Database Development of Defective and Healthy Alphonso Mangoes

Sandeep S Musale, and Pradeep M Patil

***Abstract*—**Some of the aspects of maintenance of mango fruit quality during the supply chain are harvesting practices, adequate orchard management practices, postharvest treatments, transportation and storage conditions, packing operation, temperature management and ripening at destination. Since the said area is a newly growing field, very little literature is available on the defect detection of alphonso mango. The quality attributes of alphonso include freedom from external damages such as latex or sap injury and decay, bruises, uniform weight, color, aroma, firmness, shape and size. Postharvest losses are high during the supply chain due to harvesting fruit at improper maturity, sap burn, mechanical damage during the whole chain, spongy tissue, lenticels discoloration, decay, chilling injury, fruit softening and disease and pest damage. The main aim of postharvest treatments and management practices in the supply chain is to create suitable conditions or environments to extend the storage life and retain the quality attributes, nutrition and functional compositions. To retain the overall mango fruit quality and to reduce postharvest losses during supply chain can be achieved by adopting suitable postharvest novel technologies involving image processing and pattern recognition techniques. To achieve this task the researchers in this area needs the database that contains healthy as well as Spongy Tissue affected alphonso mangoes. This paper is an attempt towards the direction to develop such database for the researchers working on the non-destructive techniques for defect detection in mangoes.

***Keywords*—**Alphonso Mangoes, Spongy Tissue, digital X-Ray imaging, database of alphonso, Non-Destructive Testing.

I. Introduction

HORTICULTURAL sector has the highest potential for export, owing to the wide diversity of horticultural flora, agro-climatic conditions coupled with efficient low cost labour and advantageous geographic location. India has an edge over other producing countries to expand its export basket and exploit the hitherto untapped potential indigenous germplasm. However, the climatic diversity offer equally diverse problems in post harvest handling of products due to their varying shapes, sizes, shelf life, nature of ripening and varied storage, transport and packaging requirements. Marketing is an important step in the post harvest handling of the horticultural produce. It is the most complicated issue that requires better understanding of the complexities and identification of the bottlenecks to provide an efficient solution. An efficient and effective marketing system is a boon to any production system in agriculture and horticulture in particular. India has accelerated in total annual production of alphonso mango. However, this fruit is susceptible to internal physiological disorders that cause appreciable losses to producers. The term "physiological disorders" in alphonso mango is used for various internal flesh breakdowns (soft nose, jelly seed and spongy tissue). Lack of an automated commercial system based on image processing techniques for detection of physiological disorders in alphonso is a reason for India being still very poor in export of the alphonso. Traditionally, chemical and biochemical methods are available to investigate compositional and metabolic differences between the healthy and the damaged tissue. The intensity and occurrence of the disorders depend upon factors related to climate, location, and cultivars. The symptoms are manifested at the final stage of fruit growth and maturation. Padda et al [1] by using Canonical Discriminant Analysis found that the best tools to assess changes in mango fruit during ripening were firmness, followed by flesh value and total soluble solids content. Subedi et al [2] showed that flesh value well correlated with maturity of fruit. Color of flesh was found to be consistent in various cultivars and although being a destructive measurement parameter, it is used as a maturity index in several producing regions [3]. Tomas [4] developed an efficient algorithm for detecting and sorting mango. The features of the mango were extracted from the acquired image and used to identify the class of the mango.

The texture is soft, spongy or leathery depending on the severity of damage. The peculiarity here is that the external symptoms of spongy tissue affected fruits are not apparent either at the ripe stage or at the time of picking. The tissue affected is visible only when the ripe fruit is cut into two halves. This necessitates the investigation of various non-destructive techniques for defect detection in alphonso mangoes. Various image processing techniques available in the literature for defect detection can be effectively used in solving such problem of identification of spongy tissue in alphonso mangoes that will enhance the export and hence the economy of India. Typically, in natural image analysis texture is the only information that can be used. Thus texture analysis has grabbed attention in the field of image analysis and pattern recognition. Thus, there is a need to develop the database of healthy and affected alphonso mangoes, which can be used by various researchers to develop efficient pattern recognition algorithms to detect the defects effectively. This paper is an

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effort towards development of such unique database. The paper is organized as follows: the work carried out has been divided into three phases. The two phases are study of various defects occurring in mango, along with various non-destructive techniques for defect detection in Mangoes. Third phase is generation of the database of various defective and non-defective mangoes especially Alphonso mango.

