PLANT SCIENCE TODAY
Vol 12(2): 1-16
https://doi.org/10.14719/pst.7092

eISSN 2348-1900

RESEARCH ARTICLE

Variations in the morphology, postharvest behaviour and phytochemical properties of commercial red-coloured cultivars of *Hibiscus rosa-sinensis* in West Bengal

Suhrrita Chakrabartty Das*[1], Lalita Mandi[1], Karabi Biswas[2], Tapas Kumar Chowdhuri[3] & Kuntal Chakravarty[4]

[1]Department of Post Harvest Technology, F/Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741 252, West Bengal, India
[2]Department of Botany, University of Kalyani, Kalyani, Nadia 741 235, West Bengal, India
[3]Department of Floriculture and Landscaping, F/Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741 252, West Bengal, India
[4]Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741 252, West Bengal, India

*Correspondence email - suhritakvk@gmail.com

Received: 01 January 2025; Accepted: 10 March 2025; Available online: Version 1.0: 08 May 2025; Version 2.0 : 19 May 2025

Cite this article: Suhrrita CD, Lalita M, Karabi B, Tapas K C, Kuntal C. Variations in the morphology, postharvest behaviour and phytochemical properties of commercial red-coloured cultivars of *Hibiscus rosa-sinensis* in West Bengal. Plant Science Today. 2025; 12(2): 1-16. https://doi.org/10.14719/pst.7092

Abstract

In West Bengal, *Hibiscus rosa-sinensis* Linn., commonly known as China rose, is one of the most important essential loose flowers cultivated commercially by farmers. Among different shades of colours, red-coloured varieties are indispensable for worshipping Goddess *Kali*. Large quantities of loose flowers at the bud stage and garlands are transported from West Bengal to other parts of India. However, almost no literature on postharvest changes in China rose. To address this issue, the present study was undertaken with four major red types of China rose: Kali Jaba, Alipore Beauty, Versicolor, Celia and Red Dragon, suggested by the All India Coordinated Research Project on Floriculture, BCKV. Based on floral biology, these five cultivars were primarily divided into two categories. Single type (Kali Jaba, Alipore Beauty and Versicolor) and Double type (Celia and Red Dragon). Moreover, the cultivar Celia could be sub-grouped under Double II and Red Dragon under Double III as per the variations in epicalyx, modified stamens and carpels. By analyzing all the data, it could be concluded that Kali Jaba among the single-petalled red cultivars and Red Dragon among the double-petalled cultivars were superior in terms of morphology, postharvest behaviour and phytochemical properties. These findings may be helpful in better understanding the morphology, postharvest behaviour and changes in phytochemical properties of red-coloured cultivars of anthocyanin-rich *Hibiscus* flowers, which might serve as valuable data for further research and breeding programs.

Keywords: flower; hibiscus; phyto-chemical properties; post-harvest

Introduction

Hibiscus rosa-sinensis Linn., commonly known as China rose, is a glabrous shrub under the family Malvaceae, extensively grown in the tropics bearing flowers of more than a hundred shades (1). It is grown as an ornamental shrub and frequently used as a hedge or for fencing purposes at home gardens. It thrives well in moderate temperatures with comparatively high humidity, on loamy, permeable and well-drained soil. The plant height can reach 4.7-5.0 metres and depending on the cultivar, flowers can be single or double types of varying size and colours (2). The species has been documented in up to 75 different forms, having ovate leaves and solitary as well as axillary flowers of various colours (3, 4). The plant is widely distributed in southwestern regions of India, tropical regions of Sri Lanka, Thailand, South Africa, the Phillipines, Myanmar, China and Pakistan (5). In India, it is extensively grown in Andhra Pradesh, West Bengal , Assam, Bihar, Karnataka, Tamil Nadu, Tripura and Uttar Pradesh (6). India is the 3rd largest exporter of *Hibiscus* in the world after Spain and Nigeria. The importing countries from India are the United States, the United Kingdom and Indonesia (7).

In West Bengal, the maximum amount of area under flower cultivation is dedicated to loose flowers, among which *Hibiscus* is having huge demand (11). Especially garlands or floral chains made up of red-coloured varieties are indispensable for worshipping Goddess *Kali* in India. There are four major local types of red *Hibiscus*, namely Kali Jaba, Alipore Beauty, Versicolor, Celia and Red Dragon, which are cultivated by the farmers of West Bengal and used for offering to the Goddess Kali (11). For making garlands, flower buds of *Hibiscus* are harvested one or two days before opening, packed in a polythene or bamboo basket and sent to the market where garlands are prepared at the bud stage itself. Though there is a number of literature available on the phytochemical properties of *Hibiscus*, but there is no information on the postharvest changes and influence of different cultivars on these changes. Also, these red cultivars may be highly suitable for preparing different value-added products, depending on their pigment retention ability and other attributes upon drying. To address these issues, the present study on variations in the morphology, postharvest behaviour and phytochemical properties of commercial red-coloured cultivars of *Hibiscus rosa-sinensis* in West Bengal was undertaken. The major objective of the study was to understand the post harvest changes in flower morphology of different red-coloured cultivars of *Hibiscus rosa-sinensis*, including variations in phytochemical properties both in fresh and dried states which can serve as valuable data for further research and breeding programs as well as in preparing value-added products with potential health benefits.

Materials and Methods

Plant materials

Hibiscus rosa sinesis flowers of five cultivars namely Kali Jaba, Alipore Beauty, Versicolor, Celia, Red Dragon (Considered as T_1, T_2, T_3, T_4 and T_5 respectively) were collected from the field of AICRP on Floriculture at Mondouri under Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, Nadia, West Bengal. Observations were recorded with four replications, each having ten flowers at a time, on flower morphology, yield (No. of flowers/ plant/week), flower opening behaviour after harvest, moisture content, total anthocyanin content (mg/100g), monomeric anthocyanin content (mg/kg C3G equivalent), total phenol content (mg/g Gallic acid equivalent) and total antioxidant activity (DPPH).

Flower morphology

The flowers of different cultivars were dissected and the parts were observed (through bare eyes and 4x microscope objective lenses). The number of epicalyx, calyx, corolla, stigma, modified stamen and modified carpels was noted. Modified stamens and carpels were found in double-type *Hibiscus* flowers due to homeosis, which was the whole or partial substitution of one structure for another (8). Modified stamens were of two types : stamen-petal intermediate and staminodium petaloid. The structure resembling petals, which contained a part of stamen, starting from the surrounding area of the anthers and continuing throughout the filament, was known as stamen-petal intermediate and the other petal-like formations that did not contain any component of a stamen were known as staminodium petaloid (9). In modified carpel, the carpels were replaced by petaloid-like structures. The style turned into a petaloid structure containing a stigma; this was known as petaloid style and the ovary with a petal-like wall structure was known as a petaloid ovule. Flower parts like the diameter of fully bloomed flowers and the length and width of the petals of different varieties were measured with an electronic digital calliper. Different parts were observed under a light microscope for a detailed study.

Yield

Yields of different red *Hibiscus* plants were observed during the monsoon (June-July) of 2022 and 2023 as the number of flowers/plant/week (11).

Total moisture content

The weight loss following heating of the samples under particular conditions till a constant weight was used to calculate the total moisture content of the samples (10).

Flower opening behaviour

Flower opening behaviour was estimated by measuring the flower diameter after harvest at an interval of 3 hr with the help of an electronic digital calliper. It was observed from the bud stage to the stage when the corolla was rolled in and petals were wilted.

Biochemical estimation

Total anthocyanin was observed in fresh *Hibiscus* flowers and dried *Hibiscus* flowers. The fresh flowers were dried in a hot air oven at the laboratory. By observing the colour at a certain wavelength where the samples' ethanolic-HCl extract was most absorbent, total anthocyanin was calculated (12). Fresh and dried flowers' monomeric anthocyanin levels were measured using the pH difference method between pH 1.0 and pH 4.5 (13). To assess the total phenol content (TPC) and total antioxidant activity of fresh and dried flowers, the following methods were used:

Total phenol content

To assess the total phenol content (TPC) of fresh and dried flowers, the Folin-Ciocalteu (F-C) assay was utilised (14). From clear extraction solution prepared from the samples, 1 mL was transferred to 100 mL volumetric flask and 5 mL of Folin-Ciocalteu's phenol reagent was added. After 1 min, again 15 mL of sodium carbonate solution (20 g in 100 mL) was added and mixed again and finally the volume was made up to 100 mL and absorption was recorded in Spectrophotometer at 760 nm after 2 h.

