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To study the structure, size and stomatal frequency in leaves of crop plants: A review paper

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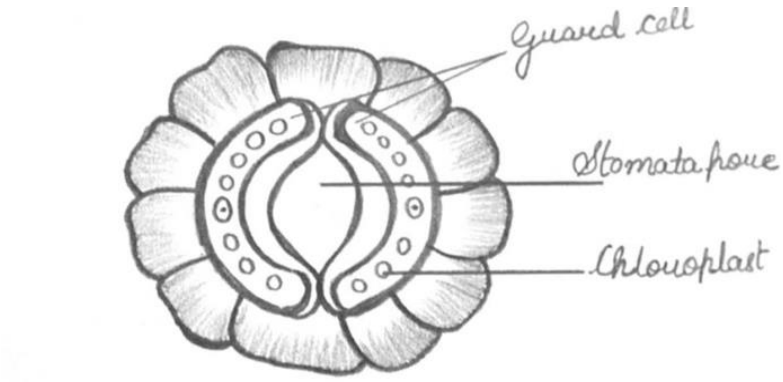
Abstract
Stomata are the important structure on the leaves. They play an important role in the plant. Major part gaseous exchange and photosynthesis. In each stomata(open) has the two kidney/bean shaped guard cells. In the terrestrial plants approx. 97% of the transpiration take places from the lower surface of the plants. According to the distribution, no. of stomata, daily movement there are several types of stomata. Stomata size is varying from 20-50 µm long & density in range from 50 to 300mm^{-2}. Stomata present on both surface of leaves or in woody plant on one side only but in woody plant like willow & poplar stomata is present on the both side of the surface. In submerged plant stomata is absent. Stomata arrangement is differed in the plants. In Monocotyledon plant stomata on the leaves are more or about similar in no. on the both surface of leaves but in Dicotyledon more stomata on the lower surface of the leaf. Xerophytes having more number of stomata than mesophytes. In tree and shrubs having higher stomata frequency than herbs. The largest stomata in size in order is: *Triticum sativum, Avena sativa, Chrysanthemum frutescence etc.* In general stomatal frequency & stomata size is inversely proportional. In Poaceae Guard cells are larger & avg. cell length on adaxial surface (55.86µm) is greater than abaxial surface (30.96 µm).

Keywords: Structure, stomatal, frequency, plants, epidermis

Introduction
Stomata: Stomata are the small opening present on the epidermis of the leaves. In many cases in some plant stomata are present on the stems & other parts of the plants. Stomata can be seen under the light microscope. Stomata plays an imp. role in the plant. It helps in the gaseous exchange & photosynthesis. It also controls the transpiration rate by opening & closing. According to the gaastra model, a change in the stomatal resistance has more effect on the transpiration than the photosynthesis because it contains large ratio of the total resistance to water vapor diffusion than to CO_2 diffusion. Stomata are present in the large amount the surface of the leaf. Mainly they are present on the lower side leaf in large amount. In other words, stomata are specialised epidermal cells which are distributed all over the leaf surface of plant but mainly in case of terrestrial plants they are present on the lower surface of the leaves. So lower side of the leaf surface is called abaxial surface and upper surface is adaxial surface. So, in the terrestrial plants approx. 97% of the transpiration take places from the lower surface of the plants.



Open Stomatal pore of Stomata

In Stomata there are minute pores called stoma. In each stomata(open) has the two kidney/bean shaped guard cells. And the inner wall of the guard cell is thick & the outer wall is thin. The cell wall which surrounds the pore s tough & flexible. Guard cell of the stomata are surrounded by the epidermal or accessory cells or subsidiary cells. Guard cells are the pair of the specialized parenchyma cells. Guard cell are the responsible for the size of the opening of stomata. Mechanism of guard cells remain same in the both dicot and monocot plants, but guard cell shape is varying little bit. In guard cell there is chloroplast present. And chloroplast has chlorophyll & they capture light energy. The chloroplast of the guard cell is able to poor photosynthesis because the absence of the enzyme RUBISCO.

There is the various function of the stomata. It controls the gases in and out of the leaves. It controls the temperature inside the leaf. When the water vapours go into the atmosphere from stomata is called transpiration. Stomata control the transpiration in plants. Like in C3 plants there is more transpiration because more stomata present in the plants. After that C4 and at last CAM plant. In CAM plants stomata are open at night and close in the day time. So, less transpiration in the CAM plant e.g. pineapple. Oxygen used in respiration are also passed through stomata. It also maintains the moisture balance. Stomata facilitate the CO_2 uptake & release of O_2 during the process of photosynthesis.

