, 3.24 and 3.75 g for *S. coccinea*, *S.farinacea*, *S.officinalis* and *S. splendens*; respectively (Table

4). However, significant increments in the dry weight of leaves were recorded at the following ages reaching in July to 25.47, 14.71, 20.33 and 18.76 g for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively. Thereafter, no substantial increase in dry weight of leaves was recorded. Evenmore, fresh weight of leaves decreased until December 2013. Such decrease would be expected due to withering and defoliation associated with aging.

The dry weight of leaves of the four studied plant species of *Salvia* increased again in January 2014. This increase continued until May 2014 reaching 23.09, 15.30, 31.52 and 19.34 g for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively.

Noteworthy to mention that, in April 2014 *S. officinalis* recorded the highest values for number of leaves (720.3), total leaf area (6971.5 cm²), fresh weight of leaves (175.51 g) and dry weight of leaves per plant (31.52 g) compared to other studied plant species.

Reproductive growth

The inflorescence

Flowering stage of *S. coccinea*, *S. farinacea* and *S. splendens* started in March 2013 and continued up to August during the first season, while the flowering period extend in the second season from January 2014 up to July 2014; i.e., flowering of three studied plant species of *Salvia* lasted some six months recording a long period of flowering. However, *S. officinalis* started flowering for the first time at the end of January 2014 up to April in the second season; i.e., flowering of *S. officinalis* lasted only for some three months.

The inflorescence of investigated species of *Salvia* is a raceme that develops in the axils of uppermost leaves on the main stem and lateral branches and forms a whorl of flowers at each node. This type of inflorescence is known as verticillaster (Figure 5). Average length of the main stem inflorescence was 24.4, 20.5, 10.7 and 19.0 cm and average number of inflorescences per plant at full blooming stage was 29.5, 17.5, 11.0 and 14.0 for *S. coccinea*, *S. farinacea*, *S. officinalis* and *S. splendens*; respectively (Table 5). It is noted that, *S. coccinea* recorded the highest values compared to other species.

The flower

The flowers are arranged in whorls at the nodes of the inflorescence. Number of flowers at each node varies depending upon the species; i.e., *S. coccinea* and *S. splendens* bearing 6-8 flowers (average 7.0), *S. farinacea* bearing 8-10 flowers (average 9.0) and *S. officinalis* bearing 6.0 flowers at each node. In concern of total number of flowers per plant at full blooming, *S. coccinea* recorded higher values (2480.0) compared to other species (1160.5, 309.5 and 542.8 for *S. farinacea*, *S. officinalis* and *S. splendens*; respectively) (Table 5).

The flower is perfect, hermaphrodite, zygomorphic and hypogynous. The calyx is persistent and composed of 5 toothed sepals. Calyx usually green in colour but sometimes coloured such as *S. splendens* which is red in colour. The flower stalk is shorter than the calyx. The corolla has 2 labiate, the upper lip is composed of two posterior petals, while the remaining three petals form the lower lip. The corolla colour is variable; red in *S. coccinea* and *S. splendens*, blue in *S. farinacea* and purple in *S. officinalis* (Figure 5). Androecium consists of 2 stamens, attached with the corolla. Gynoecium consists of a compound ovary of 2 carpels. Ovary superior, 4 chambered, single ovule in each loculus and basal placentation.

Floral formula:

$\% , \overset{\uparrow}{\underset{\oplus}{\text{♀}}}, \text{K}_{(3/2)}, \text{C}_{(2/3)}, \text{A}_{(2)}, \text{G}_{(2)}$ basal placentation

at stated by Bailey

(1969), Harley *et al.* (2004), Singh *et al.* (2008), Taktajan (2009) and Simpson (2010).

Table.3. The periodic growth and statistical analysis of total number of leaves and total leaf area, cm² per plant of investigated plant species of *Salvia* throughout two consecutive seasons.