Total antioxidant activity

The samples' capacity to neutralise free radicals was evaluated using the 1,1-diphenyl-2-picryl hydrazyl (DPPH) technique (15). The technique of DPPH testing is associated with the elimination of DPPH, which would be a stabilized free radical. The free-radical DPPH interacts with an odd electron to yield a strong absorbance at 517 nm, i.e., a purple hue. In a test tube, 3 mL DPPH workable solutions were combined with 100 μL of sample extract. Three milliliters of solution containing DPPH in 100 μL of methanol is often given as a standard. After that, the tubes were kept in complete darkness for 30 min. The absorbance was determined at 517 nm.

Statistical analysis

A completely randomized design was used to analyse the data using ANOVA during the experiment. The critical difference (P=0.05) and standard error (S.E.m±) were also determined for each effect. For post-hoc tests for statistical significance, Duncans' Multiple Range Test (DMRT) was used to compare the control treatments' mean to the other treatment means and to enable comparisons between treatment means. Several values were computed to use DMRT, each of which was compared against a particular set of pairs (16).

Results and Discussion

Flower morphology, moisture content, flower weight and yield

The floral morphology of the five flower forms is summarized in Table 1 and Fig. 2-4. These data elucidated that single cultivars, viz. Kali Jaba, Alipore Beauty and Versicolor had pentamerous petals and the double varieties, namely Celia and Red Dragon, had pentamerous petals with additional petals replacing the stamens due to homeosis. The number of epicalyx ranged from 5 to 7 in T_1, T_2, T_3 &T_4 and 5 to 8 in T_5. The calyx, corolla and stigma were consistently found to be 5 in all the varieties. None of the single varieties (T_1, $T_2$and T_3) exhibited modified stamens such as stamen-petal intermediates or stamenodium petaloids. However, Celia displayed 1 to 8 stamen-petal intermediates and Red Dragon exhibited 1 to 15 stamen-petal intermediates and 7 to 32 and 48 to 68 stamenodium petaloids, respectively. No modified carpel structures, such as petaloid styles or ovules, were observed in T_1, T_2, T_3 and T_4. However, Red Dragon displayed 1 petaloid style where the carpel organ developed into structures resembling petals and 8 to 10 petaloid ovules where the petals assumed the position of ovules.

Flower diameter varied among the different varieties, with Red Dragon (T_5) having the maximum diameter (13.698 cm), followed by Versicolor (13.27 cm), Kali Jaba (10.643 cm) and Alipore Beauty (9.34 cm) (Table 2). Petal length and width were found to be maximum in Versicolor (8.25 cm and 5.04 cm, respectively) and the minimum was observed in Celia (4.25 cm and 3.13 cm, respectively). Notably, there was no statistical difference between the petal width of Versicolor and Red Dragon.

The highest moisture content was found in Celia (84.828 %), followed by Red Dragon and Versicolor (82.154 % and 79.572 %, respectively), while Alipore Beauty contained the lowest moisture content (76.201 %) (Table 2). There was no statistical difference between the cultivars regarding moisture content. The weight of the flowers in decreasing order was as follows: Red Dragon (10.605g) > Celia (3.508g) >Versicolor (3.248g) >Alipore Beauty (2.543g) > Kali Jaba (2.13g). The highest yield was observed in Kali Jaba with a value of 137.5 flowers/ plant/ week, followed by Versicolor (26.75 flowers/ plant/ week), Celia (23.25 flowers/ plant/ week), Alipore Beauty (9 flowers/ plant/ week) and Red Dragon (6 flowers/ plant/ week) (Fig. 5). There was no statistical difference between T_2, T_3, T_4 and T_5 in terms of their yields. Microscopic photos of the dissection of flower parts are given from Fig. 6-10. Similar findings were reported where Double types differed from other flowers regarding the number of epicalyx. The double flower types exhibited various numbers of modified stamens and only the Double III type displayed modified carpels (17). In another study, the flower diameter of *Hibiscus rosa-sinensis* was observed to be 10.22 cm and the length and width of the petals were 5.64 cm and 324.78 cm, respectively and the yield was 111.33 g/plant (18). Overall, the results of this study provided detailed statistical information regarding the flower morphology of different red-coloured cultivars of *Hibiscus rosa-sinensis*, including variations in size, colour and form. These findings contributed to a better understanding of the morphology of these cultivars and can serve as valuable data for further research and breeding programs.

Postharvest behaviour

Fresh weights of the flowers were measured from the bud stage to the wilted stage after harvest, which were presented in Table 2. The changes in weight after harvest were exhibited in Fig. 11. It was observed that the weight of the flowers gradually decreased as they transitioned from the bud stage to blooming and eventually to the wilted stage. Red Dragon consistently exhibited the highest weight among the varieties throughout the developmental stages. The present study uniquely examined the flower diameter of *Hibiscus rosa-sinensis* at various time intervals, as presented in Fig. 12-14, which revealed a distinct pattern in the flowers' development after harvest. Initially, the diameter increased steadily until it peaked at 12 hours, indicating full bloom. Subsequently, as the flowers began to wilt, the diameter gradually decreased over time. At the bud stage, no statistically significant differences were observed between T_1 and T_4 and between T_1, T_2 and T_3. Significant

Table 1. Different flower parts of different cultivars at harvest

Treatment	No. of Epicalyx	No. of calyx	No. of corolla	No. of stigma	Modified stamen		Modified carpel	
					Stamen-petal intermediate	Stamenodium-petaloid	Petaloid style	Petaloid ovule
T_1	5 to 7	5	5	5	0	0	0	0
T_2	5 to 7	5	5	5	0	0	0	0
T_3	5 to 7	5	5	5	0	0	0	0
T_4	5 to 7	5	5	5	1 to 8	7 to 32	0	0
T_5	5 to 8	5	5	5	1 to 15	48 to 68	1	8 to 12

T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon

Table 2. Flower diameter, petal length and petal width, moisture content and fresh weight of different cultivars at harvest

Treatment	Flower diameter (cm)	Petal length (cm)	Petal width (cm)	Moisture content (%)	Fresh weight of single flower (g)
T_1	10.643^c	6.563^c	4.778^b	78.912^a	2.13^e
T_2	9.34^d	6.233^d	4.343^c	76.201^a	2.543^d
T_3	13.27^b	8.25^a	5.04^a	79.572^a	3.248^c
T_4	7.453^e	4.25^e	3.13^d	84.828^a	3.508^b
T_5	13.698^a	7.433^b	4.928^a	82.154^a	10.605^a
S. Em (±)	0.027	0.058	0.042	2.960	0.034
C.D (5 %)	0.083	0.117	0.126	NS	0.103

T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon

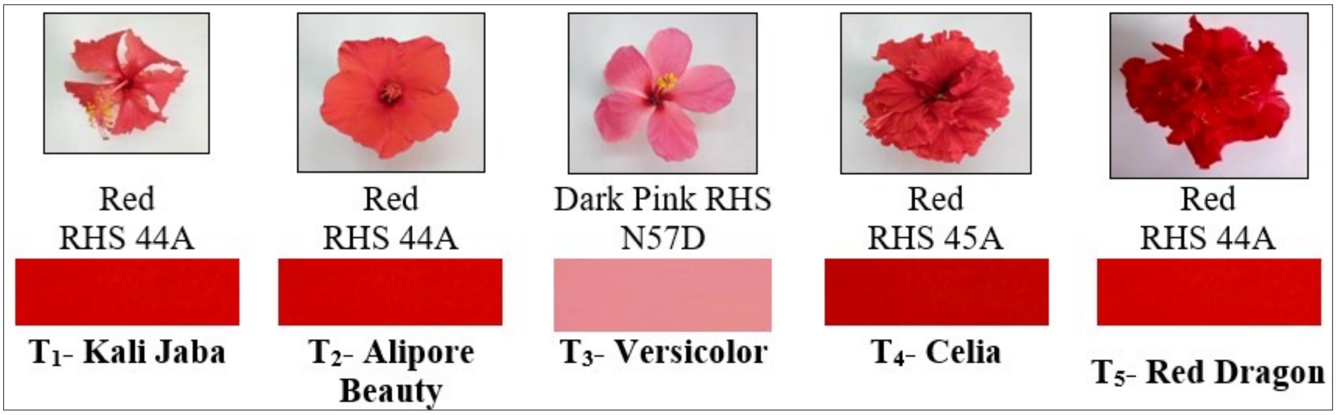

Fig. 1. Colour of fully bloomed flowers of five cultivars.

Fig. 2. Different flower parts of single type hibiscus cultivars (Kali Jaba, Alipore Beauty and Versicolor): A. epicalyx; B. calyx; C. corolla; D. stigma.

