Under the foldscope: Relatively inexpensive tool for understanding down-to-earth applications in plant sciences


Abstract

The super-cheap easy-to-use paper-based foldscope has been travelling around the world since the past decades, thereby making them operational in lab-field-based applications. In this review, we have recognized the requirements for the use of this tool in the fields of plant science and especially where measurements must be rapid, cheap and easy to access wherever we go. This new microscope doesn’t require any special labels and could help increase access to low-cost plant science diagnostic testing tool and would be beneficial in developing parts of the world where there is meagre access to agricultural science lab and few high-tech diagnostic facilities. Moreover, current challenges and future perspectives are discussed to provide recommendations for further research in plant sciences.

Keywords: easy-to-use microscope, Manu Prakash, traits of choice, crop improvement, abiotic and biotic stress

Introduction

A plant scientist without a microscope is like an astronomer without a telescope. So, every plant scientist needs a microscope to discover the hitherto mysterious microscopic world. To date, the microscopic unit’s services in plant science are in high demand and greatly admired (Banerjee, 2018) [1]. Some unwanted features that render less acceptable of a regular microscope are: it is expensive, heavyweight, bulky, fragile and need to be operated by an expert only. The high maintenance cost makes limited access especially in developing parts of the world (Choudhary and Choudhary, 2017, Sameer, 2017) [6, 12]. Suppose, during a practical farm demonstration class, when you ask plant science students to mention essential farm tools, they might say a tractor, a greenhouse, perhaps an indigenous “khurpi” or garden shovel, but probably they wouldn’t say handy microscope like “foldscope”, even some have never used and heard before (Cybulsk et al. 2014) [3]. So, we believe that microscope should become a key part of any farmer’s and plant science’s toolkit. In the adventurous beginning journey of farm science, you don’t need a really expensive, high-tech piece of kit to get started adventurous basic jobs like sampling soil micro-flora, plant disease infection studies, plant’s microscopic cells analysis etc. A simple handy inexpensive “foldscope” is sufficient to see the underlying groups of microscopic worlds, and will set you back around 500-900 INR. Furthermore, doing such analysis yourself is much cheaper in the long run, as it makes this tool viable to access outside of the regular class lab. Hence, with a relatively inexpensive “foldscope” and a yearning eye, we are able to observe bacteria, fungi, nematodes, insects, mites and parasites that threaten global food security with ease. Hence, it will offer an accessible microscope to help inspire students and researchers around the tiny globe to explore amateur microscopy and gain a hands-on approach to the plant science disciplines (Cox and Carpenter, 1989 [7]; Bredderman (1983) [9] and Cybulsk et al. (2014) [8]. Keeping in view the importance of “foldscope”, this review is aimed to produce a guide to good practice, and provide an introduction to and appreciation of some of the emerging new application of “foldscope” in plant science odyssey. Although we will provide a cursory overview and explanation of the principles of “foldscope”, we do not provide an in-depth review of the technique itself and the theory behind measurements and complete dogma, and we refer readers to some few excellent literatures covering this (see Cybulsk et al. 2014, Zev Leifer, 2018, Banerjee, 2018 and Buragohain, 2019) [8, 22, 1, 9].
Ideas of foldscope: In the year 2011, an assistant professor of Bioengineering, Manu Prakash first crystallised the ideas of “foldscope” while travelling in Thailand and he was astounded to see that several remote clinics had state-of-the-art microscopes, but never fingered it. The estimated costs of the tools were sky-high that everyone’s scared of touching them. After years of tinkering, he came up with the “foldscope” (Ed Yong, 2015) [10]. The “foldscope”, developed by Manu Prakash and his student Jim Cybulski at Stanford University in 2014, provides over 2000X magnification with submicron resolution, weighs 8.8 grams, fits in a pocket (70x20x2mm³), is battery-powered for up to 50 hours on a single button cell, and is rugged enough to withstand being dropped from three story building or being stomped on a crazy and curious plant scientist’s boot. Best of all, it’s an actual microscope that costs around 300INR (900-1000 for higher magnification), and can be assembled easily in under 10 minutes. (Cybulski et al. 2014) [8].

