INTERNATIONAL JOURNAL OF PLANT PROTECTION
VOLUME 8 | ISSUE 2 | OCTOBER, 2015 | 256-260

● e ISSN-0976-6855 | Visit us : *www.researchjournal.co.in*

IJPP

RESEARCH PAPER

DOI : 10.15740/HAS/IJPP/8.2/256-260

# Detection of pink bollworm, *Pectinophora gossypiella*, Saunders infestation using Soft X-ray machine

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ARITCLE INFO

**Received** : 28.04.2015
**Revised** : 01.08.2015
**Accepted** : 16.08.2015

KEY WORDS :
Pink bollworm, Infestation, X-ray, Non destructing sampling

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ABSTRACT

An experiment was carried on standardization of X-ray radiography methodology for the detection of pink bollworm infestation in cotton bolls during 2012-14 at Indian Institute of Crop Processing Technology, Thanjavur, Tamil Nadu, India. Studies revealed that the controllable input electrical parameters of the X-ray machine *viz.*, voltage, current and exposure period required for the detection of internal infestation varied widely for cotton bolls compared to stored grains and fruits tested by other scientists. High voltage and current were required for dense cotton bolls to ensure adequate penetration of radiation. It was observed on visual analysis that the X-ray radiation generated at 80 kV and 10 mA for 30 seconds resulted in the best visual images to view internal content of cotton bolls and observed to be the best for cotton bolls imagery out of 96 combinations tested for best detection of hidden infestation. While other combinations, for example, 60Kv, 4mA for 10 seconds and 90 Kv, 10mA for 30 seconds manifested into lighter and darker images, respectively.

**How to view point the article :** Nandini, S. and Mohan, S. (2015). Detection of pink bollworm, *Pectinophora gossypiella*, Saunders infestation using Soft X-ray machine. *Internat. J. Plant Protec.*, **8**(2) : 256-260.

## INTRODUCTION

Cotton, *Gossypium hirsutum* L., popularly called as "King of fibres" or "White gold" and it is cultivated in an area of 116.14 lakh hectare with an average production of 334 lakh bales in India (Anonymous, 2013). About 130 different species of insects and mites are reported to cause damage to cotton crop in India (Agarwal *et al.*, 1984). Among these, the bollworms *viz.*, american bollworm, *Helicoverpa armigera* (Hubner), spiny bollworm, *Earias insulana* (Boisdual), spotted bollworm, *Earias vitella* (Fabricius), pink bollworm, *Pectinophora gossypiella* (Saunders) pose greater threat to cotton production. Among the bollworms, the pink bollworm assumed major pest status in recent past (Gutierrez *et al.*, 2006). Further pink bollworm has become economically the most destructive and quarantine insect pest of cotton. Infestation of pink bollworm in cotton bolls cannot be seen through naked eyes because, the nature of PBW was soon after hatching larva enters the developing bolls through tip portion and entrance hole is closed as the boll mature. Therefore, infestation could not be seen, a kind of hidden infestation. Destructing sampling was the only conventional method for assessment of cotton boll damage. Hence, considering the importance and usefulness of non-destructive method of detecting (Milner *et al*.,1950; Schatzki and Fine, 1988; Haff and Slaughter, 1999) a laboratory experiment was undergone using X-ray radiation.

X-ray radiography provides a permanent, visible film record of the internal condition of the boll sample. It is especially useful for the rapid examination of relatively large samples to determine the extent of insect damage. X-rays pass readily through the objects, although some of the radiation is absorbed and the amount of absorption depends on the density of the material, its thickness as well as the voltage applied to generate the X-rays. For example, more radiation will pass through the areas containing hollow portions caused by insect tunneling than through the surrounding areas since the insect tunneling reduces the total thickness of the exposed material. High voltages are required to generate adequate penetration through very dense material. Adjustment of the voltage, current and exposure period to the specific material is important because it affects the contrast of the image recorded on X-ray sensitive film after exposure. If the voltage, current and exposure period is too high, too much of the radiation will pass through the exposed material and obscure differences in thickness within the material. Similarly, contrast will be poor if the voltage, current and exposure period is too low since too little radiation will pass through the material to form a usable image (Ramakrishnan *et al*., 2011). Although the technology is known and the suitable X-ray machinery available, the input factors *viz*., the voltage, current and the exposure period have not been standardized for cotton bolls. In the absence of standardized values of these input factors, users resort to standardization every time. Standardizing the methodology for a cotton boll is quite an important task to further the use of X-ray radiography. Therefore, considering the importance and usefulness of this non-destructive method of detecting insect damage levels of pink bollworm in cotton bolls using soft X-ray machine.