II. Defects Occurring In Mangoes

There are many pests, diseases and disorders occurring in mangoes that damage them. But there are few names which are common and which are important to be studied because these causes most harm to the fruit and indirectly it is a loss for the growers and exporters. Few names are given as according to category as described here [5]. The detailed information of few of them, which occurs frequently in many varieties of mango are explained as follows.

A. Mango seed weevil

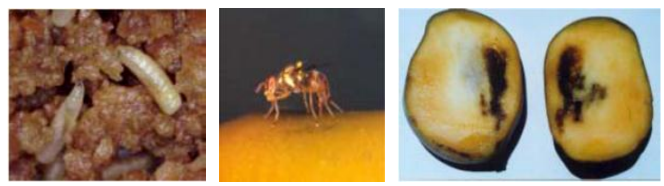
The importance of Mango seed weevil is that it is a major quarantine pest. The eggs are deposited into shallow depressions on young fruit and covered by hardened sap in a crescent shape. The immature pests are white legless grub with a brown head. The adults are dark brown to grey-black oval shaped weevil. It shows mottled markings on wing covers. The weevil has a prominent snout. Adults are about 10 mm in length. The life cycle is of one generation per year, similar to other native weevils. The Damage to fruit is due to eggs which are laid into fruit when they are 30 mm in length or larger. Egg laying sites are readily seen on fruit in association with leaking sap. Grubs move directly into developing seed and do not damage the flesh. Adults may occasionally be seen moving onto branches and the outer canopy at flowering. Take random samples of fully developed fruit, and cut fruit to inspect the seed for larvae or pupae (see Fig. 1). Adults emerge from fruit within 2 months of fruit fall. The Control Strategies include removing fallen fruit reduces populations in infested areas. Pre-flowering and post-fruit set treatments of carbaryl for leafhopper and plant hopper control, will give good control of mango seed weevil.

(a) (b)

Fig. 1 Pests of Mango (a) Adult & pupae in mango seed; (b) Damage to mango fruit.

B. Fruit flies

The importance of fruit fly is that it is also a major quarantine pest. The eggs are Creamy white eggs 1 mm in length. The immature fruit flies are white or cream colored maggots up to 8 mm in length with a black tooth-like feeding mouth part. The adults are red-brown or yellow-brown. Both species have yellow markings on the body. The adults are 9-10 mm in length. The life cycle of eggs is 1-2 days, larvae 6-8 days, pupae 10-12 days, adults live for up to a few months. Other fruit flies and this is similar and not to be confused with vinegar flies smaller in size. The damage to both species of fruit flies infests a range of commercial and native fruits. Adult females lay clumps of 6-10 eggs into the fruit. The eggs are deposited just under the skin. External damage to fruit is seen as sting marks from egg laying or bruising to the skin. Damage to the flesh is caused by larval tunneling and decay of flesh. Kensington Pride fruit harvested at the correct maturity stage is generally not infested. Flies generally infest fruit when they start to ripen. Some varieties are infested by jarvisi when they are hard green. Fruit fly traps may assist in catching flies to indicate presence and numbers (only males are intercepted) but do not control or eradicate the population. Adult females may be seen on mature fruit (see Fig. 2).



(a) (b) (c)

Fig. 2 Pests of Mango (a) Larvae, (b) Tryoni ovipositing into fruit, (c) Internal damage to fruit.

