Detection of pest through X-ray imaging: Application in Arabica Coffee Plant *(Coffea arabica L.)*

K. Sandesh[a], Swetha Sandesh[a]*

[a]Research and Development Division,
Niranthara Scientific Solutions Private Limited (NSSPL),
Shankarnag Circle, Kengeri,
Karnataka State, Bangalore-560 060, India

(*Corresponding Author: E-mail: swetha@niranthara.in, Phone: +91-80-28484646)

Abstract

Arabica coffee plant are generally affected by various pests. The *Xylotrechus quadripes* (Chevrolat), the coffee white stem borer (CWSB) is a very harmful pest as its grub feeds on the internal parts of the stem leaving very little external evidence of damage to the host plant at the initial stage. Existing pest management methods suffer from the lack of knowledge about the precise location of the pest within the plant and the extent of internal damage. Minimally invasive investigation of pest CWSB in the plant body has good potential to elucidate the stages of the pest, infestation inside the stem and the plant growth. Digital radiography (X-ray imaging) is used for *in situ* feasibility studies of plant growth in presence or absence of pest and also helps in the early detection of the pest. These techniques has challenges like, to study the imaging in the live plants addressing to environmental conditions, X-ray imaging time and distance covered with respect to plant height. In this study, the use of digital radiography involves the mechanism where X-ray auto detection mode with cassettes detects X-rays at the time of exposure and automatically enters the image detection mode and then the image construction mode. Six uprooted stem of Arabica coffee

plants were successfully scanned for CWSB. Results of X-ray imaging confirmed the presence of pest inside the coffee stem in varied stages of growth and even the exit holes of the matured pest were also observed clearly when exposed to the radiation. The advantage of using the digital radiography to study the severity of pest in the plant was investigated and discussed.

Keywords: X-ray Imaging, Arabica coffee, CWSB, *Xylotrechus quadripes*.

1. Introduction

India ranks sixth in the world for the production of coffee, after Brazil, Vietnum, Indonesia, Colombia and Ethiopia. Indian coffee is the most preferred beverages, because of its stimulating taste and unique flavour. The Arabica variety is majorly preferred in international markets when compared to Robusta coffee, and is the largest contributor of foreign exchange (1).

Arabica coffee *(Coffea arabica L.)* is known to be effected by various pests all through its life-cycle and among all, the white stem borer is a harmful insect pest. The CWSB was first reported in India in 1838 and Arabica coffee is the most preferred and a principal host plant for this pest, breeding in plants other than arabica coffee is very rare (2-3). Research had confirmed that stem borers have highest cellulose producing micro-organisms in their gut, which includes 42 unique cellulose producing strains, 5% belonged to *Bacillaceae*, 26% belonged to *Enterobacteriaceae*, 17% belonged to *Microbacteriaceae*. The stem of Arabica coffee has rich nutritional content such as 37% cellulose, 4.5% protein, 8.5% extractive in addition to 4% of moisture content hence, *Xylotrechus quadripes* (Chevrolat) spends majority of life cycle inside the stem. Extensive research has been carried out to study the growth stages of pest and its life cycle Fig. 1 (4). *Xylotrechus quadripes* is well known for its habit of boring through the stems of

arabica coffee plants and considered as a coffee pest known by the common name CWSB. The larvae of the pest damages the plant being hidden inside the woody stems, it is extremely difficult to control and/or to kill.

It does not appear in all Arabica coffee cultivating regions, but in the places where it does, it causes severe damage and loss. The damage made by the grub of the insect is by creating tunnels upward or downward in the stem of the plant. The tunnel made by the pest is by feeding under the bark in the living stem, destroying water and sap conducting tissues. This leads to girdling, branches dies back, structural weakness and eventual death of susceptible plants. These infestations will also provide an entry point for plant pathogens. If the early detection of instars is not made, then at later stage the pest can prove fatal to the plant. Currently, managing the pest is done by the usage of chemicals or the cutting down of infested plants. Usage of chemicals can be helpful to recover the plant only at the early stage of infestation. Identification of infested plant will appear to wilt and in certain cases healthy and un-infested plants are cut as a measure of precaution. All this is done without having any knowledge of the locality of the pest and the extent to which the damage is caused by the pest within the plant.