## MATERIAL AND METHODS

Laboratory experiment for standardization of X- ray radiography were proposed to be undertaken on the pink bollworm infestation in cotton bolls was conducted at Indian Institute of Crop Processing Technology, Ministry of Food Processing Industries, Thanjavur, Tamil Nadu, India. Cotton bolls for experimentation were collected from experimental farm, Tamil Nadu Agricultural University, Coimbatore.

**Description and functioning of equipment:**

***X-Ray High Tension Transformer :***

The High Tension (HT) Transformer generated the high voltages required for the X-Ray generation. Transformer generated can be upto 160kV. The transformer was fully immersed in special purpose high electrical insulation transformer oil. The transformer was housed inside a separate chamber on wheels for easy movement. The output of the HT transformer was taken to the X-Ray tube head in the Inspection Chamber using custom made insulated cables.

***X-Ray Tube Head :***

Tube head was internally cooled using HT oil. The tube head was coated with additional lead lining to prevent X-Ray leakage. The Tube Head was from where the X-Rays are generated.

***Sample Inspection Chamber :***

The inspection chamber were samples are kept for inspection one after the other. This chamber was fully lead lined inorder to prevent X-Rays from escaping into the operator area. The X-Ray chamber has the X-Ray tube head, from where X-Rays emanate. It has the object plate, with sensor area marked. The door to the chamber was also lead lined. The door also has a leaded glass window, which was usefull to view the exact position for placing the object in the chamber. An interlocking limit switch was provided, which ensures that the X-Rays can be switched ON only when the window was closed. During exposure, window should be closed. The X-Ray protection for the X-Ray chamber was as per International Standard GB 18871.

***X-Ray Sensor :***

The X-Ray sensor was housed below the inspection chamber. Sensor was a digital sensor with 5 Mega Pixel resolutions. The area covered by the sensor was 150mm x 150mm and was marked on the object plate. The output of the X-Ray sensor was provided to the PC using an

USB port. The sensor was supported by software, where the parameters are changed for effectively viewing cotton bolls. The present investigations were intended to establish a methodology to facilitate the standardization of the X-ray radiography and the input electrical parameters *viz.*, voltage (kV), current (mA) and exposure period (s). Required adjustments in voltage (kV), current (mA) and exposure period (s) in the X-ray machine were effected during the exposure procedure. Once the exposure to radiation was done, the X-ray film was processed with the help of chemicals for image development and image fixing.

**Treatments and experiment procedure :**

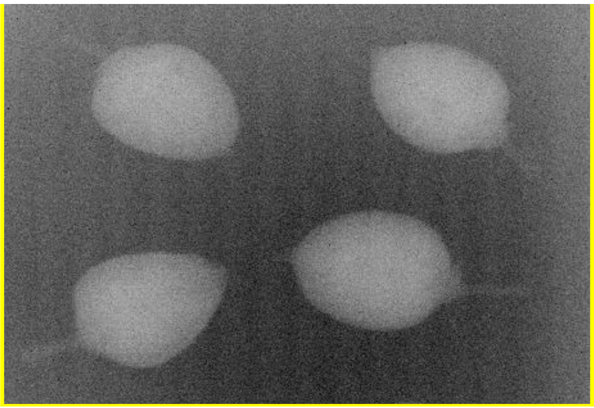
Scientists at Indian Institute of Crop Processing Technology Laboratories have found that fruit and vegetables require soft X-ray radiations ranging from 60 to 90 kV at a current of 1 to 10 mA. The period of exposure also ranges between 10 and 55 seconds. Therefore, experiments were planned for cotton boll to find out a standard voltage, current and exposure period. The combination of 96 treatments was worked out and the same combinations were given. Image analysis was taken up for different combinations to find out and standardize the right one that gives us internal view of the cotton boll. Adjustments in combinations of current and exposure periods were made based on the preliminary image results while working in the laboratory.

