INTRODUCTION

A Foldscope is an optical microscope that can be assembled from simple components, including a sheet of paper and a lens. It is a unique invention by an Indian scientist, Dr. Manu Prakash, professor at Stanford University developed to foster deep interest in science at an early stage by providing “Microscope for every child”. The Foldscope is an ultra-affordable paper microscope inspired by origami. It is a portable, sturdy and versatile microscope made mostly out of paper (waterproof) that magnifies the wonders of the microscopic world, without the bulk and expense of a conventional research microscope [1]. Foldscope is designed to bring microscopy out of science labs and into the hands of people around the world. It is extremely portable, durable and to give optical quality similar to conventional research microscopes.

Methods: For enhancing scientific temperament among rural children, Indian Born Scientist (Dr. Manu Prakash) has introduced an ultra-low-cost foldable origami-based approach for large-scale manufacturing of microscope, specifically demonstrating bright field, dark field and fluorescence microscopes. However, its potential as research tool in the area of aromatic medicinal plants is still not known. The slides were prepared by own and were observed with the magnification power of 140X.

Results: The result of the present study reported that the Foldscope images revealed viable stained areas in the respective plant parts like trichomes, stomata, pollen grains, stem and leaf of different medicinal plants and indicating their live activities.

Conclusion: Based on the attractive images captured from the Foldscope, the uses of foldscope were recommended to public. Previously we had organized some awareness cum demonstration programme regarding foldscope and its applications in the field of science education in the different educational institute of Erode District, Tamilnadu. Based on the clarity of images and easy handling of Foldscope the uses of origami microscope were recommended for higher studies.

Keywords: Foldscope, Anatomical, Medicinal plants, Origami, Paper microscope

MATERIALS AND METHODS

For the review and documentation of medicinal plants, intensive exploration trips were conducted for one year from May 2018 to May 2019 in Manar beat, Karamadai range, Coimbatore District, The Western Ghats, Tamil Nadu (fig. 1). The vegetation of the study area is floristically rich compared to other regions and represents several unique habitats. The investigation was conducted in six small villages of Manar beat situated in Karamadai range, which are occupied by Irula tribes. Based on the tribes traditional knowledge, the active plant specimens were collected from the study area and were stored in polythene bags to prevent desiccation. The field data regarding their habitat, activity, phenology and flower colour etc. were noted down in the field note book. The collected plant species were identified with the help of existing Floras (The Flora of Presidency of Madras (Gamble and Fischer, 1957) and The Flora of Tamil Nadu Carnatic (Matthew, 1983). The identity is authenticated by matched with type specimens available in the herbarium of Botanical Survey of India, Southern Circle, TNAU Campus, Coimbatore, Tamilnadu.
Experimentation

Illustration of a diagnostic tool

A Foldscope is an optical microscope that can be assembled from a punched sheet of cardstock, a spherical glass lens, a light-emitting diode and a diffuser panel, along with a watch battery that powers the LED [4]. Based on the lab light conditions, even normal sunlight or LED light can be used as light source. Once assembled, the Foldscope is about the size of a bookmark. The Foldscope weighs 8 grams and comes in a kit with multiple lenses that provide magnification from 140X to 2,000X [5]. The kit also includes magnets that can be stuck onto the foldscope to attach it to a Smartphone, allowing the user to take pictures of the magnification. Foldscope punched cards can be printed on a standard A4 sheet of paper and assembled in seven minutes duration [6]. Dr. Prakash claims that the Foldscope can survive harsh conditions, including being thrown in water or dropped from a five-story building (fig. 2) [7].

Sectioning

Free hand section of plant materials were used for the anatomical studies. These sections were mounted in glycerin stained with safranin. The paraffin-embedded specimens were sectioned with the help of Rotary Microtome. The thickness of the section was 10-12 μm. Dewaxing of the sections was done by customary procedure [8]. The internal plant constants such as trichomes distribution, stomatal and pollen morphology, stem and leaf anatomy of different active medicinal plants were studied. Descriptive terms of the anatomical features are taken from the standard anatomy book [9].