Internal visualization and quantification of stem borer in arabica coffee plant are essential to understand the mechanism and stages of pest inside the plant parts.

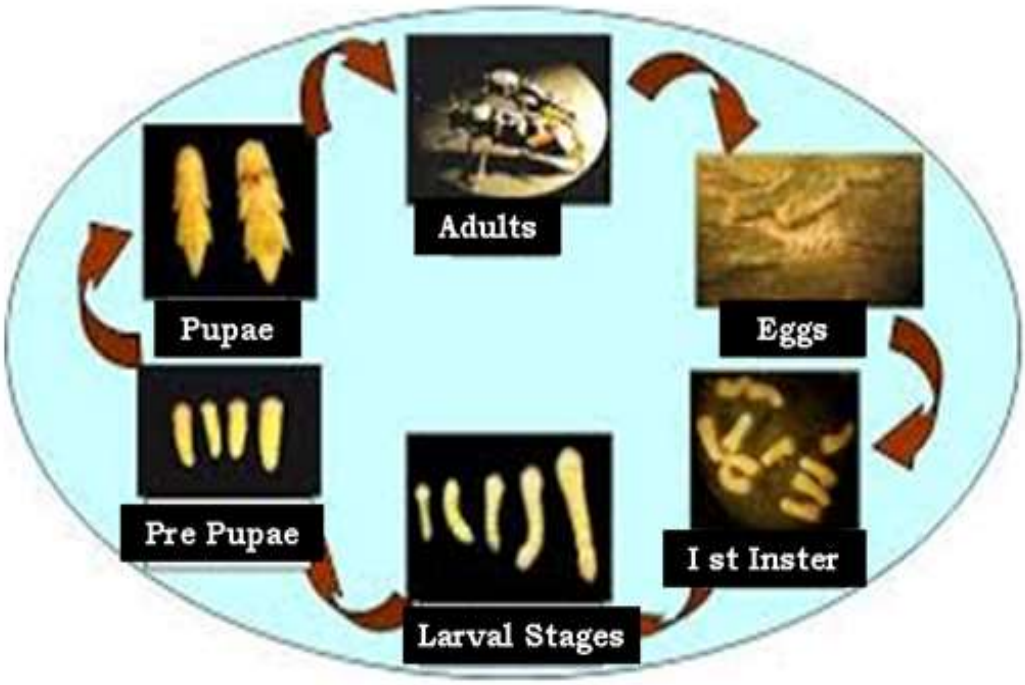

Fig. 1: Stages of *Xylotrechus quadripes* (CWSB) Life Cycle.

Originally the X-ray technique was designated for diagnostic medicine, later in 1980s the technique was adopted to study soil science to monitor physiological and dynamic processes in live plants using Computed Tomography (CT) along with X-ray (5-6).Currently X-ray Computed Tomography (CT) imaging technique is used to observe and quantify aspects of the soil environment including plant root development, fungal influences, changes to pore structure and the influence of microbial activity.

Along with the plant studies, even the X-ray radiation technique was extensively used by Insect Pest control Laboratory to produce sterile male insect there by reducing the population of the harmful pest attacking the crop yielding plants (7-9). Recently the X-ray, gamma and neutron radiation were used for plant mutagenesis studies. The study utilized the X-ray radiation in the plant mutagenesis for the germination of seeds and effectiveness of X-ray irradiation was assessed through the Relative Biological Effectiveness (RBE) by measuring growth of seedlings (10-11).