III. Diseases Of Mango

A. Anthracnose

Anthracnose is caused by, Colletotrichum gloeosporoides (the fungus's teleomorph, Glomerella cingulata, is observed rarely on mango). Anthracnose occurs in essentially all mango producing regions that have high rainfall. It affects leaves, stems and floral panicles, but its most important damage occurs on fruit (see Fig. 3). Typically, conidia of the fungus initiate infection by producing aspersoria shortly after germination. Chemical control of anthracnose is difficult. The occurrence of anthracnose disease is widespread. Young shoots, flowers and fruits suffer serious losses due to the disease under favorable climatic conditions of frequent rains, high humidity, and a temperature range of 24-32^{o}C. It also affects fruits in the storage stage. The symptoms of the disease are leaf spot, blossom blight, wither tip, twig blight and fruit rot indication. Foliage and tender shoots are affected very easily which ultimately cause 'die back' of branches that are young. Fatal loss can be caused in severe cases to older twigs that may be infected through wounds. Based on the prevailing weather conditions blossom blight may vary in severity from slight to a heavy infection of the panicles. Panicles as well as on fruits show black spots. Infection that is severe in nature destroys the entire inflorescence resulting in no setting of fruits. Infected young fruits develop black spots, shrivel and drop off. Fungus is seen on fruits infected at mature stage during storage and cause considerable storage, transit and marketing loss. Fungus perpetuates on twigs and leaves of mango or other hosts. A variety of differences have been noted in India in terms of susceptibility. Maximum damage was observed on Neelum in Kerala, whereas Edward variety was reported to be resistant. The fungus has long saprophytic survival ability on dead twigs and hence the diseased twigs should be pruned and burnt along with fallen leaves for reducing the inoculum potential.

(a) (b)

Fig. 3 Diseases of Mango (a) Fruit with tear-stain anthracnose; (b) Advanced stem-end and general anthracnose.

Infected fruit may not show symptoms until ripe. Affected fruit is unmarketable. As symptoms may not be visible until after the fruit has left the packing shed, it is important to undertake effective preventative field and packing shed treatments. The latent (invisible) infection is present in the green fruit in a dormant state, and becomes active during the ripening process. Note that fruit symptoms may not become evident until the fruit arrives at the market. Dark brown to black spreading lesions can occur anywhere on the fruit, but two forms have specific names: tear-stain and stem-end anthracnose. The tear-stain lesions are the result of fungus inoculum (spores) carried down the fruit surface in dew or rain droplets. It is similar to post-harvest anthracnose can be confused with other post harvest rots. Stem end anthracnose can be confused with stem end rots caused by other fungi.

To control, trees may be sprayed twice with Bavistin (0.1%) at 15 days interval during flowering to control blossom infection. Spraying of copper fungicides (0.3%) is recommended for the control of foliar infection. Post-harvest fruit treatments including fungicide sprays (in the packing shed), post-harvest heat treatments. Pre-harvest management of the orchard, such as pruning, strategic fungicide spray applications, orchard hygiene and optimum nutrition including calcium play an important role in reducing incidence of postharvest anthracnose. Forced air cooling and maintaining the cool chain at 13-20°C are essential for post-harvest anthracnose control.

IV. Disorders Of Mango

A. Spongy tissue

The spongy tissue is an internal breakdown a ripening disorder which is often described as soft centre, white corky tissue is a internal breakdown in Alphonso mango. This problem is not apparent from outside, niether at the time of picking nor at the time of ripe stage. The affected tissue is visible only when the ripe fruit is cut into two halves. It is a serious physiological disorder in ripe fruits. This disorder is characterized by the spoilage of pulp close to the stone with an off-flavor, rendering it unacceptable for consumption. The overall loss caused due to this problem is about 30% that leads to the amount nearly about Rs 135 million. Currently it has become a major problem in Alphonso mangoes that needs to be addressed. As a result of this problem, the quality of spongy tissue affected fruit gets spoiled. It renders the fruit unfit for human consumption and fetches low value in the market. Convective heat acts as a causal agent and vegetation or mulch over the soil helps in protecting the fruits from the spongy tissue disorder. Protection of the orchard soil from excessive heating by solar radiation can be easily achieved with the help of mulches of paddy straw and mango dry leaves effectively. These treatments keep the soil surface temperature down by 12.21°C to 15.90°C. This resulted in small amount of convective heat currents from the soil that ultimately reduced the occurrence of spongy tissue.

The problem remained a mystery despite extensive investigations in the past. Ravindra et al [6] describe the identification of the cause of spongy tissue in 'Alphonso' mango to the shift of recalcitrant seed into germination mode and the consequential drain of water from the adjoining mesocarp during fruit maturation and ripening phase. Physiological studies confirmed a shift of seed to the germination mode in ST affected fruits as revealed by their faster and higher germination percentage compared to stones from healthy fruits. Biochemical analysis of seeds from healthy and ST-affected fruits also corroborated these observations as revealed by increased hydration, higher activities of hydrolases, DNA and RNA levels in seeds from ST-affected fruits.