Fig 1: Motif of foldscope Images showing diverse application in Plant science

(a) Nematode (b) Gram positive bacterial rods (c) Trichome of cucurbit (d) Stomata of lily (e) Stomata of tobacco plant (f) Stomata of canna (g) Spores of Colletotrichum causing Anthracnose of chilli (h) Spores of Helminthosporium (i) Spores of Pithomyces (j) Spores of Curvularia (k) Filaments of Spirogyra (l) Filaments of Nungsam (Lemanea manipuresinis, Red algae) (m) Cross section of leaves of Trapa natans (n) Cross section of leaf stalk of Trapa natans (o) Pollen of Hibiscus cannabius (p) Pollen of Mimosa pudica (q) Pollen of Hibiscus sinensis (r) Pollen of Ageratum (Photos copyright: Mrs N. Sundari Devi, Dr. Senjam Jinus S., Dr Thoudam Santosh Singh and Mr. Sukham Joybi Singh)
Components of foldscope: The “Foldscope” is a completely down-to-earth microscope with all kinds of advanced microscopy, built purely by folding paper. Its kit contains pre-assembled “foldscope” for ready use (fig. 2), prepared glass slide, standard paper slides, microwell paper slide, extra magnetic coupler, ring stickers, cover slip stickers and cotton swab. Components included in pre-assembled foldscope kit (fig. 2) are enough to observer various specimens around us. The deluxe individual kit is made to allow any curious explorer to perform microscopy experiments anywhere at any time. It came packed with handy accessories, it includes LED magnifier, scissors, tweezers, well plates, petridish, eyependufc tubes, pipettes, striainers, clear tape roll, microscope slide set, reusable slide and coverslips, circle dot stickers, diffuser stickers, ziplock sample bags, filter sheets, notebooks and pencil. Once assembled, the “foldscope” is operated by inserting a standard microscope glass slide, turning on the LED, and viewing while panning and focusing with one’s thumbs. The microscope components are versatile and each can be designed to execute a single microscope technique, such as brightfield, darkfield, fluorescence, or lens-array. Cheap manufacturing costs could allow for labs around the world, especially in developing countries, to have plant science students’ lab drawers full of magical wand “foldscopes”, each for carrying out a unique diagnostic test of microscopic world (Cybulski et al. 2014) [8].