Based on a wide application of X-ray technique and also by thorough analysis of the current diagnostic routines, we decided to explore the usefulness of X-ray technology for studying the effect of CWSB on the Arabica coffee plant detection problem. Despite the fact that current X-ray systems are mainly designed to identify human and animal tissues, this technology has been used in other applications, including a number of non-destructive tests and procedures. Additionally, there have been several attempts to use X-ray imaging to inspect wood surfaces for different purposes, but never before in identifying the CWSB in Arabica coffee plant by visual methods.

2. Materials and Methods

CWSB infested arabica coffee plants showing external exit holes and visible ridges around the stem and exhibiting signs like wilting and yellowing in the plantation were selected (Fig. 2). The selected plants were trimmed to take only the stem portion of the plant, as the pest hosting will be there in stem portion only (Fig. 3). The stems were exposed to digital radiography (Make = Fuji, Model = FDR Visionary Suite) with tube current = 5 milli amps, source to image receptor distance = 36" and exposure time was 1-2 sec. DR Panels

Fig. 2 : CWSB infested arabica coffee plant

used was FDR D-EVO advanced C43A is a new multifunctional portable flat panel sensor that can be used in a wide range of clinical scenarios. This new panel displays excellent performance, allowing for Energy Subtraction and Tomosynthesis imaging. All the necessary safety measures were taken while handling the X-ray device.

Fig. 3. Trimmed stem taken for X-ray studies.

The X-ray device works in auto detection mode and direct radiography cassettes detect X-rays at the time of exposure and automatically enter the image detection mode and then the image construction mode (Fig. 4).

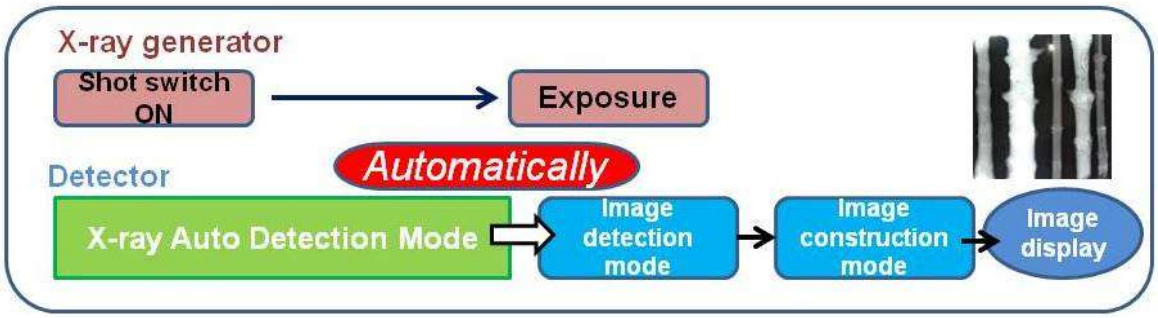

Fig. 4. Pictorial representation of X-ray detection and image display process.

3. Results and Discussion

Currently the identification of the presence of CWSB pest inside the stem of severely infested arabica coffee plant is based on the appearance of plant which will have less number of leaves in the branches and physical growth of the plant will be hindered. CWSB rarely infest healthy plants growing in natural environments, when plants are in stress as drought, soil compaction, sun scald or injuries can weaken them and make them more susceptible to attack. Adults will locate suitable egg lying sites by responding to volatile chemicals that emit from stressed plant. The only way of visualizing the pest is by cutting the stem to halves where by the live grubs will be visible to eyes.