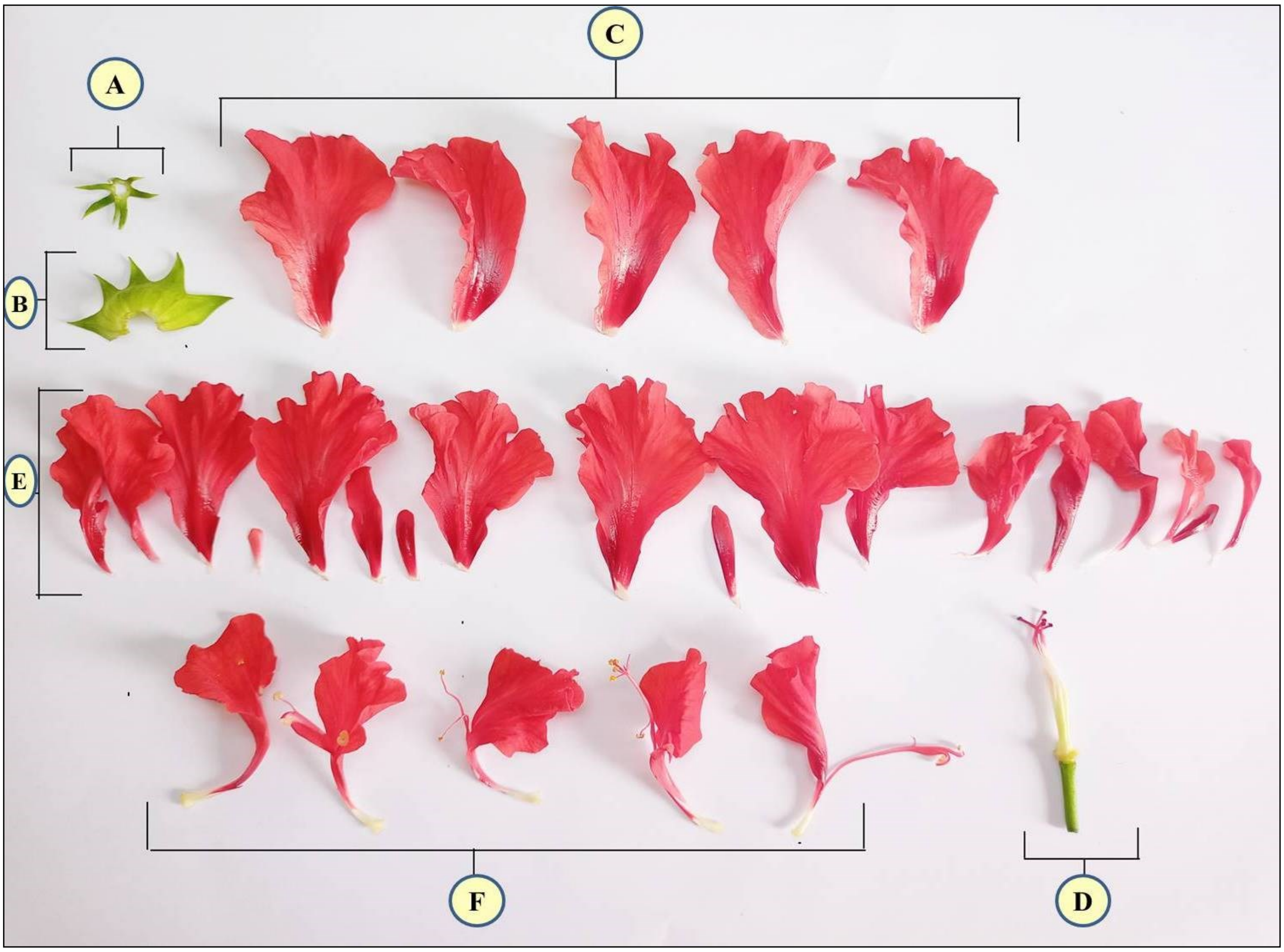

Fig. 3. Different flower parts of double type hibiscus cultivar (Celia): A. epicalyx; B. calyx; C. corolla; D. stigma; E. stamenoidium petaloids; F. stamen-petal intermediate.

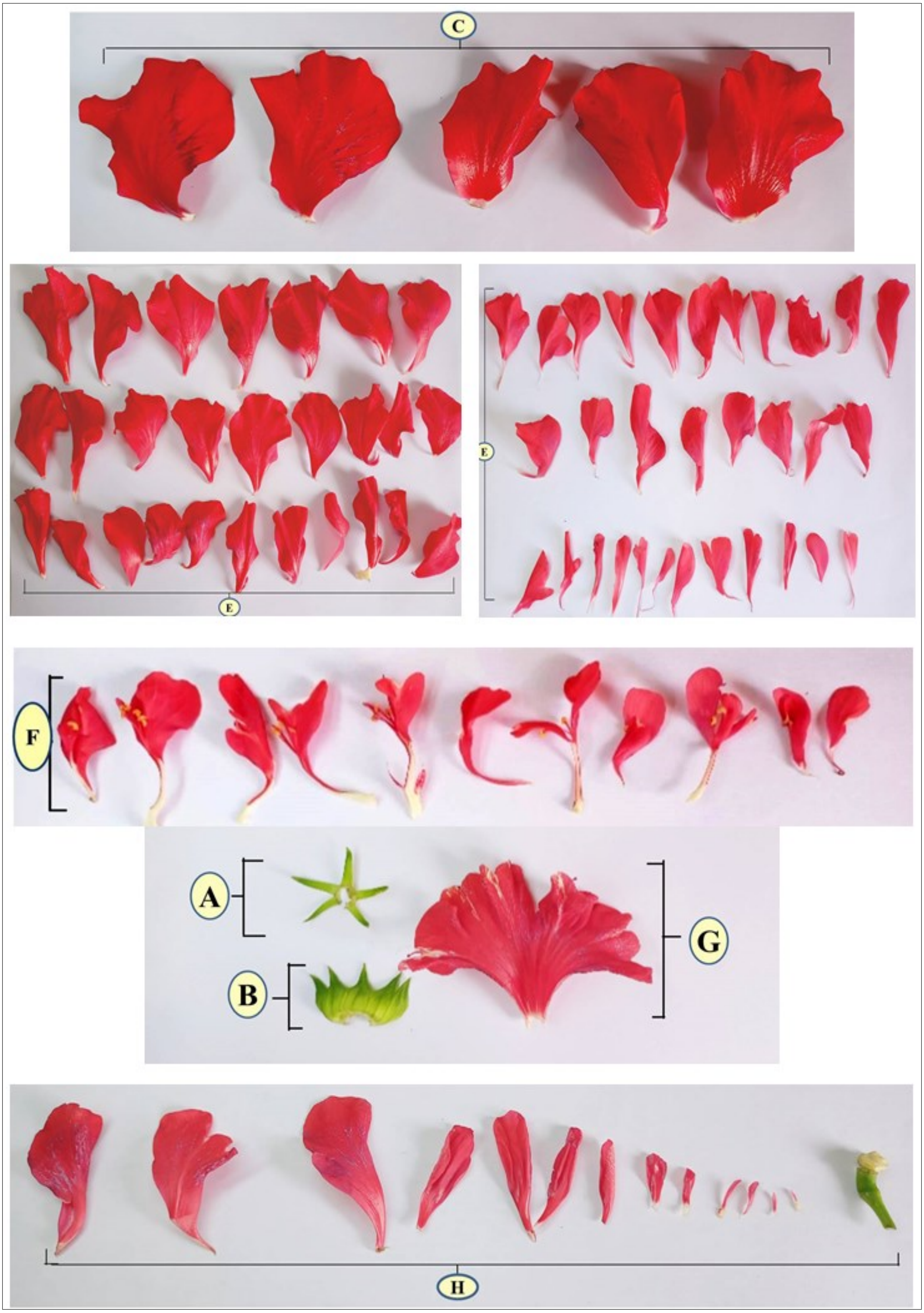

Fig. 4. Different flower parts of double type hibiscus cultivar (Red Dragon):

A. epicalyx; B. calyx; C. corolla; D. stigma; E. stamenoidium petaloids; F. stamen-petal inetermediate; G. petaloid styles; H. petaloid ovule.