Stomata mostly present on the terrestrial plant. Many like algae, fungi & submerged plant do not any kind of stomata. Stomata distribution varies in the plants. Monocot and dicot plant have varied in the stomata distribution. In dicotyledon plant there are more stomata on the lower side of the leaf then the upper side of leaf. But in monocotyledon plants such as maize, wheat have the same no. of stomata on both the leaf surfaces. While in the floating leaves, stomata may only found on the upper epidermis & in the submerged leaves they may lack the stomata. Mostly on the lower leaf surface stomata present and that are called hypostomatous. Stomata present on the upper surface of the leaf is called hyperstomatus. In case of stomata present on the both the upper & lower side of the leaf is called as amphistomatous.

Size of the stomata varies from the plant to plant. Generally, in the fully open the stomatal pores are measured in the width of 3-12 & 10-40 in the length. Plant that grown in the desert (xerophytic) & gymnosperms have the deep embedded in the leaves and don't exposed directly to the sunlight. And these types of the stomata are called sunken stomata. In many species size varies, in the length range is 10-80 µm & width ranges from few to 50 µm.

The number of the stomata present on the per unit area of the leaf is called as stomatal frequency. To determine the stomatal freq. & the total leaf area of stomata covered in a leaf area is important to assess the rate of lower water loss through the stomata. There are many environmental & genetic factors affect the stomatal freq. Like in the water stress situation stomatal frequency is increase. In wet soil with high humidity has lower freq. and vice-versa. In polluted atmosphere stomatal frequency is decrease. In full light condition stomatal freq. incr. and vice-versa. Stomatal frequency not remain constant in the plant.

Classification of Stomata

Acc. to the distribution of stomata, plant are divided in five categories:

- **Potato type:** In this type more stomata present on the lower surface than on upper surface.
- **Apple & Mulberry type:** In this categories type of plant, stomata present on under surface only.
- **Oat type:** In this type of category, Stomata are equally distributed on both the surface of the leaf.
- **Water Lily type:** In this Stomata only present on upper surface.
- **Potamongeton type:** In this type stomata are either absent or functionless. Such plant are most of submerged aquatic plants.

Acc. to the number and characteristics of the surrounding subsidiary cells.

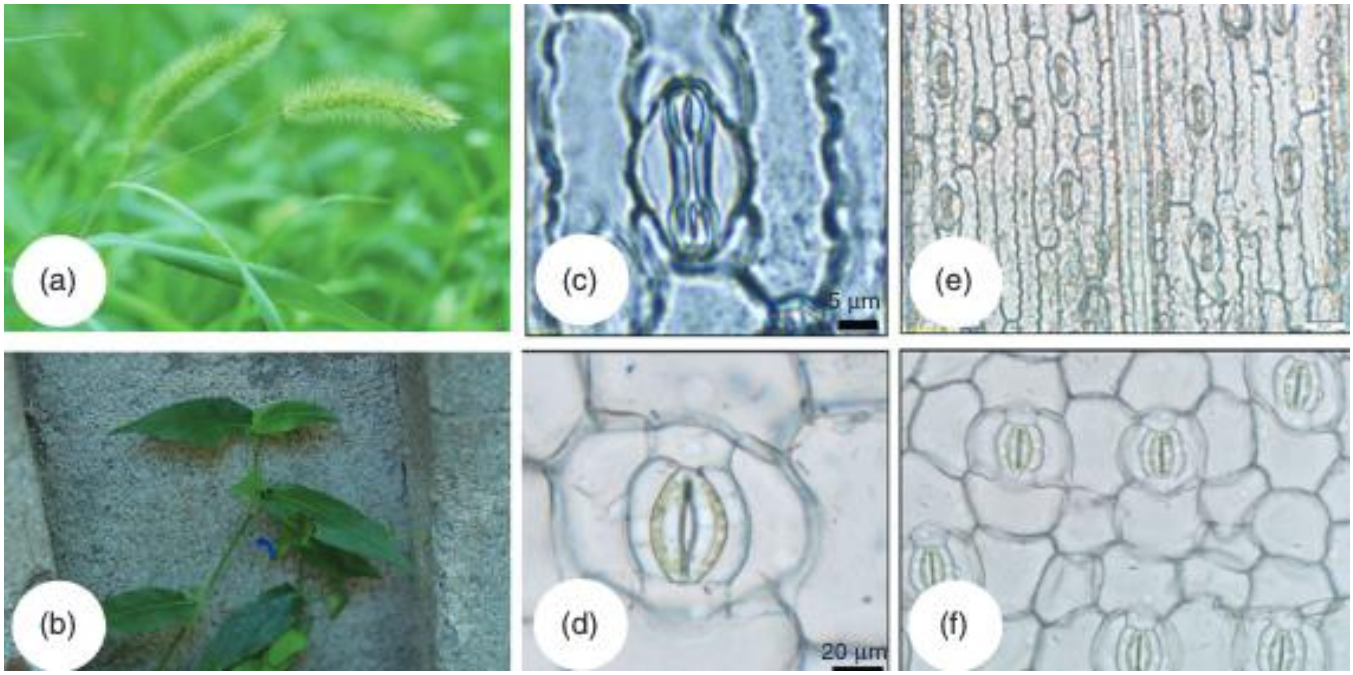
- **Anomocytic Stomata:** These type of stomata are surrounded by the epidermal cells which has a fixed shape & size. In this stomata appear to be embedded in the epidermal cell.
- **Anisocytic Stomata:** In this type of stomata are surrounded by the three subsidiary cell which has unequal size, one is smaller in comparison with other two.
- **Diacytic Stomata:** In this type of stomata are surrounded by two subsidiary cells that are perpendicular to the guard cell.
- **Paracytic Stomata:** These type of stomata are regularly surrounded by two subsidiaries, which are arranged parallel to the stomatal pore & the guard cells.
- **Gramineous Stomata:** In this type each stomata possesses two guard cells, which are shaped like dumbbells. And the subsidiary cells are parallel to the guard cells. The guard cells are found narrow in the middle & wider at the ends.