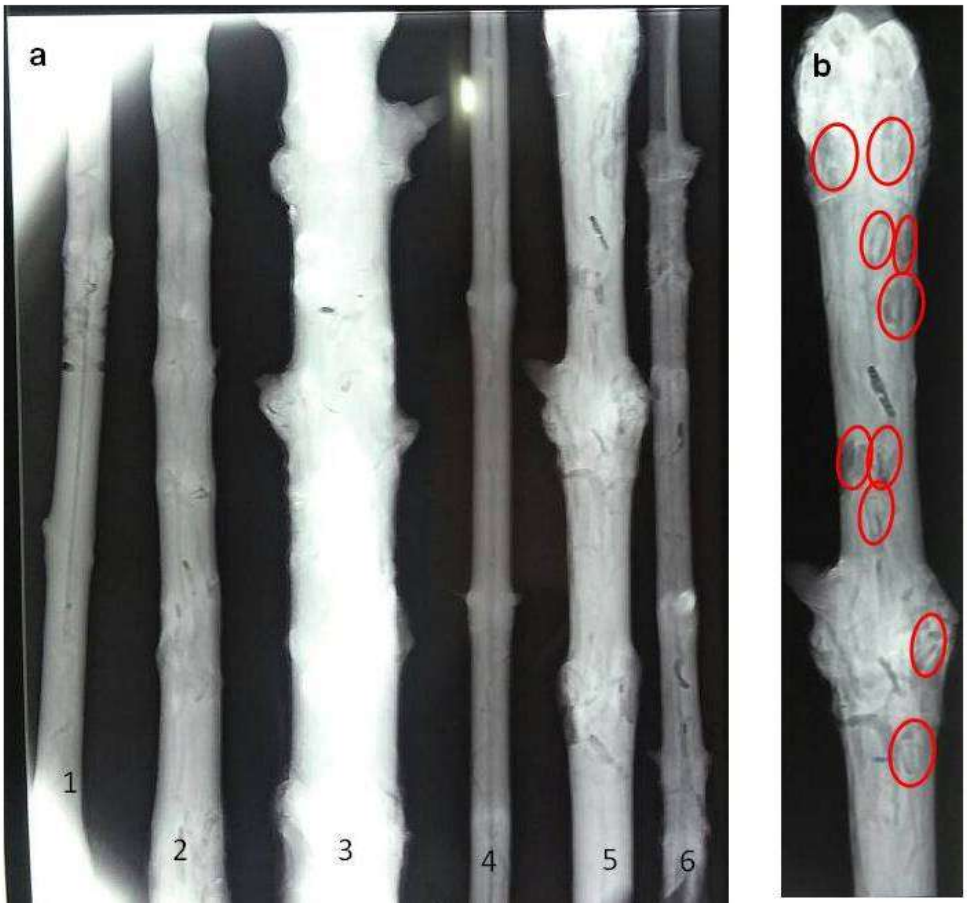

Fig. 5. (a) X-ray images of trimmed stems (b) Enlarged view of 5th stem (pest highlighted with red marking).

In Fig. 5 (a) the cut stem were exposed to X-ray radiation and without cut opening we were able to identify the presence and the total number of pest/grubs inside the stem. Among 6 stems the 5th stem as seen in Fig 5 (b) is severely infested and we could see 10-12 grubs in one stem. By looking into the plant one cannot imagine the number of pest inside the plant the only way is to cut opening the stem. In Fig. 5 The stem exposed under X-ray and cut opened stem is shown where pest detected in X-ray device can be easily seen through the cut opened stem.