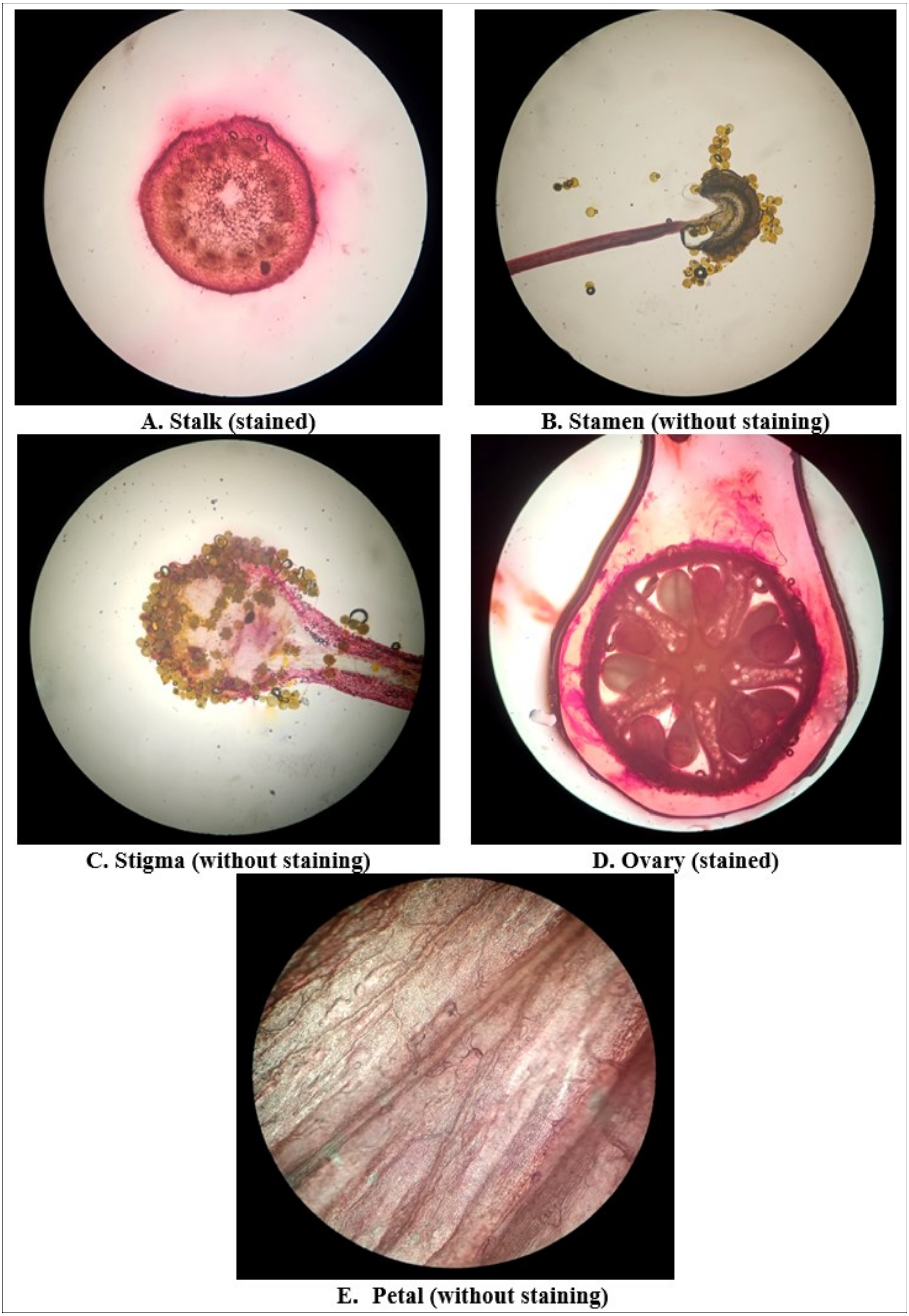

Fig. 6 A-E. Microscopic view of different cross-sectional parts of Kali Jaba cultivar.

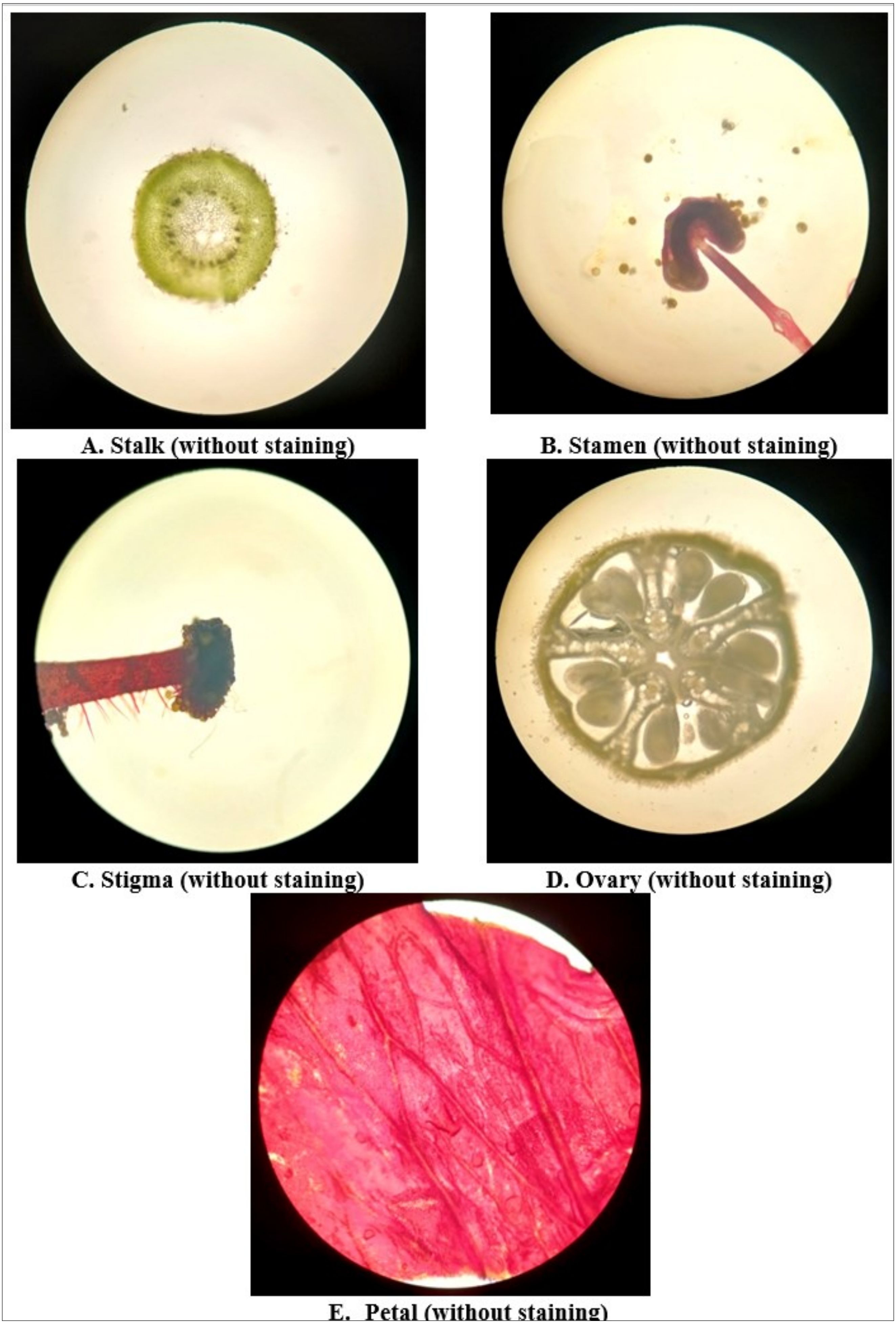

Fig. 7 A-E. Microscopic view of different cross-sectioned parts of Alipore Beauty cultivar.