A significant decrease in spongy tissue incidence by pre-harvest application of Paclobutrazol (anti-gibberellin and a growth retardant) and an increase with GA3 (germination promoter) as compared to control, clearly indicated the central role of seed in spongy tissue formation. Absence of spongy tissue in Alphonso mango fruits naturally infested with mango stone weevil (Sternochetus mangiferae), where funiculus and/or embryonic axis were found damaged by the random feeding activity of weevil provided evidence supporting the causative role of seed in formation of spongy tissue.

In an experiment, 300 fruits each of Alphonso and Totapuri (ST-free) mango varieties were given pre-harvest dip treatments at ten day intervals between 50 and 70% maturity stages with GA3 (2000 ppm) and GA3 (1000 ppm) + tungstate (10 mM) solutions to enhance the metabolic activity of seed and the results were compared. Tungstate is an inhibitor of abscisic acid (ABA) biosynthesis5, 6 and is, therefore, expected to alter the ratio of growth promoters to inhibitors in favour of GA3, thereby increasing seed metabolic activity leading to ST formation. Fruits were harvested at 85% maturity, ripened under ambient conditions (28–30 ^{0}C and 70–80% RH) and observed for ST incidence. A marked increase in ST incidence with GA3 treatment (70.5–71.7%) over the corresponding control fruits (45.8%) of Alphonso mango was consistent with the results reported earlier. Surprisingly, there was no induction of ST in Totapuri fruits.

A closer examination of stones revealed that the funiculus connection at hilum was intact in Alphonso mango, while it was cutoff in Totapuri. Hilum marks the point at which the seed is attached to the ovary tissue via funiculus. Thus, Alphonso fruits in which either the funiculus connection at hilum and/or the embryonic axis was damaged due to random feeding activity of the MSW, were free from ST while those fruits in which the seed had shifted into germination mode with an intact funiculus and embryonic axis were affected by ST. On the contrary, there was no induction of ST in Totapuri even though the seed was in an advanced stage of germination. It was also observed that funiculus in Totapuri was always found desiccated and cutoff at hilum irrespective of MSW infestation thus preventing the seed from drawing nutrients from the mesocarp. Therefore, it is obvious that the shift of seed into germination mode along with an intact funiculus connection at hilum is essential for initiation of spongy tissue. It is likely that Totapuri seed, by virtue of its higher moisture content (43.29%), does not depend on the mesocarp for initiation of pre-germination events, unlike Alphonso mango in which the seed moisture was lower (32.63%). Incidentally, the moisture content of the Totapuri seed (43.29%) was higher than that of ST-affected Alphonso mango (42.04%), showing its self-sufficiency to initiate germination events without depending on the mesocarp. That the Totapuri seed was not deriving moisture from the mesocarp was also evident from the predominance of plumule growth as against radicle growth in Alphonso mango.

During fruit development, the seed remains in direct connection with the tree through the funiculus, ensuring food supplies for its growth and development. Normally, mango seed gets physiologically detached from the tree towards maturity due to breakage of vasculature at peduncle end of the fruit. Once the seed is cut-off from direct supplies of the tree, it draws nourishment from the mesocarp for its growth, provided the funiculus link between the seed and mesocarp is intact as seen in Alphonso mango. In Totapuri, the funiculus was found cut-off at hilum, thus preventing the drain of resources from the mesocarp into the seed.