  On the basis of daily movement of stomata, Loftfield classified in into three main groups.
- **Alfalfa type:** These type of stomata are open throughout the day & night. They are mostly found in thin leaved mesophytes. E.g. Pea, bean, radish, mustard, vitis etc.
- **Potato type:** In this type of stomata are open throughout the day & night except for the few hours in the evening. E.g. Onion, plantain, pumpkin, cabbage etc.
- **Barley type:** In this case of stomata type, they are open only for the few hours during the day. E.g. Cereals.

Material and Methodology

Study the structure of stomata

Stomata is very important in plant. It has the various function on that plant growth completely depend. In plants stomatal size, no. & arrangement differ in plants. In general stomata has a central pore and around that there is two guard cells then subsidiary cell and epidermal cells. Stomata control transpiration, temperature inside leaf and gas exchange. In desert plant and also in pine tree to save the water they do stomata recessed in stomata crypts, which is the small chambers below the surface of the leaf or stem.



(Liang, he, 2018)

The phenotypic distribution of Stomata: (A,c) Dumbbell-shaped stomata of *Seteria virdis* typical of the grasses. (b,d) The kidney-based stomata typical of other species such as *Commelina commnis.* (e) Stomata in grass are arranged strictly in cell files with the identical orientation. (f) Stomata distributed scattered & no-isotropic orientation in *C.communis.*

There are two type of guard cell one is dumbbell shape like in *Seteria virdis* & other one is kidney shape like in *Commelina commnis.* Kidney shaped stomata is mostly found in leaf of plants. Study by the (Raschke, 1975; Hetherington & Woodward, 2003) support that stomata with dumbbell-shaped guard cells are more efficient physiologically & more advanced in evolutionary because their guard cell require fewer solutes & less water to achieve a given unit incr. in aperture. In guard cell there is chloroplast present. And chloroplast has chlorophyll & they capture light energy. The chloroplast of the guard cell is able to poor photosynthesis because the absence of the enzyme RUBISCO.

There is variation in stomata distribution, size, arrangement & frequency among the species or within in species also. Stomata size is varying from 20-50 µm long & density in range from 50 to 300mm^{-2}. They can be found on leaves, stem, flowers & fruits but not found in the roots. In the leaves stomata present on the both side of surface or in many woody plant only one side e.g. apple & peach. But exception in woody plant like willow & poplar stomata is present on the both side of the surface. In submerged plant stomata is absent. Also in parasitic plant stomata is absent.

Stomata arrangement is differ in the plant. There pattern is varying in the plants like in grasses & some dicot stomata is arranged in the parallel rows. But in the plant leaves with netted venation often has randomly scattered stomata.

Stomata distribution

As previously written stomata arrangement and distribution varying plant to plant. Like the avg. no. of stomata in the plant leaf surface is 300/ square mm.

This table will represent the total no. of stomata in present on the both upper & lower leaf of the different plant.

Table 1: Total no. of Stomata/mm^2

	Upper surface	Lower surface
Monocotyledon		
Barley	70	85
Wheat	50	40
Onion	175	175
Dicotyledon		
Alfalfa	169	188
Geranium	29	179
Sunflower	120	175

As we can see in the table barley as more stomata in lower surface but in case of wheat more stomata in upper surface. In case of onion stomata present same in both upper & lower surface. In case of dicotyledon (Alfalfa, Geranium, Sunflower etc.) more stomata present on lower surface than upper surface. From this we can conclude that Dicotyledon has more stomata present on the lower surface but in monocotyledon stomata more or less distributed equally on both the surface.