RESULTS

The Foldscope is comprised of four stages cut from paper they are lens stage, sample stage, panning guide and focus ramp (fig. 3). Other primary components include a spherical ball lens, lens-holder apertures, an LED with diffuser or condenser lens, a battery, and an electrical switch. Plant materials were collected from the different locality of Manar beat and viewed by foldscope for anatomical characterization in field conditions. Anatomical examination was carried out in trichomes, stomata, pollen grains, stem and leaf of different medicinal plants shown in fig. 4. Unicellular trichomes were seen in Acalypha indica and Passiflora foetida. Multicellular trichome was observed in Euphorbia hirta. Diacytic stomata were observed in Adathoda vasica, where else paracytic stomata were seen in Ixora coccinea. Morphology of pollen grains was captured in Tribulus terrestris. Transverse section of stem was examined in Acalypha indica, Adathoda vasica, Tribulus terrestris, Passiflora foetida and Catharanthus roseus. The wedge-shaped vascular bundles were viewed in Nerium odorum.

We had demonstrated many programs at various educational institutions regarding "Foldscope assembly and its applications". Of these some workshops and hands-on training were conducted for the student community. Every session started with interaction on foldscope preparation and handling method along with some slides for the students to know the assembly and utility of the low-cost microscope, which can be attached to a smartphone to take photographs of the specimen. Later, a MoU was signed between Vellalar College for Women (Autonomous), Tamil Nadu with Mizoram University, Aizawl, Mizoram, India for effective teacher-student exchange programme. List of institutions (table 1), different demonstration and workshop photograph (fig. 4) and foldscope images (fig. 5) are given below. The foldscope images were uploaded in the website https://microcosmos.foldscope.com

| Antonie von Leeuwenhoek (Senior) | Microscope | Manu prakash (Junior) | Foldscope |
|----------------------------------|------------|----------------------|----------|
| ![Antonie von Leeuwenhoek](image1) | ![Microscope](image2) | ![Manu prakash (Junior)](image3) | ![Foldscope](image4) |

Fig. 1: Panoramic view of manar beat, karamadai range

Fig. 2: Pioneers in microscopy
Explained the theme of Foldscope in Workshop at Mizoram University, Aizawl.

Introducing the foldscope to College Students, Vellalar College for Women, Erode, Tamil Nadu

Assembly of origami paper microscope to school Students, Government Higher Secondary School, Vijayamangalam, Erode district, Tamil Nadu

Foldscope workshop was conducted in e-lab, Erode, Tamil Nadu

Fig. 4: Workshop and training programmes at various institutes
**Trichome distribution**

*Stomatal Morphology*

- Diacytic stomata in *Adathoda vasica* Nees.
- Paracytic stomata in *Ixora coccinea* L.

*Pollen Morphology*

- Unstained pollen of *Tribulus terrestris* L.
- Stained pollen of *Tribulus terrestris* L.

**Stem and Leaf Anatomy**

- *Acalypha indica* L. Stem
- *Adhatoda vasica* Nees. Stem
- *Tribulus terrestris* L. Stem
- *Passiflora foetida* L. Stem
**CONCLUSION**

Foldscope is an advanced technology developed in microscopic world that will help the people to understand the microscopic world troubleously. Scientists like Dr. Manu Prakash have shown that simple and affordable scientific devices can be designed, fabricated for the use of Foldscope Workshop.

**Table 1: Foldscope Workshop-List of various institutions**

| S. No. | Name of the institutions | Theme of the programme | Date of visit | No. of students participation |
|--------|---------------------------|------------------------|--------------|------------------------------|
| 1.     | Government Higher Secondary School, Vijayamangalam, Erode Dt, Tamil Nadu | One Day Skill Development Workshop on Foldscope Assembly and its Usage | 8th June 2018 | 60 |
| 2.     | Vellalar College for Women, (Autonomous), Erode Dt, Tamil Nadu | Foldscope assembly and usage for UG students | 11th September 2018 | 145 |
| 3.     | Government Boys Higher Secondary School, Manickampalayam, Erode Dt, Tamil Nadu | One Day foldscope training Programme | 16th October 2018 | 50 |
| 4.     | Vellalar College for Women, (Autonomous), Department of Botany, Erode Dt, Tamil Nadu | Foldscope–A new research tool for better understanding of Biological Sciences | 13th November 2018 | 30 |
| 5.     | Vellalar College for Women, (Autonomous), Department of Botany, Erode Dt, Tamil Nadu | Applications of Foldscope in Bioscience and Ecosystem Biomonitoring through Environmental DNA Metaborcoding approach | 10th January 2019 | 40 |
| 6.     | Research Committee, Vellalar College for Women (Autonomous), Erode Dt, Tamil Nadu | Tools to Revitalize Research and Teaching | 28th February 2019 | 25 |
| 7.     | Erode Diagnostic Laboratory, Erode Dt, Tamil Nadu | Foldscope–A new scientific research kit for simple indulgent of microbiological and clinical sciences | 2nd May 2019 | 10 |

