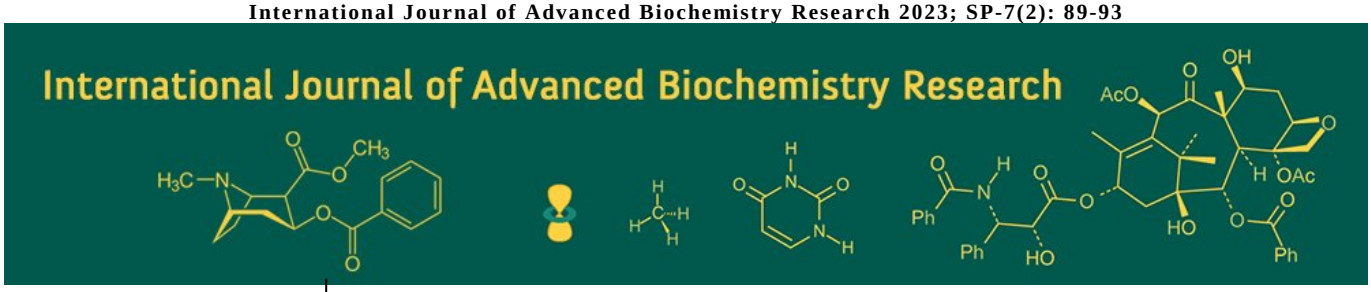

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Foldscope (Paper Microscope): Inexpensive research tool for farmers to identify plant pathogens

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Abstract
Foldscope is a paper microscope based on origami which is easy to use and extremely portable. Paper microscope doesn't require any special laboratory facilities or high-cost chemicals. The present research study is how foldscope can be used as an efficient and easy tool for farmers to be get known about plant pathogens by seeing symptoms on plant parts. For optical visibility of pathogen glass slides were used along with small diseased plant part and for staining methylene blue or lactophenol have been taken. Various samples from field were observed under foldscope in which various plant pathogens were visible i.e., *Alternaria, Fusarium, Rhizoctonia, Helminthosporium* and *Curvularia* from class *Deuteromycetes*; *Albugo candia* from class *Oomycetes*; *Aspergillus* and *Penicilium* from class *Eurotiomycetes*; *Ustilago* and *Uromyces* from class *Basidiomycetes*; *Mucor* and *Rhizopus* from class *Zygomycetes; Erysiphe, Leveillula* and *Oidium* from class *Ascomycetes* which causes spots, rotting or blights.

Keywords: Foldscope, farmer, plant pathogen

Introduction
Foldscope is an origami-based paper microscope. It was developed by Dr. Manu Prakash, Associate professor, Stanford University, California, USA and designed to cost less than US$1 to build The Foldscope has multiple lenses and a kit that enables magnification ranging from 140X to 2,000X and weighs 8 grammes. With that, we may observe minute objects or samples like worms, bacteria, algae, and fungi, among others. Additionally, the kit comes with magnets that can be applied to the Foldscope to enable the user to connect it to a smartphone and capture images or movies of the magnification. 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; Bredderman, 1983) [3, 2]. Regarding foliar plant pathogenic fungal diseases, such as powdery mildew, downy mildew, leaf blight, leaf spot, and post-harvest illnesses, foldscope discovered a revolutionary instrument. To date, the microscopic unit's services in plant science are in high demand and greatly admired (Banerjee, 2018) [1]. Foldscope can be used to do agrobiodiversity research on crops, animals, insects, microorganisms, crop variability, seeds, and so on (Jayateertha *et al*., 2018) [7].

Material and Methods
Ideology
The "Foldscope," created in 2014 by Manu Prakash and his student Jim Cybulski at Stanford University, has a submicron resolution and over 2000X magnification, weighs 8.8 grams, fits in a pocket (70 x 20 x 2 mm 3), and can run for up to 50 hours on a single button cell. It is also tough enough to withstand being dropped from a three-story building or being stomped on by a crazy and curious plant scientist's boot. The best part is that it actually functions as a microscope, costing around 300INR (900-1000 for higher magnification), and assembles in less than 10 minutes (Cybulski *et al.*, 2014) [4].

Components of Foldscope
The pre-assembled foldscope kit comes with enough parts to study a variety of nearby specimens. The deluxe individual kit is designed to make it possible for any inquisitive explorer to conduct microscopy experiments at any time, any place.

LED magnifier, scissors, tweezers, well plates, Petri dish, Eppendorf tubes, pipettes, strainers, clear tape roll, microscope slide set, reusable slide and coverslips, circle dot stickers, diffuser stickers, ziplock sample bags, filter sheets, notebook, and pencil are just a few of the useful accessories that came with it.

Foldscope is a paper microscope with the following metrics

- Magnification: 140x.
- Resolution: 2 microns.
- Back focal length: 0.56 mm.
- Depth of field: 0.013 mm.
- Field of view: 0.51 mm (diagonal radius).

Attachment of the camera phone with Foldscope

- Place a double-stick ring sticker over the centre of the phone's flashlight. Tape can also be used to attach a coupler in place of the ring sticker.
- Place the coupler (silver side UP) on top of the sticker.
- Mount the blue side of the Foldscope to the back of the phone.