Date	Total number of leaves per plant					Total leaf area, cm ² per plant				
	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	Mean (A)	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	Mean (A)
Nov. 2012	6.0	6.0	6.0	6.0	6.0	21.9	20.8	14.3	18.4	18.9
Dec.	10.0	11.0	8.5	10.7	10.1	34.8	31.5	20.1	24.2	27.7
Jan. 2013	22.8	12.5	20.1	13.0	17.1	104.3	40.8	76.1	53.9	68.8
Feb.	55.5	28.3	44.8	34.7	40.8	273.7	115.3	161.2	167.1	179.3
March	184.3	135.7	88.5	59.5	117.0	1508.5	852.5	571.3	648.7	895.3
April	377.3	234.1	349.2	117.5	269.5	2804.4	1642.7	3045.3	1398.0	2222.6
May	550.0	265.5	417.2	252.3	371.3	4030.7	1960.2	3847.8	1632.8	2867.9
June	584.5	345.8	465.3	287.2	420.7	4254.9	2583.9	4187.1	2256.5	3320.6
July	620.0	357.3	574.5	294.3	461.5	5122.5	2826.4	4363.1	2518.1	3707.5
August	421.8	318.2	592.5	236.0	392.1	3948.2	2238.6	4576.7	1519.5	3070.8
Dec.2013	185.8	119.3	500.0	98.1	225.8	952.2	718.1	3714.9	587.8	1493.3
Jan. 2014	225.3	164.4	628.8	144.5	290.8	1657.0	1053.1	4985.1	814.1	2127.3
Feb.	382.5	223.5	657.1	184.3	361.9	2776.8	1463.2	5516.2	1529.3	2821.4
March	436.5	258.3	711.3	252.2	414.6	3840.2	1937.1	6178.5	2173.0	3532.2
April	489.9	296.5	720.3	269.2	443.9	4611.9	2363.7	6971.5	2286.4	4058.4
May	548.8	313.5	639.5	280.8	445.7	4984.5	2790.6	6590.7	2350.7	4179.1
June	530.2	300.7	534.5	271.3	409.2	4431.9	2731.4	4363.6	2343.7	3467.7
July	367.3	252.8	529.2	244.5	348.5	2912.0	2097.6	3652.8	1596.3	2564.7
Mean (B)	333.3	202.4	415.9	169.8		2681.7	1526.0	3490.9	1328.8	
	L.S.D._{0.05} (A) 17.87					278				
	L.S.D._{0.05} (B) 8.43					131				
	L.S.D._{0.05} A x B 35.75					555.9				

Table.4. The periodic growth and statistical analysis of fresh and dry weight of leaves, g per plant of investigated plant species of *Salvia* throughout two consecutive seasons.

Date	Fresh weight of leaves, g per plant					Dry weight of leaves, g per plant				
	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	Mean (A)	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	Mean (A)
Nov. 2012	0.29	0.24	0.26	0.46	0.31	0.03	0.02	0.02	0.02	0.02
Dec.	0.33	0.40	0.35	0.48	0.39	0.15	0.20	0.03	0.21	0.15
Jan. 2013	1.82	1.49	2.38	2.55	2.06	0.28	0.20	0.38	0.30	0.29
Feb.	5.69	2.58	5.08	5.33	4.67	1.04	0.47	0.98	0.92	0.85
March	26.27	19.28	16.70	18.80	20.26	9.23	4.45	3.24	3.75	5.17
April	80.57	39.72	67.76	66.45	63.63	16.41	10.35	14.57	13.08	13.60
May	89.13	50.13	86.05	75.50	75.20	21.69	11.43	18.93	16.82	17.22
June	100.10	65.22	89.21	78.13	83.17	24.13	13.09	19.78	17.21	18.55
July	115.60	75.91	90.74	88.73	92.75	25.47	14.71	20.33	18.76	19.82
August	88.42	64.83	92.61	69.31	78.79	19.92	12.18	20.52	15.45	17.02
Dec.2013	40.51	32.15	74.61	37.32	46.15	12.58	9.25	17.65	11.58	12.76
Jan. 2014	65.35	40.65	98.21	62.21	66.61	13.73	10.39	20.82	14.27	14.80
Feb.	79.56	52.12	128.28	68.40	82.09	15.21	12.18	22.78	15.53	16.42
March	84.14	56.75	159.24	75.14	93.82	17.04	12.94	26.14	17.36	18.37
April	87.35	61.80	175.51	76.90	100.39	17.89	13.59	31.20	18.15	20.21
May	94.25	70.68	170.05	81.31	104.07	23.09	15.30	31.52	19.34	22.31
June	91.72	68.92	166.76	79.30	101.68	22.31	14.77	30.55	18.91	21.64
July	82.21	50.31	145.85	71.55	87.48	20.44	11.26	25.13	16.50	18.33
Mean (B)	62.96	41.84	87.20	53.22		14.48	9.27	16.92	12.12	
		L.S.D._{0.05} (A)	6.94			1.61				
		L.S.D._{0.05} (B)	3.27			0.76				
		L.S.D._{0.05} A x B	13.89			3.22				

The fruit and the seed (nutlet)

Fruiting stage occurred when all inflorescences were developed and turned to fruits with mature seeds. Fruits are arranged in whorls at the nodes of the inflorescence. The fruit enclosed by the persistent calyx of 4 mericarps (nutlets) separating at maturity. Each nutlet comprised one non-endospermic seed with a thin testa and dicotyledonous embryo.