Stomata frequency

Stomata frequency can be defined as the no. of stomata per unit area of leaf. The no. of stomata in specific area of leaf varies from plant to plant. Stomatal frequency is measure by the impression method (Wilson & Palmer, 1989) [8]. Xerophytes having more number of stomata than mesophytes. 1000-6000 stomata/sq. cm in different plant species. In tree and shrubs having higher stomata frequency than herbs. When stomata fully open it occupy 1to 2% of total leaf area. In isobilateral leaves having same number of stomata are found on both surfaces (lower and upper surface). But in dorsiventral leaves having less number of stomata on upper surface as compare to lower surface.

Several factors like environment factor and genetically factor affect the stomata frequency. Due to environment factor change in stomata frequency –temperature, water availability, light intensity and CO_2 concentration. Water stress effect in a larger stomata frequency. Those plants grown in wet soil with high humidity have lower stomata frequency than plants growing in dry soil. Due to polluted environment stomata

frequency reduced. Example Trifolium partense

Light intensity also effect on stomata frequency .stomata frequency reduce in low light intensity. When plant grown in full sunlight stomata frequency becomes higher. When tomato grown under controlled conditions its having hypostomatous leaves and when grown in high light intensity its having amphistomatous leaves. In polyploid plants have less frequency and larger stomata. Where Stomata are larger normally stomata frequency decreases. Stomata frequency is not constant. Higher frequency found on top leaves. For example in grass leaf has low frequency at the tip. Observed the higher frequency at the point of insertion of leaf where cells are still developing and smallest.

Stomatal size: As like Stomatal frequency impression method use for the stomatal size. Stomatal size is widely varying in plant to plant. According to briefer articles works done: they measure the stomatal size by measuring the length & breadth. They measure the length and breadth when guard cell apparatus is closed & also when pores it widely open. In order to prevent the closure of the pores of by any means like wilting, drought etc. they remove the epidermis and leave remain there. The pores of the stomata is widely open at the 10am according to their result or measurement taken. In that experiment the measurement is done by the ocular micrometre and done the comparison with stage micrometre. Many measurement were taken. Data is taken from the green house plants.

Table 2: Size Length & breadth in micron

	Upper surface		Lower surface	
	Guard cell closed	Pore open	Guard cell closed	Pore open
Avena sativa	64 × 32	31 × 7	70 × 36	38 × 8
Chrysanthemum frutescence	57 × 31	31 × 11	58 × 31	33 × 11
Cucurbita pepo	21 × 14	5 × 2	20 × 16	6 × 3
Ficus repens	0	0	21 × 17	5 × 3
Helianthus annuus	33 × 21	18 × 8	36 x 21	22 × 8
Lycopersicum esculentum	27 × 20	10 × 5	33 × 23	13 × 6
Phaseolus vulgaris	25 × 14	8 × 3	21 × 13	7 × 3
Triticum sativum	79 × 37	40 × 7	84 × 35	38 × 7
Vicia faba	44 × 27	19 × 8	46 × 28	20 × 8
Zea mays	47 × 36	19 × 4	45 × 36	19 × 5

The largest stomata in size in order is : *Triticum sativum*, *Avena sativa*, *Chrysanthemum frutescence etc.* In general stomatal frequency & stomata size is inversely proportional. The mean size of the open pores is 17.7 × 6.7 µ. Acc. to the briefly article stomata size is not just vary in different variety of same species but also if the same varieties grown under different condition.

- **Cyperaceae:** The highest frequency found in *Carex nigra* (179mm^{-2}) and lowest in *C. distans* (120mm^{-2}). In Cyperaceae family stomata present only on abaxial surface. Stomata absent at the leaf margin. Length of guard cell range 27.06- 39.3µm.
- **Poaceae:** In poaceae family stomata found on both surfaces. Highest frequency observed in bromus genus close to the leaf margin and lowest in next to the central vein. Guard cells are larger & avg. cell length on adaxial surface (55.86µm) is greater than abaxial surface (30.96 µm).
- **Juncaceae:** stomata only observed on abaxial surface. The stomatal type is anomocytic & the guard cells lengths vary b/w 21.6 to 35.3µm. Stomata are located in linear groups.
- **Liliaceae:** Stomata spotted on both surfaces with exception of *Polygonatum orientale*, where stomata fully absent on adaxial surface.

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