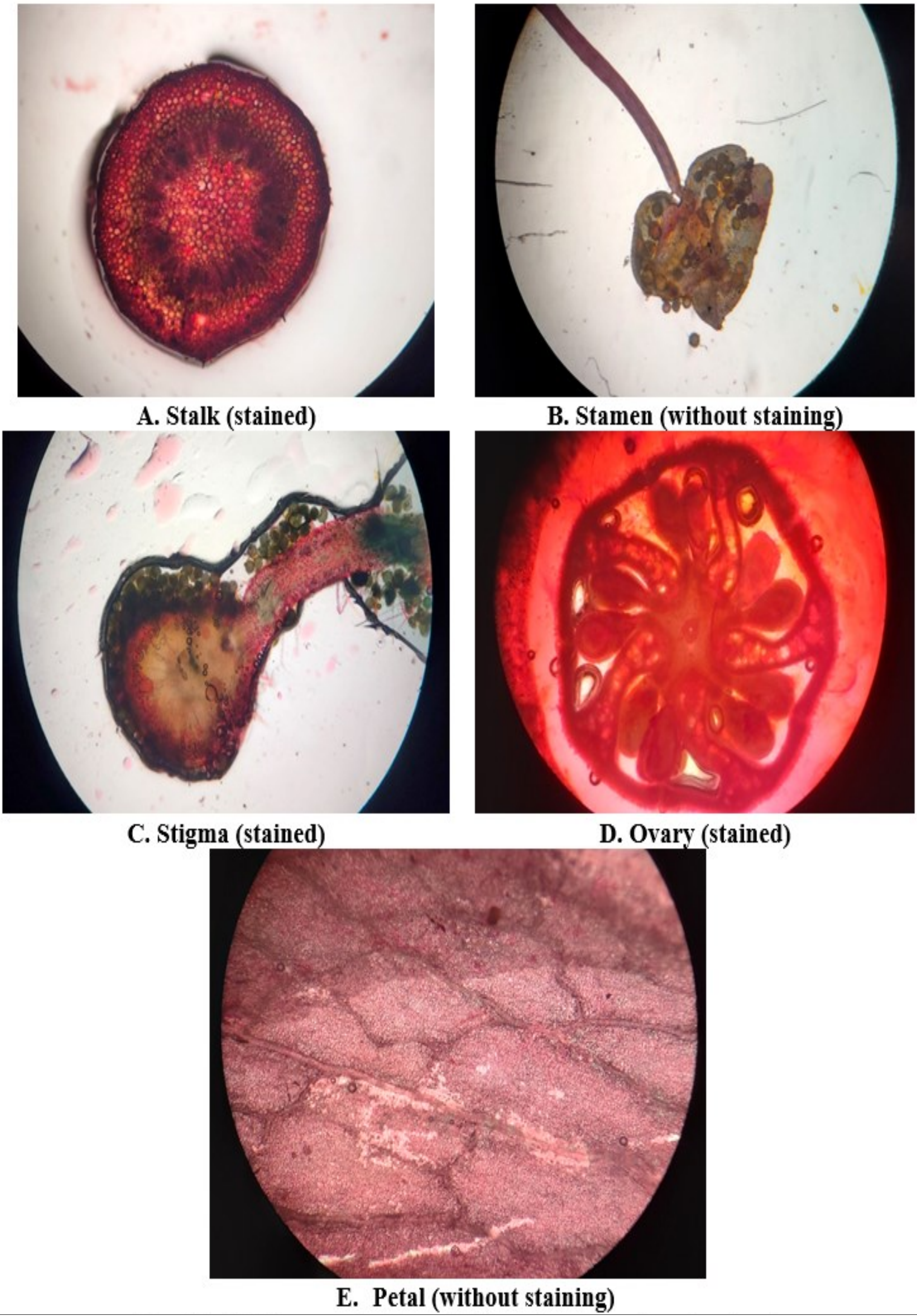

Fig. 8 A-E. Microscopic view of different cross-sectioned parts of cultivar Versicolor.

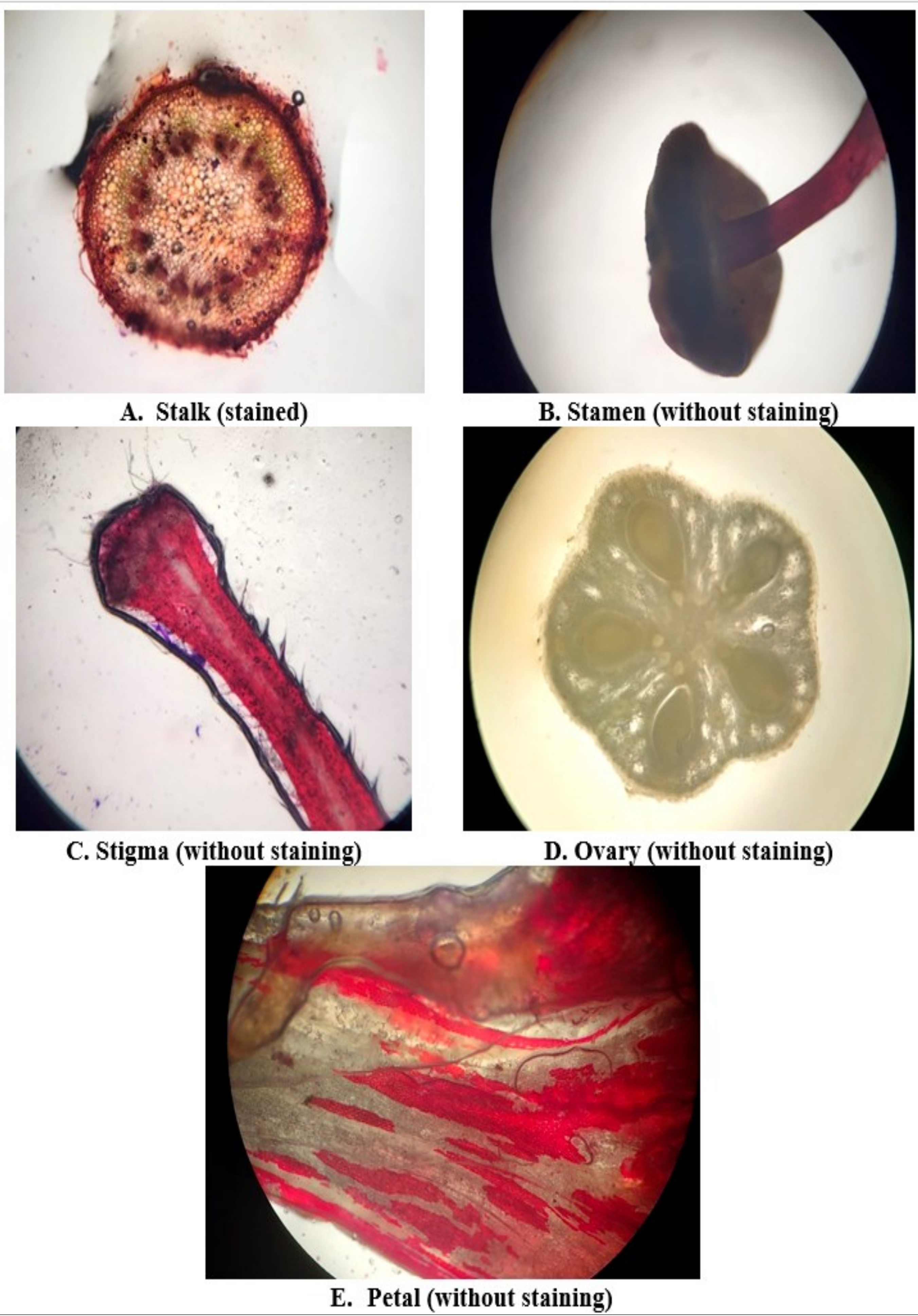

Fig. 9 A-E. Microscopic view of different cross-sectioned parts of cultivar Celia.