## RESULTS AND DISCUSSION

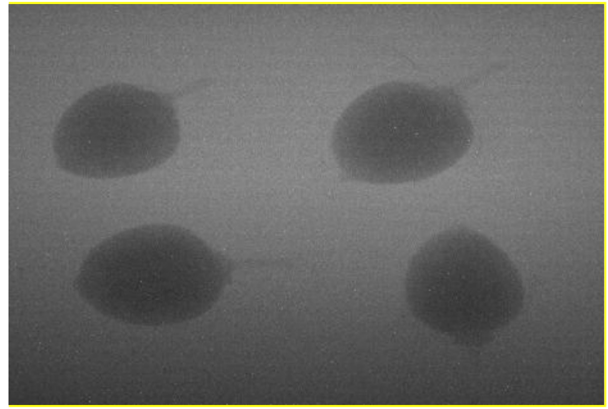
Out of ninety six different combinations of voltage, current and exposure period tried for cotton bolls infested with pink bollworm it was observed on visual analysis that the X-ray radiation generated at 80 kV and 10 mA for 30 seconds resulted in the best visual images to view internal content of cotton bolls and observed to be the best for cotton bolls imagery out of 96 combinations tested for best detection of hidden infestation (Table 1). While other combinations, for example, 60Kv, 4mA for 10 seconds and 90 Kv, 10mA for 30 seconds manifested

**Table 1: Treatment combinations of voltage, current and exposure period**

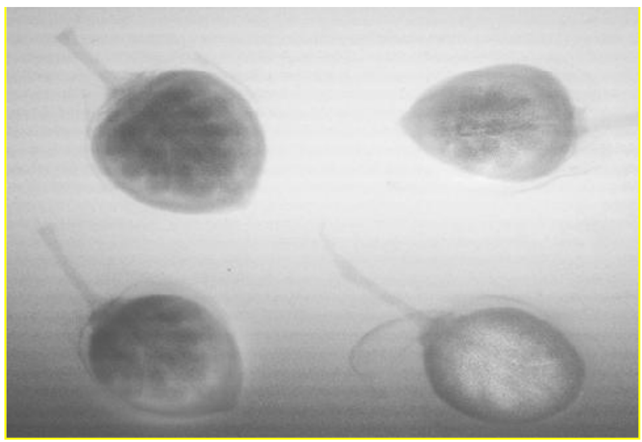
| Sr. No. | Kv | mA | Sec. | Sr. No. | Kv | mA | Sec. | Sr. No. | Kv | mA | Sec. | Sr. No. | Kv | mA | Sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 60 | 4 | 10 | 25. | 70 | 4 | 10 | 49. | 80 | 4 | 10 | 73. | 90 | 4 | 10 |
| 2. | 60 | 4 | 15 | 26. | 70 | 4 | 15 | 50. | 80 | 4 | 15 | 74. | 90 | 4 | 15 |
| 3. | 60 | 4 | 20 | 27. | 70 | 4 | 20 | 51. | 80 | 4 | 20 | 75. | 90 | 4 | 20 |
| 4. | 60 | 4 | 25 | 28. | 70 | 4 | 25 | 52. | 80 | 4 | 25 | 76. | 90 | 4 | 25 |
| 5. | 60 | 4 | 30 | 29. | 70 | 4 | 30 | 53. | 80 | 4 | 30 | 77. | 90 | 4 | 30 |
| 6. | 60 | 4 | 35 | 30. | 70 | 4 | 35 | 54. | 80 | 4 | 35 | 78. | 90 | 4 | 35 |
| 7. | 60 | 6 | 10 | 31. | 70 | 6 | 10 | 55. | 80 | 6 | 10 | 79. | 90 | 6 | 10 |
| 8. | 60 | 6 | 15 | 32. | 70 | 6 | 15 | 56. | 80 | 6 | 15 | 80. | 90 | 6 | 15 |
| 9. | 60 | 6 | 20 | 33. | 70 | 6 | 20 | 57. | 80 | 6 | 20 | 81. | 90 | 6 | 20 |
| 10. | 60 | 6 | 25 | 34. | 70 | 6 | 25 | 58. | 80 | 6 | 25 | 82. | 90 | 6 | 25 |
| 11. | 60 | 6 | 30 | 35. | 70 | 6 | 30 | 59. | 80 | 6 | 30 | 83. | 90 | 6 | 30 |
| 12. | 60 | 6 | 35 | 36. | 70 | 6 | 35 | 60. | 80 | 6 | 35 | 84. | 90 | 6 | 35 |
| 13. | 60 | 8 | 10 | 37. | 70 | 8 | 10 | 61. | 80 | 8 | 10 | 85. | 90 | 8 | 10 |
| 14. | 60 | 8 | 15 | 38. | 70 | 8 | 15 | 62. | 80 | 8 | 15 | 86. | 90 | 8 | 15 |
| 15. | 60 | 8 | 20 | 39. | 70 | 8 | 20 | 63. | 80 | 8 | 20 | 87. | 90 | 8 | 20 |
| 16. | 60 | 8 | 25 | 40. | 70 | 8 | 25 | 64. | 80 | 8 | 25 | 88. | 90 | 8 | 25 |
| 17. | 60 | 8 | 30 | 41. | 70 | 8 | 30 | 65. | 80 | 8 | 30 | 89. | 90 | 8 | 30 |
| 18. | 60 | 8 | 35 | 42. | 70 | 8 | 35 | 66. | 80 | 8 | 35 | 90. | 90 | 8 | 35 |
| 19. | 60 | 10 | 10 | 43. | 70 | 10 | 10 | 67. | 80 | 10 | 10 | 91. | 90 | 10 | 10 |
| 20. | 60 | 10 | 15 | 44. | 70 | 10 | 15 | 68. | 80 | 10 | 15 | 92. | 90 | 10 | 15 |
| 21. | 60 | 10 | 20 | 45. | 70 | 10 | 20 | 69. | 80 | 10 | 20 | 93. | 90 | 10 | 20 |
| 22. | 60 | 10 | 25 | 46. | 70 | 10 | 25 | 70. | 80 | 10 | 25 | 94. | 90 | 10 | 25 |
| 23. | 60 | 10 | 30 | 47. | 70 | 10 | 30 | 71. | 80 | 10 | 30 | 95. | 90 | 10 | 30 |
| 24. | 60 | 10 | 35 | 48. | 70 | 10 | 35 | 72. | 80 | 10 | 35 | 96. | 90 | 10 | 35 |