The nutlets of *Salvia* species are different in shape, i.e.; the nutlets shape are ellipsoidal elongated in *S. coccinea*, ovoid in *S. farinacea*, spherical to oval in *S. officinalis* and elliptical in shape with uneven apex in *S. splendens*. The colour of the nutlets is generally brown (Figure 6).

It is realized from Table (6) that the average number of nutlets (seeds) per plant was 7740 seeds weighed 10.7g in *S. coccinea*, 3920 seeds weighed 4.6g in *S. farinacea*, 9560 seeds yielded 7.3g in *S. officinalis* and 1820 seeds yielded 6.5g in *S. splendens*. *S. officinalis* showed increments in seed dimensions and also recorded a significant increase for the specific weight of nutlets (weight of 1000 nutlets) 7.6 g compared to other species of *Salvia* (1.4, 1.2 and 3.4g for *S. coccinea*, *S. farinacea* and *S. splendens*; respectively).

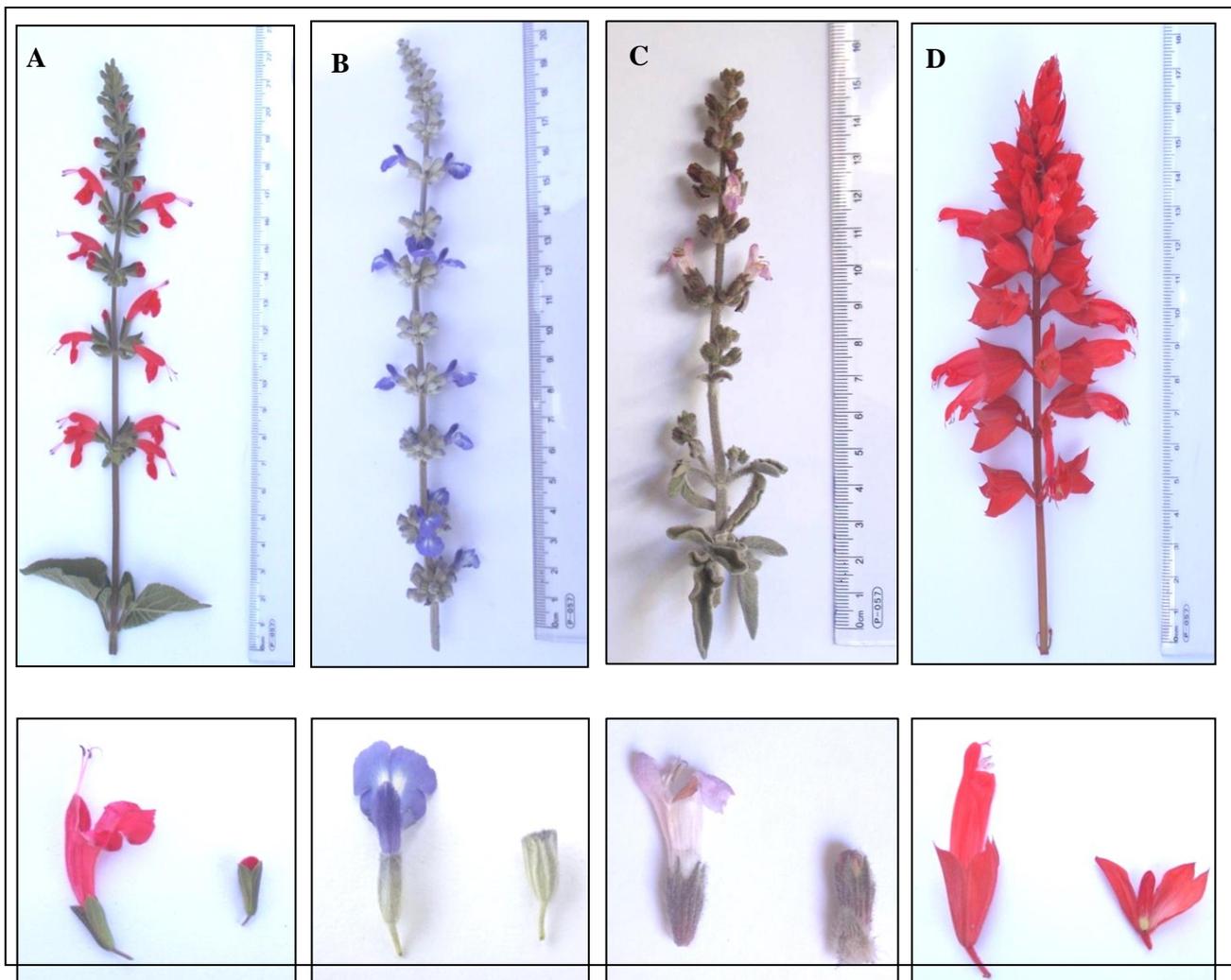


Fig. 5. Photographs showing the inflorescences (verticillaster raceme) and different colour of flowers of the four investigated plant species of *Salvia*. (A) *S. coccinea* (B) *S. farinacea* (C) *S. officinalis* and (D) *S. splendens* .