Sample insertion

Simply place a sample into the Foldscope microscope so that there is something to observe. It is simplest to observe samples that have been put on a glass slide or a paper slide. Flip your Foldscope to the yellow side and open the back flap to enter a sample.

Viewing method

1. By direct Eye viewing

- Make temporary slides of the sample first, then hold the Foldscope with the blue side facing and put the lens to your eye to view any sample directly.
- Point the Foldscope's back toward a source of light while viewing, such as a lamp or a clear sky, but avoid looking directly at the sun.

2. By Phone viewing

In order to see any sample with a phone, first secure a coupler over the camera's lens. (Make that the coupler is positioned such that the silver magnet side is towards the phone.) The phone camera lens needs to be centred in the ring magnet's hole. With the help of a double-sided ring sticker or any other type of tape, secure the coupler to the phone.

Components of foldscope

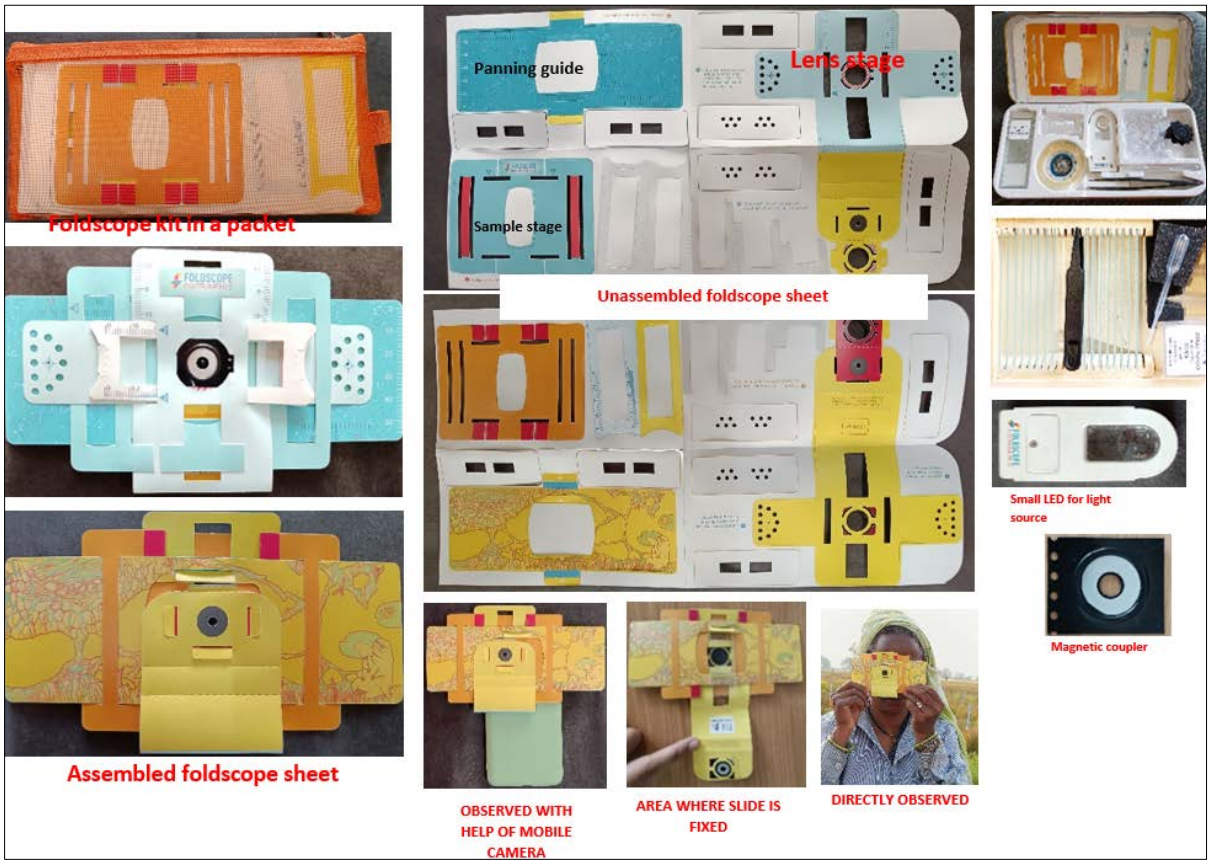

Fig 1: Unassembled and Assembled foldscope kit with its accessories

Results and Discussion

The present investigation was done around the campus of College of Agriculture, Raipur and samples were collected for study. Collected samples were cut into small sections or scrapped with the help of sharp blade and for optical visibility of pathogen glass slides were used along with small diseased plant part and for staining methylene blue or lactophenol and covered with glass cover slips. Seed viability, and visualization of cells were shown by making it easier to identify foreign varieties, mites, or fungal diseases in leaves, and seed samples at the spot in farmers' fields (Dev and Nischal, 2019; Maheswari *et al.*, 2019) [5, 8].

Foldscopes can now be used to teach aspiring young farmers of our country or state and (Jayashree *et al*., 2020; Surla *et al.,* 2021) [6, 9] by observing the presence of fungal contamination.