**Table 2: Foldscope upload views-https://microcosmos.foldscope.com**

| S. No. | Date | User name | Id-sticker No. | Title |
|--------|------|-----------|----------------|-------|
| 1.     | 5.6.2018 | Dr. S. Sharmila | 0002D5F1A74E | Morphoanatomical characters of medicinal plants in Manar region |
| 2.     | 5.6.2018 | Dr. S. Sharmila | 0002D5F1A74E | Litter study in Manar hill range |
| 3.     | 12.6.2018 | Dr. S. Sharmila | 0002D5F1A74E | One day DBT funded skill development workshop on foldscope assembly and its usage |
| 4.     | 9.7.2018 | E. K. Ramya | 0002D5F1A74E | Isolation of litter decomposing microorganisms in Manar hill range-The Western Ghats |
| 5.     | 23.7.2018 | S. Mounika | 0002BF1DCDFDE | Specific focus on histological characterization-Medicinal plants in Manar range |
| 6.     | 13.8.2018 | S. Mounika | 0002BF1DCDFDE | Recent approach to view stomatal anatomy under foldscope |
| 7.     | 11.09.2018 | Dr. S. Sharmila | 0002D5F1A74E | Rauwolfia serpentine and Acacia caesia anatomical view under foldscope |
| 8.     | 17.09.2018 | M. Anusha | 00023D2CFBFB | Workshop on “Foldscope assembly and usage for UG students” |
| 9.     | 11.10.2018 | Yuvarajeswaran | 0002A0C5B28 | Foldscope vision of Passiflora foetida L-a protocarnivorous plant in Mannar region, Western Ghats, Tamil Nadu |
| 10.    | 17.10.2018 | Rosekavin | 0002227BD7A4 | One-Day-Foldscope-Training Programme-in-Government-Boys Higher-Secondary-School-Manickampalayam, Erode, Tamilnadu |
| 11.    | 10.11.2018 | Sudhakar | 00025057C66B6 | Outcome of Foldscope Workshop-Government Higher Secondary School, Vijayamangalam, Erode District, Tamil Nadu |
| 12.    | 27.11.2018 | Dr. S. Sharmila | 0002D5F1A74E | Northeast collaborative Training Workshop on Foldscope |
| 13.    | 21.01.2019 | Dr. S. Sharmila | 0002D5F1A74E | Workshop on Foldscope Applications in Bioscience |
| 14.    | 23.01.2019 | Dhibyani | 000239AAEFCDE2 | Foldscope anatomical view of Solanum trifoliatum and Mukia maderaspatana |
| 15.    | 11.03.2019 | Vinovinothini | 0002505998B8 | Pollen grains under Foldscope |
| 16.    | 12.03.2019 | Dr. S. Sharmila | 0002D5F1A74E | Workshop on Foldscope-“Tools to Revitalize Research and Teaching” |
| 17.    | 03.05.2019 | Kirithiga | 0002D91127E6 | A Collaborative and Innovative Foldscope Workshop in Erode |

**Fig. 5:** Anatomical features of different medicinal plants-Foldscope view
of common masses and can be made available in the remotest part of
the world for scientific exploration which is very easy, useful and
affordable for all mankind. Based on this data it was concluded that
coldscope can be a cheap, portable and powerful efficient biological
tool to evaluate plant biology-based studies. The coldscope was used as
an educational and training tool to help students in various disciplines
like Physics, Chemistry, Biology and instrumentation. The coldscope is
mainly used to study floras and faunas. With the help of a coldscope we
can study the plant anatomical view, microorganisms, pathogens,
water samples etc. Definitely our workshop instigates spark among
rural students and also enrich the usage of this research tool in
scientific field. We are eagerly waiting for the day that each basic
biology practicals in school and college level should use this Foldscope
as a research tool to update science among young minds.

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AUTHORS CONTRIBUTIONS

All the author have contributed equally.

CONFLICT OF INTERESTS

Declare none

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