V. Non-Destructive Techniques For Defect Detection In Mango

There are a number of non-destructive techniques available like X-ray or X-ray CT, NIRS, sonic / ultrasonic, MRI / NMR, etc. for defect detection in Mango. The X-ray or X-ray CT technique uses X-ray source and detectors like photographic plate, X-ray film in a cassette, rare earth screens, photostimulable phosphors (PSPs) computed radiography or digital radiography, semiconductor. The advantages of this method are convenience, accurate, available as a portable x-ray unit, costly but less costly than MRI, simple than MRI and more reliable. The method also has certain disadvantages like good image segmentation methods required, more image sample files required, more work need to be performed to increase recognition percentage, danger of X-rays being ionizing radiation and limited amount of information obtained. The required apparatus for NIRS method are light source, detector and wavelength selector. The advantages of this method are simple working, high resolution, accurate, gives quantitative information, sample preparation necessary and several constituents measured concurrently. The disadvantages of the method are working not well for all fruits and all parameters, expensive, estimation of best wavelength range difficult, dependent on less-precise reference methods and need to calibrate for each situation. The apparatus required for sonic / ultrasonic method are ultrasound transducer and digital noise corrector. The advantages of the method are portable device, insensitive to fruit mass/size and rapid. The method has disadvantages like acoustic impedance for biological tissues very difficult to determine, theoretically difficult task due to multiple scattering and strong attenuation and not suitable for small and soft fruits. Another method MRI / NMR requires super-conducting magnet, surface coil and imaging coil coupled to a conveyor system. The advantages of the method are ability to image different regions and in any plane, very high level of detail, does not use ionizing radiation, good quality and clarity. The disadvantages of this method are costly than x-ray, NMR response many times not clear, very still object holding required, poses problems when constituents other than water present, machine makes tremendous noise and hardware causes alteration in main magnetic field.

VI. Generation Of Database

Here we have generated a soft tissue database of 1000 alphonso mangoes. “DIAGNOX - 300 II” a digital X-ray machine (used for medical purpose) manufactured by MEDITRONICS manufacturing company private limited, Anand Nagar, Ambarnath, India, is used for capturing the images. The specifications of the machine are as follows: Input 415 volts, 50 Amps, 50 Hz; Output 125 kV, 300 mA, 5 sec. The machine with its top and back panel view is shown in Fig. 4. The output conditions of the machine during photography of these soft tissues were adjusted to 40-55 kV, 100 mA and 4-12 mAs. When an X-ray machine is operated at 80 kV, the X-rays produced contain energies varying from 0 to 80 keV.

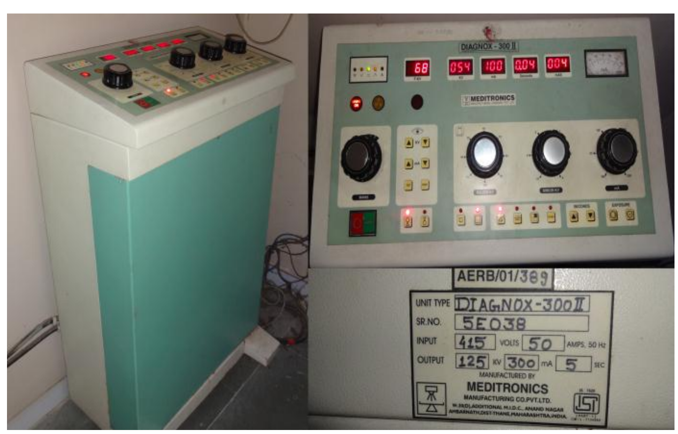


Fig. 4 Digital X-ray machine used for database generation.

The generated X-ray image database can be divided into three categories. The first category consists of X-ray images in which defects have been introduced artificially in the unripe healthy mangoes. The second category contains natural defective alphonso mangoes whereas third category contains non-defective or healthy alphonso mangoes. All these X-ray images of the fruit were taken on the medical X-ray system under certain conditions as,

A. Experiment 1

During first experiment, conventional X-ray imaging is used. This experiment was carried out with any mango and that too with unripe mangoes. The Specifications with which first x-ray exposure was taken are as: kV = 48; mAs = 8; d ~ 1m, where d is distance between source and film. This exposure was taken on the X-ray film, the next step was to scan the film with the help of flatbed scanner to get the soft copy of X-ray image for further Image Processing application. The resultant image generated from scanning of X-ray film was containing maximum dark pixels which gave full black image. Thus, we have decided to go for a Digital X-ray Machine to conduct all further experiments. Also, after discussion with Senior Radiographer, we have decided to change the output of the machine specifications during X-ray exposure.

B. Experiment 2

The new output specifications with which second X-ray exposure was taken are as: Voltage = 42 kV; Current = 100 mA; Exposure Time = 12 msec; d ~ 105cm. This time we have tried out with some human made defects, that is, we have created a cavity or vacant space, tried to keep a piece of sponge (since the Spongy Tissue is spongy in nature), tried keeping a small stone and taken X-ray from both sides etc. Fig. 5 shows all these cases of artificially created defects in mangoes and their respective X-ray images.