Filed symptoms easily observed by farmers

A. White Rust of *Amaranthus*: *Albugo candida*

Filed Symptoms: It appears as shiny, white, smooth, uneven patches (pustules) or blisters on the leaves, stems, and other aerial portions of the plant, the disease brought on by *Albugo* is frequently referred to as "white rust." The lower surface of the leaf is where the pustules first appear, but in some situations, they may appear on both surfaces.

B. Rot of Brinjal: *Alternaria*

Filed Symptoms: Brown patches on the foliage are one of the earliest indications of eggplant early blight. On the lower leaves, the spots first appear before moving up the plant, then later also seen at fruits in form of rotting.

C. Leaf and pod spot of Linseed: *Alternaria*

Filed Symptoms: Numerous lesions will appear on the surface of leaves on an infected host. Small, circular lesions will have light-brown centres and black, concentric rings around them. While fresh leaves are also prone to spotting, lower, older leaves tend to exhibit it more frequently. A huge spot can form when several small spots come together in close proximity. Due to a lack of water, heavily marked leaves will swiftly turn yellow, wilt, and fall. These signs primarily affect leaves, but they can also impact stems, blossoms, and seed pods.

D. Rot of Grapes: *Aspergillus*

Filed Symptoms: Fruits discovered with black fungal sporulation and the signs of sour rot. Berry breaking and leakage, as well as a strong vinegar odour, were symptoms. It has been determined that a variety of bacteria that penetrate ripe berries after damage cause sour rot, also known as summer bunch rot. Among the fungi that are frequently linked to sour rot is *Aspergillus.*

E. Root Rot of Chickpea: *Fusarium*

Filed Symptoms: In the field, affected chickpea plants display premature drying and yellowing of the leaves. Unmanned aerial vehicle-based field photography reveals that rot-affected plants appear in patches that are dispersed irregularly over the field and are of erratic size and form.

F. Phomopsis blight of Brinjal: *Phomopsis* (Pycnidia)

Filed Symptoms: Leaves begin to grow small, round spots that subsequently turn grey with a light-coloured center. On the ripe fruits, pale to light brown sunken dots appear. Small spots spread out and combine to cover the entire fruit or the majority of it.

G. Powdery mildew

Filed Symptoms: A common plant disease that affects plants all over the world, powdery mildew generates a powdery buildup on the surface of leaves, buds, young shoots, fruits, and flowers.

H. Root root: *Rhizoctonia*

Filed Symptoms: This illness is confined and is distinguished from healthy beet tissue by sharply defined, dry sunken lesions overlying a brown spongy substance. The cankers' surface tissues also create an eye-catching pattern of concentric circles.

I. Rust of Chickpea: *Uromyces ciceris-arietini*

Filed Symptoms: Small, round or oval, light brown to dark brown pustules on both surfaces of the leaves are the first signs of chickpea rust disease. These pustules typically developed on the leaf's underside.

J. Smut of grass: *Ustilago*

Filed Symptoms: Only the floral sections show the symptoms. The flower spikes turn black and continue to contain smut spores inside of them. The wind can readily carry away the spores' dark powder, leaving the inflorescence's stem exposed.

Table 1: Key characters observed in foldscope

Serial No.	Pathogen name	Key characters observed in Foldscope
1.	*Albugo*	Conidia: Globose to oval, hyaline with uniform thin wall
2.	*Alternaria*	Brownish conidia with a short beak; Transverse and longitudinal septa
3.	*Aspergillus*	Long and large conidiophore; thick walls; vesicle with long chains of conidia
4.	*Curvularia*	Curved with two-three septa; light to dark brown colour
5.	*Erysiphe*	Hyaline and cylindrical conidia; single-chains
6.	*Fusarium*	Hyaline curved for macro-conidia with two three septa
7.	*Helmithosporium*	Conidia are long, slender, 3-7 celled; tapering upwards, straight or slightly curved; light brown to dark brown in colour.
8.	*Rhizopus*	Globular-ovoid shape head with Rhizoids (root-like structure) seen at the base, also through rhizoids it is connected with its side structures too.
9.	*Rhizoctonia*	Mycelium septate near branching; branched at 90 degrees; uniform hyphae; constricted hyphae at branching point.
10.	*Ustilago*	Light brown-dark brown spores
11.	*Uromyces*	Brown coloured, round spores

Diseased samples and their foldscope microphotographs

Fig 2: Diseased samples and their foldscope microphotographs

Conclusion

Various samples from field were observed under foldscope in which various plant pathogens were visible i.e., *Alternaria*, *Fusarium*, *Rhizoctonia*, *Helminthosporium* and *Curvularia* from class *Deuteromycetes*; *Albugo candia* from class *Oomycetes*; *Aspergillus* and *Penicilium* from class *Eurotiomycetes*; *Ustilago* and *Uromyces* from class *Basidiomycetes*; *Mucor* and *Rhizopus* from class *Zygomycetes; Erysiphe*, *Leveillula* and *Oidium* from class *Ascomycetes* which causes spots, rotting or blights.

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