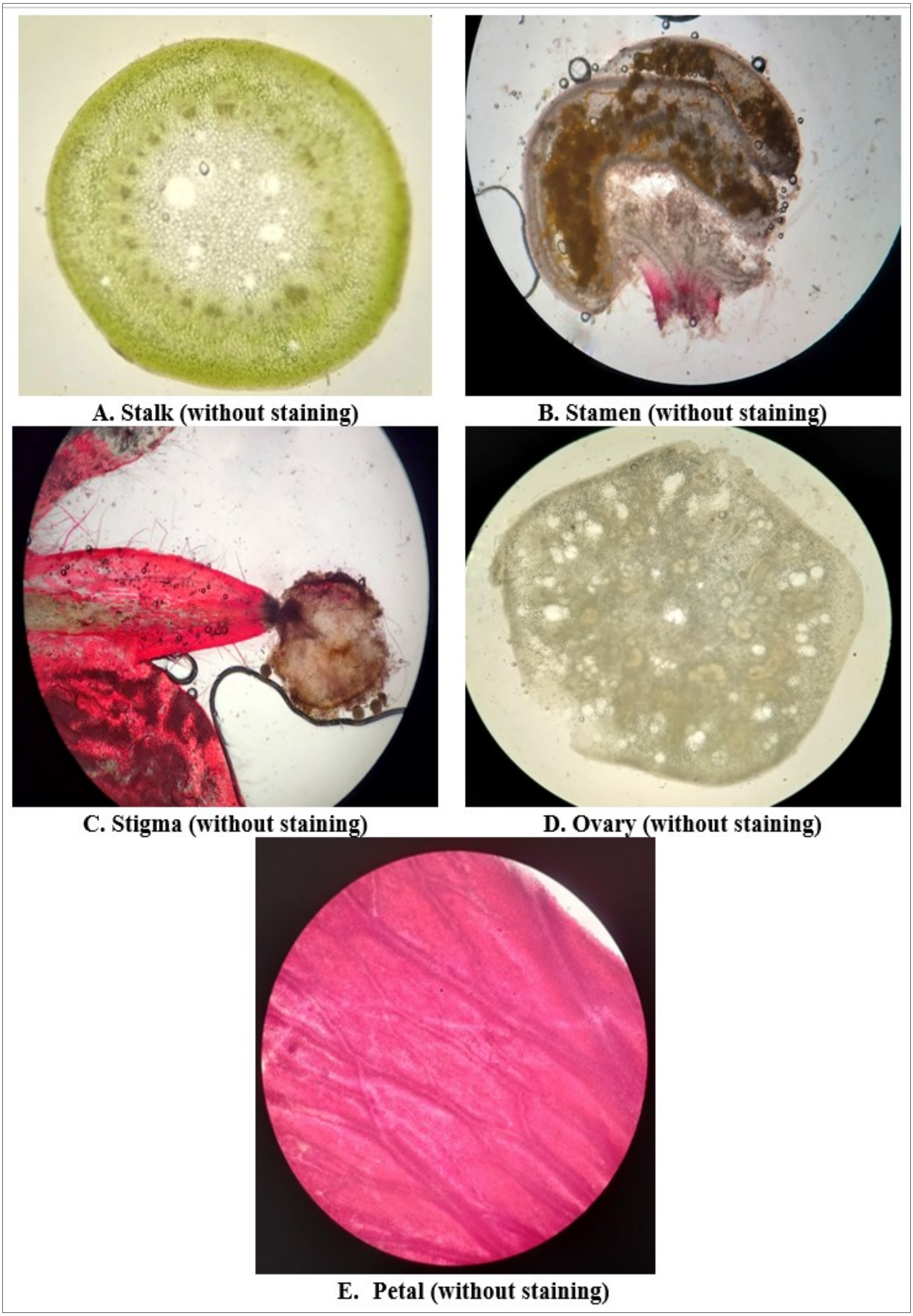

Fig. 10 A-E. Microscopic view of different cross-sectioned parts of cultivar Red Dragon.

Fig. 12. Blooming of Kali Jaba, Alipore Beauty and Versicolour.

Time	Celia	Red Dragon
0 hour		
3 hours		
6 hours		
9 hours		
12 hours		
15 hours		
18 hours		

Fig. 13. Blooming of Celia and Red Dragon.

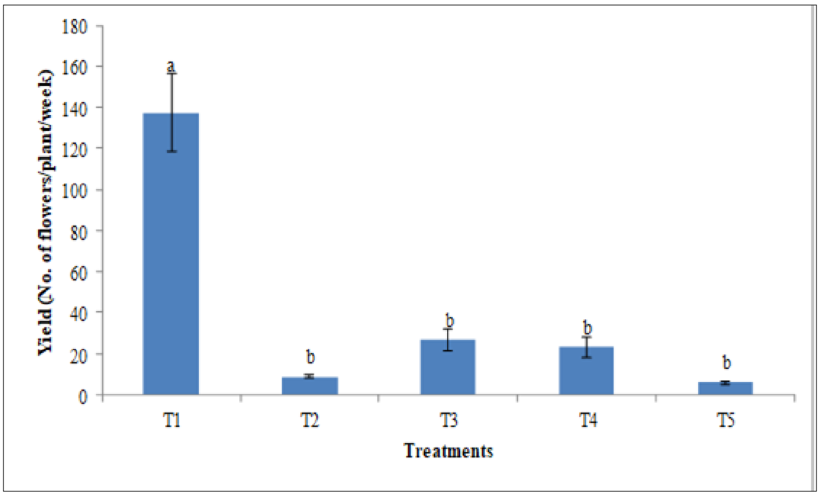

Fig. 5. Yield of five red cultivars of *Hibiscus rosa-sinensis.* T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon. The error bars represent the standard error of the mean, indicating the variability of the measurements.

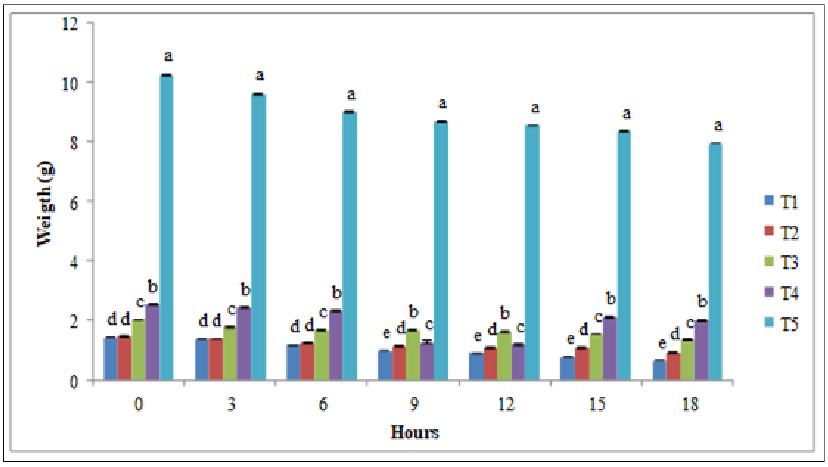

Fig. 11. Changes in fresh weight (g) of the flowers after harvest. T1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon. The error bars represent the standard error of the mean, indicating the variability of the measurements.

differences in flower diameter were observed at 3, 6, 9 and 12 h, suggesting variations in growth patterns during these intervals. These findings underscored the significance of proper timing in assessing the developmental progression and subsequent changes in *Hibiscus rosa-sinensis* flowers.

The moisture content of the flowers at different development phases was illustrated in Fig. 15. At the bud stage, Red Dragon exhibited the highest moisture content (19.25 %), followed by Celia (18.875 %), Alipore Beauty (18.75 %), Kali Jaba (18.5 %) and Versicolor (18.25 %). During the full bloom stage, the moisture content of T_1, T_2, T_3, T_4 and T_5 was recorded as 17.25 %, 17.375 %, 17.625 %, 17.875 % and 18.25 %, respectively. At the wilting stage (after 18 h), Red Dragon displayed a maximum moisture content of 16.5 %, while Alipore Beauty had the lowest moisture content of 15.25 %. The order of decreasing moisture content in the flower varieties at the full bloom stage (12 h) was Red Dragon > Celia >Versicolor> Alipore Beauty > Kali Jaba. These statistical findings provided valuable insights into the differences in the weights of the flowers, flower diameter and moisture dynamics among different developmental stages and varieties of *Hibiscus rosa-sinensis* flowers, which could contribute to improved postharvest handling and preservation techniques for these flowers.

Phytochemical properties of fresh and dried flowers

The total anthocyanin content of the five different varieties presented in Table 3 depicted the highest total anthocyanin content in both fresh and dried flowers of Red Dragon (T_5), with values of 192.59 mg/100g and 149.618 mg/100g, respectively. On the other hand, Versicolor displayed the lowest total anthocyanin content in both fresh (94.73 mg/100g) and dried flowers (73.625 mg/100g), which was corroborated by other studies where the total anthocyanin content of fresh *Hibiscus rosa-sinensis* was reported as 165 ± 8 mg/kg (23). It is important to note that the total anthocyanin content decreased in the dried flowers due to the thermo-sensitivity of anthocyanin.