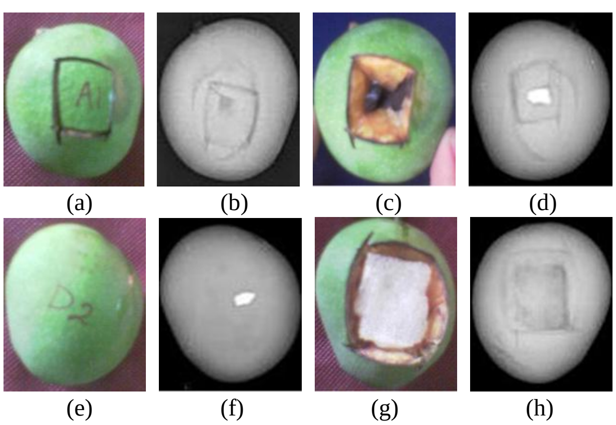


Fig. 5 Artificially created defects in mangoes and their respective X-ray images: (a) cavity is created, (b) X-ray of fig-a, (c) stone inserted in cavity, (d) X-ray of fig-c, (e) Mango from fig.(c) kept upside down, (f) X-ray of fig-e, (g) Sponge inserted in cavity, (h) X-ray of fig-g.

C. Experiment 3

In this experiment we have successfully collected and used ripen Alphonso mangoes that were containing Spongy tissue and also few healthy mangoes. The Specifications with which X-ray exposure was taken are as: Voltage = 54 kV; Current = 100 mA; Exposure Time = 4 msec; d ~ 1 m. Fig. 6 and Fig.7 shows all these cases of Alphonso mangoes and their respective X-ray images.