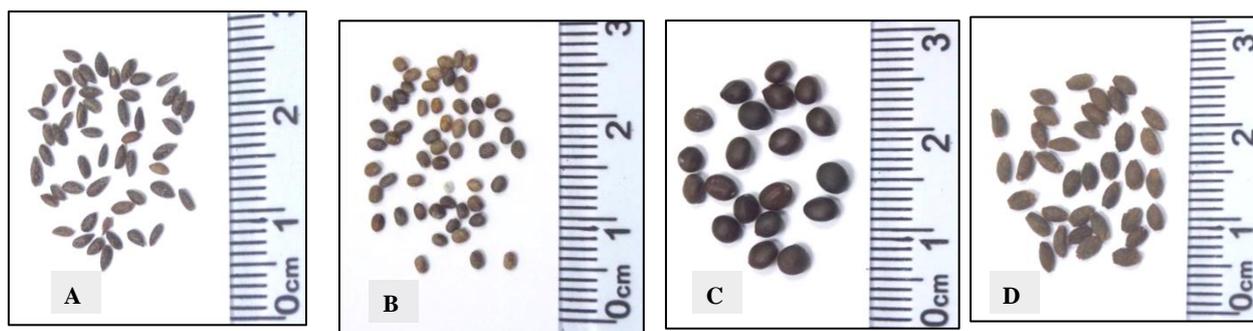


Fig. 6. Photographs showing the nutlets (seeds) of the four studied plant species of *Salvia*.
(A) *S. coccinea* (B) *S. farinacea* (C) *S. officinalis* and (D) *S. splendens*.

Table 5. Morphological characters of inflorescences, flowers and their statistical analysis at full blooming stage of the four investigated plant species of *Salvia*.

Characters	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	L.S.D. _{0.05}
Type of infl.	Verticillaster raceme	Verticillaster raceme	Verticillaster raceme	Verticillaster raceme	-
Calyx colour	green	green	green	red	-
Corolla colour	red	blue	purple	red	-
Length of the main stem infl.	24.4 A	20.5 B	10.7 C	19.1 B	2.91
No. of inflorescences / plant.	29.5 A	17.5 B	11.0 C	14.0 B	3.97
No. of flowers of main stem infl.	124.3 B	170.5 A	39.5 D	74.0 C	13.18
No. flowers at each node of the infl.	7.0 BC	9.0 A	6.0 C	7.0 B	1.09
Total no. of flowers / plant.	2480.0 A	1160.5 B	309.5 D	542.8 C	216.2

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

Table 6. Morphological characters of seeds (nutlets) and seed yield characters at harvest time of the four investigated plant species of *Salvia*.

Characters	<i>S. coccinea</i>	<i>S. farinacea</i>	<i>S. officinalis</i>	<i>S. splendens</i>	L.S.D. _{0.05}
(A) Nutlets :					
Shape	Ellipsoidal elongated	Ovoid	Spherical to oval	Elliptical with uneven apex	-
Colour	Dark brown	Light and dark brown	Dark brown	Brown	-
Appearance	Marbled	Smooth	Smooth	Marbled	-
Length (mm)	2.25 B	2.0 B	3.23 A	3.18 A	0.33
Width (mm)	1.00 C	1.25 BC	2.38 A	1.55 B	0.39
(B) Seed yield:					
No. of nutlets (seeds) / plant	7740 A	3920 B	956 D	1820 C	583
Weight of 1000 nutlets (g)	1.4 C	1.2 D	7.6 A	3.4 B	0.2
Yield of seeds / plant (g)	10.7 A	4.6 C	7.3 B	6.5 B	1.2

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

Key for the four studied plant species of *Salvia*:

- Leaf surface grayish-green in colour, corolla purple in colour and inflorescence of the main stem averaged about 10 cm in length and developing < 40 flower.....1. *S. officinalis*
Leaf surface green in colour, corolla red or blue in colour and inflorescence of the main stem averaged about 20 cm in length and developing > 70 flower.....2

2. Petals blue in colour2. *S. farinacea*
 Petals red in colour3.
 3. Stem crimson, calyx green, corolla 1.5-2.5cm long.....3. *S. coccinea*
 Stem green with reddish nodes, calyx red, corolla more than 3.5cm long.....4. *S. splendens*

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