Regarding the monomeric anthocyanin content of fresh and dried flowers (Table 3), it was recorded that for fresh flowers, the highest monomeric anthocyanin content was found in Red Dragon (159.335 mg C3G/ kg eq.), followed by Celia (114.108 mg C3G/kg eq.), Kali Jaba (81.06 mg C3G/ kg eq.), Versicolor (69.23 mg C3G/kg eq.) and Alipore Beauty (68.19mg C3G/kg eq.). No statistical differences were observed between T_1, T_2 and T_3. In the case of dried flowers, the monomeric anthocyanin content decreased due to the drying process in all varieties. Monomeric anthocyanin contents of the dried flowers, in decreasing order, were as follows: Red Dragon (123.57 mg C3G/kg eq.) > Celia (80.988 mg C3G/kg eq.)> Kali Jaba (70.57 mg C3G/kg eq.) > Alipore Beauty (61.788 mg C3G/kg eq.) > Versicolor (57.613mg C3G/ kg eq.). Earlier researchers have recorded that monomeric

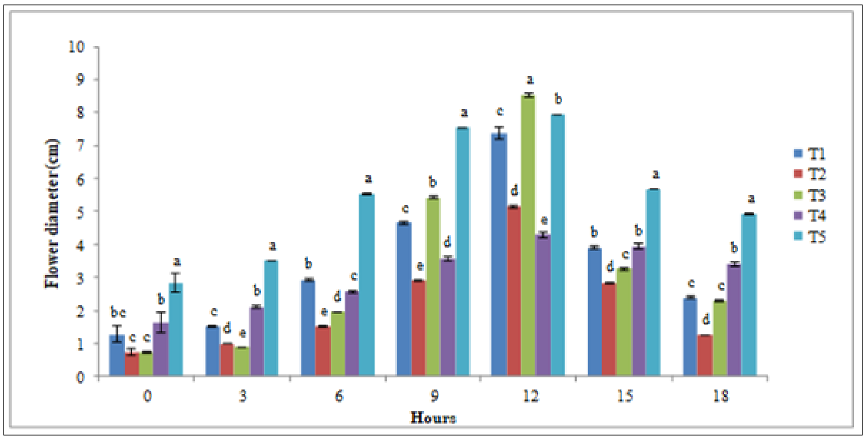

Fig. 14. Changes in flower diameter (cm) after harvest. T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon. The error bars represent the standard error of the mean, indicating the variability of the measurements.

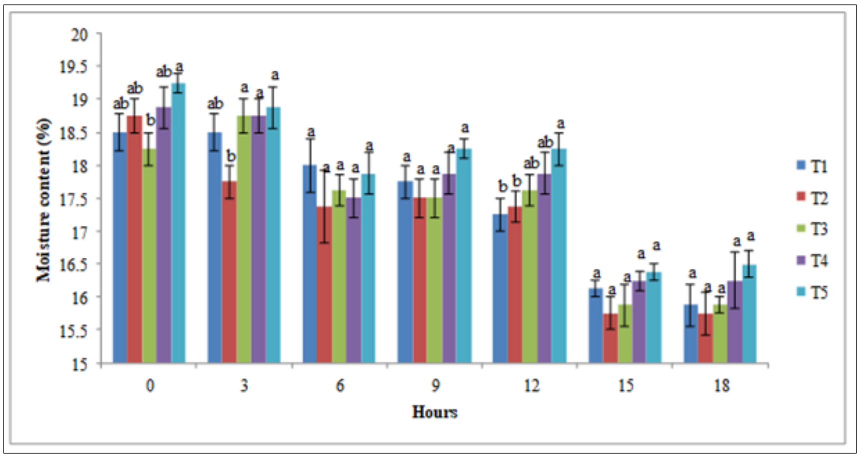

Fig. 15. Changes in moisture (%) content of flowers after harvest. T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon. The error bars represent the standard error of the mean, indicating the variability of the measurements.

anthocyanin content was 0.6012 ± 0.013 mg cy-3-glu/g in water extract and 153.20 µg/g in 80 % ethanol extract of *Hibiscus rosa-sinensis* (19,20). Other scientists also observed that monomeric anthocyanin contents were 205.76 mg c-3-gE/100g and 155.28 mg c-3-gE/100g in aqueous and ethanolic extract, respectively (21).

Total phenol content of fresh and dried flowers from the five different varieties presented in Table 4 depicted that among the fresh flowers, Red Dragon exhibited the highest total phenol content (3.768 mg GAE/L), followed by Celia (3.565 mg GAE/L), Kali Jaba (2.42 mg GAE/L), Alipore Beauty (1.53 mg GAE/L) and Versicolor (1.268 mg GAE/L). Similarly, in the dried flowers, Red Dragon had the highest total phenol content (2.893 mg GAE/L), followed by Celia (2.665 mg GAE/L), Kali Jaba (1.26 mg GAE/L), Alipore Beauty (0.615 mg GAE/L) and Versicolor (0.363 mg GAE/L). However, previous reports exhibited that ethanolic extract of *Hibiscus rosa-sinensis* petals contained 50.66 mg of GAE of total phenol (22) and fresh *Hibiscus rosa-sinensis* flowers had 14.4 ± 0.4 mg/g (23). Some observed that the total phenolic contents of methanolic extract and ethanolic extract of the flower of *H. rosa-sinensis* were 61.45±3.23 mg/100g dry extract and 59.31±4.31 mg/100g dry extract (5).

The total antioxidant activity of fresh and dried flowers (Table 4 and Fig.16) elucidated that the highest antioxidant activity of fresh flowers was found in Red Dragon (39.423 %), followed by Celia (37.578 %), Kali Jaba (32.008 %), Alipore Beauty (27.715 %) and Versicolor (18.595 %). Total antioxidant activity decreased as the flowers were dried with heat. The maximum total antioxidant activity in dried flowers was 29.095 % in Red Dragon and the minimum content was 11.615 % in Versicolor, with a commendable statistical difference. According to the previous study, *H. rosa-sinensis* flower extract showed an IC50 value of 45 g/mL and scavenged 95 % of DPPH radicals at a concentration of 250 g/mL and inhibition of DPPH was 72.81 % in the red

Table 3. Total anthocyanin and monomeric anthocyanin content (mg/100g) of fresh and dried flowers of five cultivars

Treatment	Total anthocyanin content (mg/100g)		Monomeric anthocyanin content (mg C3G/ kg eq.)	
	Fresh flowers	Dried flowers	Fresh flowers	Dried flowers
T_1	110.923^{c}	93.378^{c}	81.06^{c}	70.57^{b}
T_2	104.94^{d}	90.7^{d}	68.19^{c}	61.788^{b}
T_3	94.73^{e}	73.625^{e}	69.23^{c}	57.613^{b}
T_4	131.605^{b}	102.77^{b}	114.108^{b}	80.988^{b}
T_5	192.59^{a}	149.618^{a}	159.335^{a}	123.57^{a}
S. Em (±)	0.712	0.515	6.9	9.787
C.D (5 %)	2.166	1.567	20.988	29.77

T1- Kali Jaba, T2- Alipore Beauty, T3- Versicolor, T4- Celia, T5- Red Dragon

Table 4. Total phenol content (mg GAE/ L) and total antioxidant activity (%)of fresh and dried flowers of five cultivars

Treatment	Total phenol content (mg GAE/ L)		Total antioxidant activity (%)	
	Fresh flowers	Dried flowers	Fresh flowers	Dried flowers
T_1	2.42^b	1.26^b	32.008^{ab}	24.708^b
T_2	1.53^{bc}	0.615^c	27.715^b	20.025^c
T_3	1.268^c	0.363^c	18.595^c	11.615^d
T_4	3.565^a	2.665^a	37.578^a	28.098^{ab}
T_5	3.768^a	2.893^a	39.423^a	29.095^a
S. Em (±)	0.298	0.177	2.588	1.353
C.D (5 %)	0.907	0.537	7.873	4.115

T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon

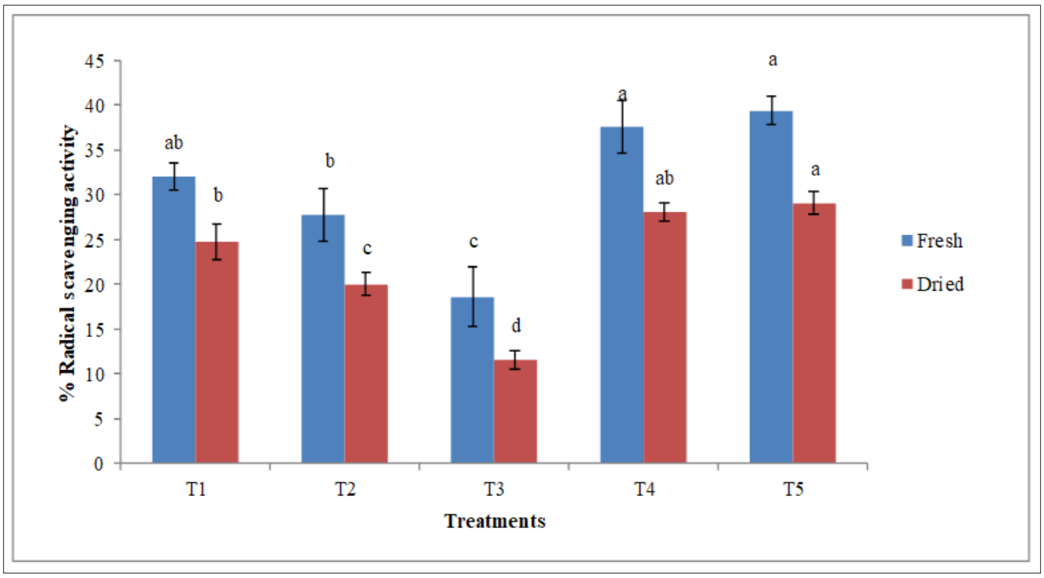

Fig. 16. Total antioxidant activity (%) of fresh and dried flowers of five cultivars. T_1- Kali Jaba, T_2- Alipore Beauty, T_3- Versicolor, T_4- Celia, T_5- Red Dragon; the error bars represent the standard error of the mean, indicating the variability of the measurements.

cultivar of *H. rosa-sinensis* (22, 24).