(A) 1). 60 Kv 2). 4 mA 3). 10 s



(B) 1). 90 Kv 2). 12mA 3). 30 s



(C) 1). 80Kv 2). 12mA 3). 30 s

**Plate 1 : X-ray radiography images of cotton with different combinations of A, B and C**

into lighter and darker images, respectively (Plate 1). In the Plate 1, image with the combinations of 80 kV and 12 mA for 30 seconds, shows that the boll (bottom - left side) was found to be infested with 2nd instar PBW larva. Presence of insect stage will hide the internal content of the boll (enlarged image).

X-ray radiography method is also used in detecting the hidden insect infestation for it is also a non-destructive method. These techniques of X-ray radiography were effectively used by Sarath Babu (1997) during quarantine processing of the germplasm imported from different countries and detection of several bruchids and chalcid species which were not reported from India. Similarly, this methodology was also used by Thomas *et al.* (1995) on mango fruit infested with nut weevil, Shahin *et al.* (2002) on apple, Karunakaran *et al.* (2003a and 2003b) on western red spring wheat, on cherries and apple and on various fruits. Further investigations are necessary to carry out the brief usage of X-ray radiography in detection of internal infestation of pink bollworm in cotton bolls. This study holds the basic research on non destructing sampling method or X-ray radiography. However there was a change in current and exposure period which may be attributed to built-in minor variations in different X-ray machine used in experimentations. In future, we can expect precise work on detection of internal infestation of pink bollworm.

Extensive work has been reported on the use of X-rays to detect infestations in stored products due to internal grain feeders, the granary weevil, *Sitophilus granarius* Linnaeus, the rice weevil, *Sitophilus oryzae* L., the maize weevil, *Sitophilus zeamais* Mots., and the Angoumois grain moth, *Sitotroga cerealella* (Olivier) ingrain kernels by visual examination of the X-ray radiographs (Keagy and Schatzki, 1991; Fenton and Waite, 1932). Only a few studies have used image processing algorithms to identify the insect infested wheat kernels using digital images of kernels (Karunakaran *et al*., 2000; Keagy and Schatzki, 1993).

From this context, the present findings are that X-ray generated at 80 kV and 10 mA for 30 seconds resulted in the best visual images to view internal content of cotton bolls. Whereas, quarantine workers in India traditionally used only a range of 10 KV to 30 KV and a current of 4mA to 12mA for an exposure period of 10-25 seconds. The range of X-ray radiography values of about 20-34 KV, 12-30 mA current as optimum for the detection of stone weevil infestation in mango fruit. The present finding will form basis for Cotton Entomologist who want to work on detection of hidden infestation of cotton pink bollworm using soft X-ray.

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