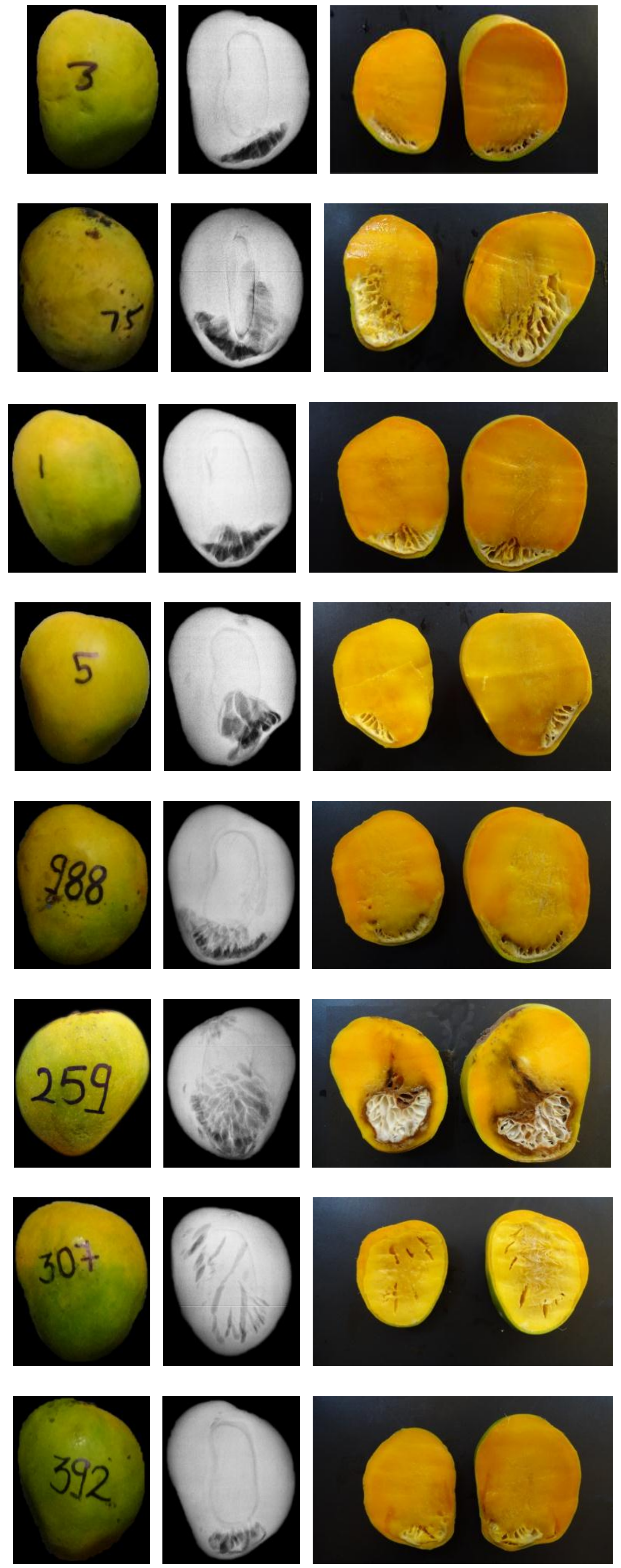


Fig. 6 Alphonso mangoes containing Spongy tissue; corresponding X-ray images and cut-sections of mangoes.

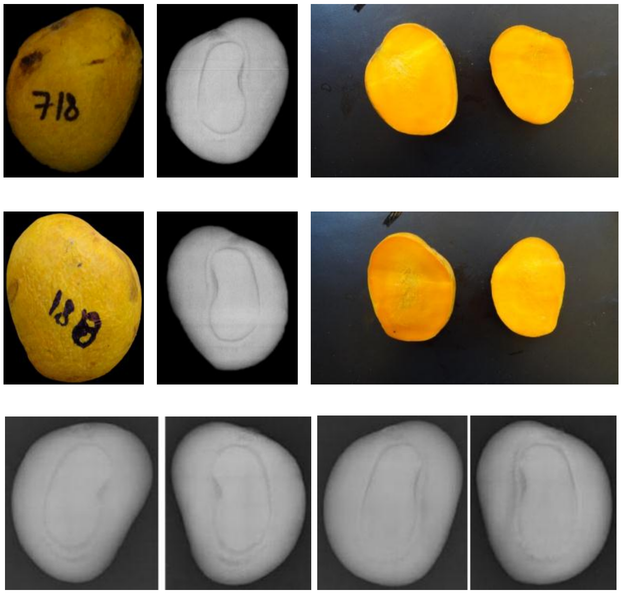


Fig. 7 Healthy Alphonso mangoes; corresponding X-ray images and cut-sections of mangoes.

VII. CONCLUSIONS

Significant reduction of Spongy Tissue in paclobutrazol-treated fruits reported earlier in the literature revealed the involvement of seed in Spongy Tissue formation. Therefore, it is obvious that Spongy Tissue in Alphonso mango is an effect of the seed shifting into germination mode and not vice versa. It is possible that a similar mechanism may be operating in mango varieties prone to Spongy Tissue formation, while the funiculus disconnection at hilum might be crucial in mango varieties free from Spongy Tissue. Digital X-ray imaging has ability and also it is most suitable to detect internal defects like Spongy Tissue in fruit like Alphonso mango. With X-ray method we can increase automated defect detection system accuracy with Image Processing Algorithms and by working on more number of samples. X-Ray technique is feasible solution for detecting Spongy Tissue considering the available infrastructure. All the images of X-rays (both healthy and defective fruits) revealed density changes inside the fruit. The best contrast of images revealing internal injuries caused by larvae was when the voltage of the X-ray source was around 45-55 kV (with an exposure time of 4 msec). The defects could be identified by observing the image in comparison with the normal images, however for on-line detection and more accurate identification the images needs to be processed digitally by storing them in computer. The images recorded on conventional films could not be scanned properly due to high contrast. Hence the digitally captured images are considered for image processing. The database generated here contains 65% of defected mangoes whereas 35% healthy mangoes. The dataset will be made available on google drive. Interested researchers can contact the authors trough e-mail for downloading the same. The URL to download the dataset will be sent to them by e-mail.

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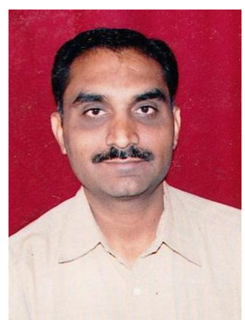

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