Manifold application in plant sciences: The “foldscope” has a wide range of application in plant science research purposes. With a “foldscope” microscope using the required magnification levels, we can view the microscopic cells of plants in good magnification with relatively good image quality. Thereby we can quickly examine under the lens. The relative important traits for crop improvements such as: stomata density counting, diseases identification, algae’s structural studies, pollen morphology analysis, plant’s pollen sterile line determination, trichomes variation studies and soil microbe detection as a diagnostic test making it very easy to identify foreign microbial communities, pathogen or fungal diseases in your plant and soil samples. To decipher few instances, recently the in-tissue activity analysis was reported to detect various antioxidant (including glutathione, NADPH oxidase, SOD, POD, MDAR etc) and secondary metabolites (including lignin, lipid, cellulose and hemicelluloses, etc.) in pollens and stomata. Moreover, some of the relative important traits and observation, which have been mentioned above and, given in the fig. (1), as a part of preliminary research was conducted with a team collaboration of some colleges and institutions (fig. 2, h1&2) located at Manipur, and those “traits of choice” (fig.1) can be studied and used further in various crop improvement programmes in plant science. Briefly deciphering, some supported literatures of various co-workers on which the “traits of choice” mentioned for crop improvement programme which are viable to access under the foldscope are discussed. As we observed the “traits of choice” say the motifs of stomata here (fig.1. d,e&f), many co-workers in abiotic stress study deciphered that the majority of water loss from plants occurs via transpiration through epidermal pores stomata making these cellular structures an attractive target in the battle to prevent water loss. Recent several laboratory studies have demonstrated that it is possible to improve drought tolerance and Water Use Efficiency (WUE) by reducing the frequency of stomata on leaves, by using genetic manipulation, to reduce stomatal density, improved WUE has been achieved across several model dicot species including Arabidopsis (Franks et al. 2015) [11], Nicotiana tabacum (Yu et al. 2008) [27] and Hordeum vulgare (Jon et al. 2017) [15]. Another special structures and physiological functions of trichome (fig.1c) such as reflectance, energy balance (Bickford, 2016) [3]; ultraviolet
protection (Karabourniotis et al. 1992) [16], drought resistance (Hong-Qin and Ping, 2010) [14], gas exchange, insect resistance (Levin, 1973, Handley et al. 2005) [17, 13] and disease resistance (see Xiao et al. 2017) [20]. Recent study also indicated that fresh water algae (fig.1, k&l) biomass can be used to develop high capacity bioisorbent materials for the removal and recovery of toxic heavy metal ions from dilute industrial wastewater streams (Rezaee et al. 2006) [23] and even we examined the beautiful hairy clear pattern of spirigryra and Lemanea manipureensis (fig.1, k&l) under the foldscope too. According to an estimate, plant parasitic nematodes (fig.1a) are causing much more damage annually compared to insect pests. A crop yield loss due to these tiny unseen pests in various countries is enormous (see Singh and Singh, 2015) [24]. Some of the most damaging nematode is shown in the fig.1(a) through the lens of “foldscope”. Meanwhile, rice brown spot (BS), caused by Cochliobolus miyabeanus which is seen in the image (Fig. 1h) is a chronic disease that affects millions of hectares of rice every growing season, grown by some of the most resource-poor farmers. Reported yield losses in relative terms vary widely from 4 to 52% (Barnwal et al. 2013) [2]. Of the 5000 and above recognised bacterial species, over 100 species are the causal agents of plant diseases. They constitute a very important factor limiting growth and cropping of cultivated plants. Identification of such aggressive species from the base level with the help of “foldscope” by studying its phenotypic characters will also ease the pain of many plant pathologists’ dilemma (Sobiczewski, 2008) [25]. Colletotricum which is shown in the fig. 1(g), the most frequently isolated species and causes anthracnose on numerous plants worldwide (Damm et al. 2012) [9]. Leaf spot disease of cabbage, pithomyces which is shown in the fig. 1(i), is affecting 80% of plants growing in greenhouse and field. Identification of such isolate from the basic level under the lens of “foldscope” helps to determine its morphological characters and can also be used for student’s lab analysis purpose (Naschi et al. 2014) [19]. Over and above, pollen biology has direct apropos in agriculture, horticulture (vegetable science and pomology), plant pathology, plant breeding (vegetable breeding), agricultural microbiology and biotechnology (Margaret et al. 2000, Noor et al. 2004) [18, 20]. Taking into account, the applied form of palynology was found desirable to carry out palynological work (fig.1, o,p,r&s) dealing with the fundamental palynology of the plant, cultivated in Manipur. Wherefore, the epistome dossier provided here could prove worthwhile for the identification of many microbial flora of plants and soil, as well as for diagnostic screening through the lens of cheapest paper based “foldscope” in the field of plant science.

**Conclusion remarks**

The neoteric increased heed in the use of “foldscope” tool has been mainly due to viable research applications for the crop improvement tool and particularly for the screening of desirable “traits of choice” with responses to abiotic and biotic stress. However, several challenges remain, spotlighting differences compared to using a glass or digitized slide – e.g., holding the “foldscope” up to a light source resulted in the liquid sample dripping on the observers face (Rebecca et al. 2018) [22]. The practicable strategies can be using semi-permanent slide with the help of transparent nail polish on the periphery of cover slips or methods can be developed to keep it flat, with attention to clamps to hold it and a light source appropriately placed. In addition, methods can be developed to take the images with ipad or android cell phone. Therefore, further development is needed as to methodology and as to validation given the requirement of increasing magnification in images analysis and further new advanced applications.

**Acknowledgement:** This research publication was supported by a grant from Dept. of Biotechnology (DBT), Govt. of India, New Delhi as part of Major Research Project vide. No. BT/IN/Indo-US/FOLDSCOPE/39/2015, dated 20th March, 2018.

**References**