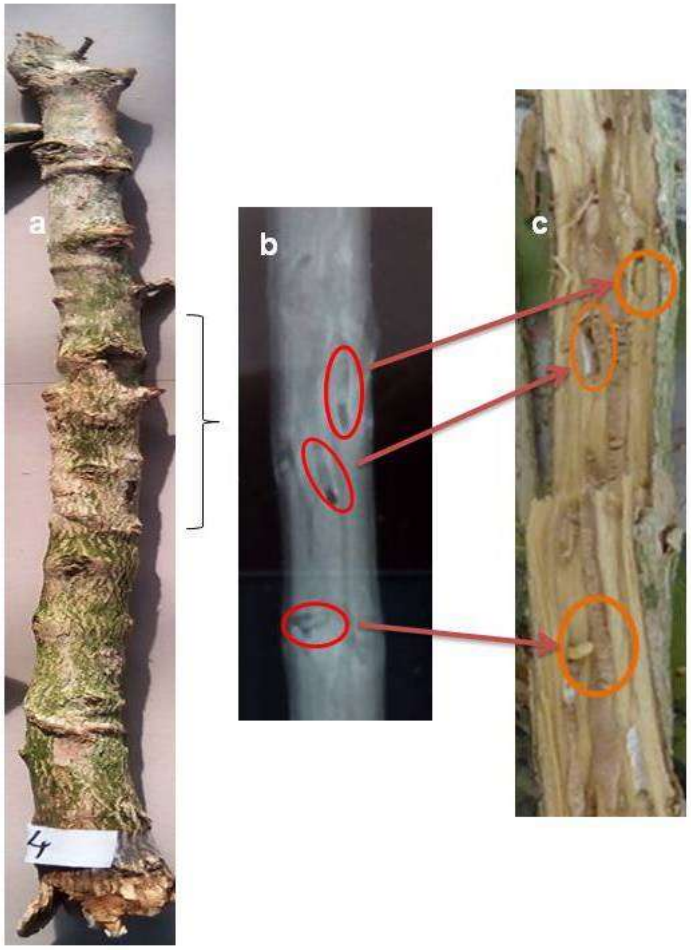

Fig. 6. a) Infested Stem b) Pest seen through X-ray c) Same pest seen in the cut opened stem.

Usually as per the life cycle of the CWSB, the damage made by the grub of the insect is by creating tunnels upward or downward and once it is matured it flies off from the plant by making the ridges in the stem. In Fig. 7 the ridges seen outside the plant stem, when exposed to X-ray a zigzag tunnel can be observed. There by it damages the whole plant and if the entire pest goes out of the plant by making this type of ridges then the chance of survival of plant will be very less or it dies.