These statistical findings provided valuable insights into the variations in total and monomeric anthocyanin content, total phenol and total antioxidant activity among different varieties of *Hibiscus rosa-sinensis*, both in fresh and dried states, paving the way for a better understanding of the potential health benefits and nutritional value associated with the consumption of these flowers.

Conclusion

Five cultivars of *Hibiscus rosa-sinensis* (red-coloured types) considered for the present study were primarily divided into two (2) categories, viz., Single (Kali Jaba, Alipore Beauty and Versicolor) and Double types (Celia and Red Dragon), which had no difference in the number of calyx, corolla and stigma. However, the cultivar Celia could be grouped under the Double II type and Red Dragon under the Double III type as per the variations in epicalyx, modified stamens and carpel. The highest moisture content was found in Celia, but the highest yield was observed in Kali Jaba, followed by Versicolor and Celia. Regarding postharvest behaviour, it was observed that the weight of the flowers gradually decreased from the bud stage to blooming and eventually reached the wilted stage. In the case of flower diameter, it increased steadily until reaching a peak after 12 hours, indicating full bloom and gradually decreased till the wilting stage.

Regarding phytochemical properties, Red Dragon had the highest monomeric and total anthocyanin content, phenol and antioxidant activities. Versicolor resulted in the lowest amount of all the phytochemicals in both fresh and dried forms. From all the data, it could be concluded that Kali Jaba among the single-petalled red cultivars and Red Dragon among the double-petalled cultivars were superior in morphology, postharvest behaviour and phytochemical properties of these flowers. These findings contributed to a better understanding of the morphology of these cultivars, potential health benefits and nutritional value associated with anthocyanin-rich *Hibiscus* flowers, which might serve as valuable data for further research and breeding programs.

Acknowledgements

The authors thank the Director, DFR, Pune, ICAR Bidhan Chandra Krishi Viswavidyalaya for the necessary facilities.

Authors' contributions

SD conceived the study, participated in its design layout and coordination and drafted the manuscript. LM performed the experiments under the guidance of SD and collected data. KB participated in the botanical studies and biochemical estimation. TC participated in field studies. KC participated in the study design and statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Adhirajan N, Kumar TR, Shanmugasundaram N, Babu M. *In vivo* and *in vitro* evaluation of hair growth potential of *Hibiscus rosa–sinensis* Linn. J Ethnopharma. 2003;88:235–39. https://doi.org/10.1016/s0378-8741(03)00231-9
2. Khristi V, Patel VH. Therapeutic potential of *Hibiscus rosa–sinensis*: A review. Int J Nutr Diet. 2016;4(2):105–23. https://doi.org/10.17654/ND004020105
3. Akpan GA. Hibiscus: *Hibiscus rosa–sinensis*. In: Neil OA, editor. Flower Breeding and Genetics: Issues, Challenges and Opportunities for the 21st Century. Dordrecht: Springer Netherlands; 2007. p. 479–89. https://doi.org/10.1007/978-1-4020-4428-1_17
4. Bhattacharjee SK. Advances in ornamental horticulture. Jaipur: Pointer Publishers; 2006. p. 128–39.
5. Hoyer L. Critical ethylene exposure for *Hibiscus rosa–sinensis* is dependent on an interaction between ethylene concentration and duration. Postharvest Bio Tech. 1996; 9(1):87–95. https://doi.org/10.1016/0925-5214(96)00027-0
6. Indiabiodiversity. *Hibiscus rosa–sinensis* L. [Internet] [cited 2023 June 9]. Available from: https://indiabiodiversity.org/species/show/229932
7. *Hibiscus* flower export from India. [Internet]. 2023 [cited 2023 June 9]. Available from: https://www.volza.com/p/hibiscus-flowers/export/export-from-india/.
8. Salamah A, Prihatiningsih R, Rostina I, Dwiranti A. Comparative morphology of single and double flowers in *Hibiscus rosa–sinensis* L. (Malvaceae): A homeosis study. AIP Conference Proceedings. 2018;2023(1). https://doi.org/10.1063/1.5064133
9. Saifudin A, Salamah A. Variations in the morphology of *Hibiscus rosa–sinensis* crested peach flowers in nature. Math Sci. 2017;2021:012039. https://doi.org/10.1088/1742-6596/1725/1/012039
10. Nielsen SS. Determination of moisture content. 2nd ed. United States of America: Food Science Texts Series, Springer; 2002. p. 17–27.
11. Chakrabarty DS, Chowdhury TK, Mandi L. High valued *Hibiscus*. Floriculture Today. 2023:28–32. https://floriculturetoday.in/online-edition
12. Ranganna S. In: Handbook of Analysis and quality control for fruit and vegetable products. 2nd ed . New Delhi, Tata McGraw–Hill; 1986
13. Lee J, Durst RW, Wrolstad RE. Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants and wines by the pH differential method: collaborative study. Int J AOAC. 2005;88(5):1269–78. https://doi.org/10.1093/jaoac/88.5.1269
14. Gao MR, Xu QD, He Q, Sun Q, Zeng WC. A theoretical and experimental study: the influence of different standards on the determination of total phenol content in the Folin–Ciocalteu assay. J Food MC. 2019;13:1349–56. https://doi.org/10.1007/s11694-019-00050-6
15. Baliyan S, Mukherjee R, Priyadarshini A, Vibhuti A, Gupta A, Pandey RP, Chang CM. Determination of antioxidants by DPPH radical scavenging activity and quantitative phytochemical analysis of *Ficus religiosa*. Molecules. 2022;27(4):1326. https://doi.org/10.3390/molecules27041326
16. Gomez KA, Gomez AA. Statistical procedure for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984
17. Slamet A. The diversity of *Hibiscus rosa-sinensis* based on morphological approach. Sci Edu: J Pendi Sain. 2018;7(1):33–41. https://doi.org/10.24235/sc.educatia.v7i1.2503
18. Braglia L, Bruna S, Lanteri S, Mercuri A, Portis E. An AFLP-based assessment of the genetic diversity within *Hibiscus rosa-sinensis* and its place within the *Hibiscus* genus complex. Sci Horti. 2010;123(3):372–78. https://doi.org/10.1016/j.scienta.2009.10.003
19. Cheok CY, Ragunathan A. Anthocyanin degradation kinetics and thermodynamic analysis of *Hibiscus Rosa–Sinensis L. Clitoria Ternatea L.* and *Hibiscus Sabdariffa L.* Progress Energy Environ. 2022;19(3):1–12. https://doi.org/10.37934/progee.19.1.112
20. Afify AEMMR, Hassan HMM. Free radical scavenging activity of three different flowers– *Hibiscus rosa–sinensis, Quisqualis indica and Senna surattensis.* Asian Pac J Trop Biomed. 2016;6(9):771–77. https://doi.org/10.1016/j.apjtb.2016.07.006
21. Mak YW, Chuah LO, Ahmad R, Bhat R. Antioxidant and antibacterial activities of Hibiscus (*Hibiscus rosa–sinensis* L.) and Cassia (*Senna bicapsularis* L.) flower extracts. J King Saud Univ Sci. 2013;25(4):275–82. https://doi.org/10.1016/j.jksus.2012.12.003
22. Pillai SS, Mini S. *In vitro* antioxidant activities of different solvent fractions from the ethanolic extract of *Hibiscus rosa–sinensis* petals. Int J Pharma Sci Res. 2014;5(9):3879. https://doi.org/10.13040/IJPSR.0975-8232.5(9).3879-85
23. Falade OS, Aderogba MA, Kehinde O, Akinpelu BA, Oyedapo BO, Adewusi SR. Studies on the chemical constituents, antioxidants and membrane stability activities of *Hibiscus rosa–sinensis*. Nige J Natural Pro Med. 2009;13:58–64. https://doi.org/10.4314/njnpm.v13i1.61609
24. Sheth F, De S. Evaluation of comparative antioxidant potential of four cultivars of *Hibiscus rosa–sinensis* L. by HPLC–DPPH method. Free Rad antioxi. 2013;2(4):73–78. https://doi.org/10.5530/ax.2012.4.13

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.