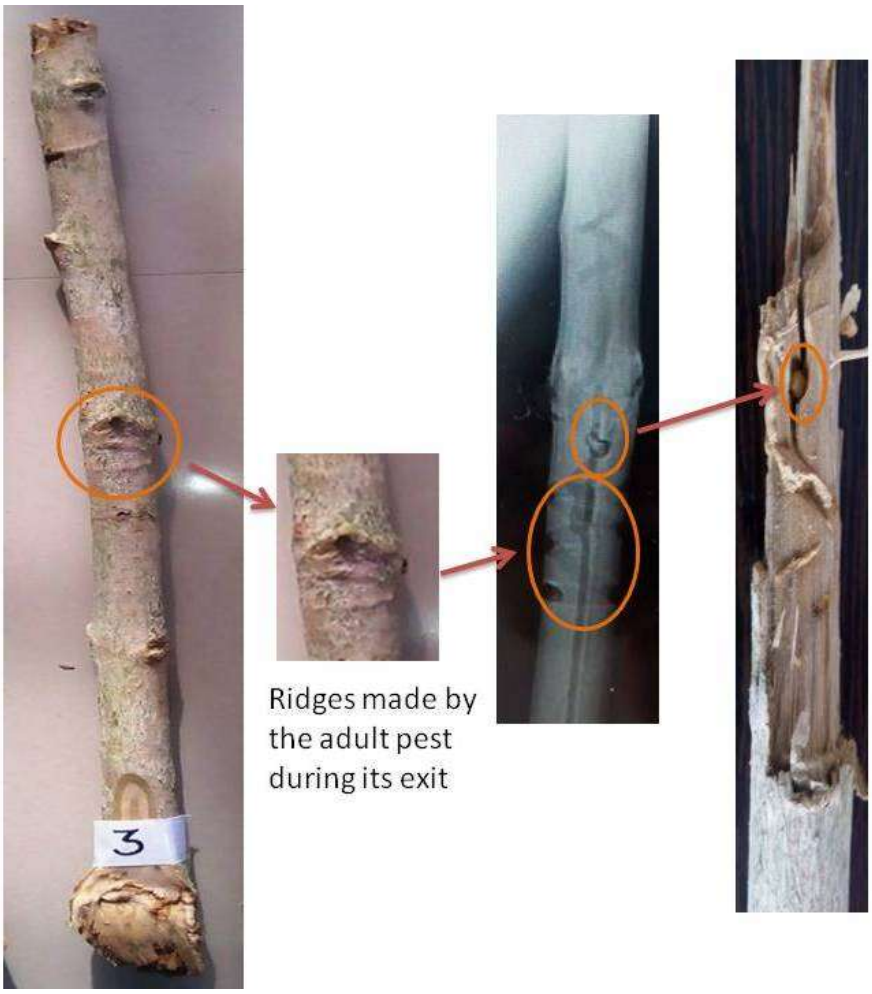

Fig. 7. Ridges and pest exit hole seen through X-ray and cut opened stem to see the pest inside.

The aim of the study to expose the Arabica coffee plant stem infested by WSB to X-ray is to check whether the pest can be seen without cut opening the stem. The study clearly showed that the pest even with different stages can be seen through the X-ray device. So the lab level study of identifying the pest in the cut stem was successful but the major idea of carrying out this experiment is to provide a solution to the coffee growers with a device which can be able to show the presence of grubs inside the live stem of coffee plant. By adopting this technology one can detect the stages of infestation and ultimately carry out necessary precautions to save the plants.

Our research is under progress to design such device which can be used at the field level at the cost affordable by the farmers and can be handled in any environmental conditions like humid, rainy and sunny weathers.

4. Conclusion

In Conclusion, the X-ray imaging studies on trimmed stem of arabica coffee plant is studied for the first time. Currently the X-ray device used was fixed model and images were collected in the lab with uprooted stems. The results obtained from this investigation will provide an opportunity to develop a handheld portable X-ray device for screening of *Xylotrechus quadripes* pest in the early stage of the infestation. Portable device will help in taking images of live plants without disturbing its habitat. By this device many issues related to CWSB like, identification of the pest, extent of internal damage to the stem and prevention at the initial stage with the precise knowledge of the presence of the pest and more specific treatment in terms of location and economy loss pertaining to this infestation will also be addressed.

References

1. Le Pelley, Tropical Science Series, 1968, 147, 590.
2. P. Santosh, H. L. Sreenath, P. K. Vinod Kumar, H. G. Seetharama and Jayarama, Journal of Plantation Crops, 2011, 39 (3), 396 - 398.
3. M. G. Venkatesh and A. G. Dinesh, International Journal of Tropical Insect Science, 2012, 32, 177-188.
4. K. P. Srivastav and G.S Dhaliwal, 2011, Vol II, A text book of Applied Entomology Kalyani Publication.
5. J. A. Quintero, J. Moncada and C. A. Cardona, Bioresource Technology, 2013, 139 - 307.

6. C. Karunakaran, R. Lahlali, N. Zhu, A. M. Webb, M. Schmidt, K. Fransishyn, G. Belev, T. Wysokinski, J. Olson, D. M. L. Cooper and E. Hallin, Scientific Reports, 2015, 5, 12119.
7. S. Zappala, J. R. Helliwell, S. R. Tracy, S. Mairhofer, C. J. Sturrock, T. Pridmore, M. Bennett and S. J. Mooney, PLoS One. 2013, 8(6), e67250.
8. M. Enserink, Welcome to Ethiopia's Fly Factory, 2007, 317, 310 -313.
9. T. Mastrangela, A. G. Parker, A. Jessup, R. Pereira, D. Orozco-Davila, A. Islam, T. Dammalage and J. M. M. Walder, Journal of Economic Entomology, 2010, 103(1), 85-94.
10. A. Parker and K. Mehta, Florida Entomologist, 2007, 90(1), 88-95.

F. J. Novak and H. Brunner, IAEA Bulletin, 1992, 4, 25-33