Importation of Fresh *Mangifera indica* (mango) Fruit from India into the Continental United States

Risk Management

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Executive Summary:

The Government of India (GOI) requested permission to import *Mangifera indica* (mango) fruit into the continental United States (U.S.). Mangoes have not been imported from India before, so a pathway-initiated risk assessment was conducted. A list of mango pests in India was prepared based on (1) documents submitted by the GOI, (2) United States Department of Agriculture (USDA)'s Animal and Plant Health Inspection Service (APHIS) records of intercepted pests, and (3) scientific literature. The pest risk assessment document, *Importation of Fresh Mango Fruit (Mangifera indica L.) from India into the Continental United States, A Qualitative Pathway-Initiated Pest Risk Assessment* (USDA 2006a; Table 5) identified fourteen insect pests, five fungi and one bacterium likely to follow the pathway on fresh Mango Fruit *(Mangifera indica L.)* from India that is cleaned and washed as part of the standard post-harvest practices in Indian mango production.

In May 2006, an APHIS team visited India and verified the following standard post-harvest practices (in sequential steps) (VanDersal et. al 2006):

1. stem attached to the fruit is cut by hand and the fruit is turned upside down for desapping on a conveyor belt,
2. the fruit passes through a bath of 52º C water bath for 3-4 minutes
3. the fruit is dried using forced hot air,
4. the fruit is rinsed using a clear water bath and bristle rollers,
5. the fruit is dried and brushed using bristle rollers,
6. the fruit is then dried using forced hot air,
7. the fruit is graded and sorted by size,
8. the fruit is packed in boxes by hand into a layer of shredded paper placed along the bottom of each box at the rate of 9-12 mangoes per box depending on the size,
9. the fruit is pre-cooled for 6 hours to 12.5º C,
10. the fruit is stored at 12.5º C until it's picked up for shipment.

The pest risk analysis (PRA) of mangoes from India determined that risk is high for *Ceroplastes rubens* and the seven fruit flies in the genus *Bactrocera*; medium for *Coccus viridis* and the two mango weevils in the genus *Sternochetus*, medium for three pathogens, *Macrophoma mangiferae*, *Cytosphaera mangiferae* and *Xanthomonas campestris* pv. *mangiferaeindicae*; and low for *Actinodochium jenkinsii, Hendersonia creberrima*, *Phomopsis mangiferae*, *Aulacaspis tubercularis*, *Pseudaonidia trilobitiformis*, and *Parlatoria crypta*.

As one of the options under review to mitigate identified pest risks, India proposed to treat mangoes with an APHIS approved generic irradiation treatment that would mitigate pathway risks from all insect pests. All insect pests will be effectively neutralized[1] with the irradiation generic dose of 400 Gy (USDA 2006b). The six non-insect pests that are likely to follow the pathway include five fungi, *Actinodochium jenkinsii* Uppal, Patel &

[1] A pest is considered neutralized when it is killed, rendered sterile or its further development into an adult is stopped

Kamat, *Cytosphaera mangiferae* Died, *Hendersonia creberrima* Syd., Syd. & Butler, *Macrophoma mangiferae* Higorami & Sharma, and *Phomopsis mangiferae* Ahmad apud Petrak & Ahmad, and one bacterium, *Xanthomonas campestris* pv. *mangiferaeindicae* (Patel *et al*.) Robbs *et al*. These six pathogens may not be effectively neutralized with irradiation and require additional measures. The pathogens are further discussed in this document.

A. Quarantine Pests Expected to Follow the Mango Pathway

The pest list completed by the Center for Plant Health Science and Technology (CPHST) for mangoes from India identified twenty potential quarantine pests that could follow the pathway on *Mangifera indica* fruit (USDA 2006a, Table 5). These include fourteen insect pests, five fungi and one bacterium as follows:

Insects:
Bactrocera caryeae (Kapoor) (DIPTERA:Tephritidae)
Bactrocera correcta (Bezzi) (DIPTERA:Tephritidae)
Bactrocera cucurbitae Coquillett (DIPTERA:Tephritidae)
Bactrocera diversa (Coquillett) (DIPTERA:Tephritidae)
Bactrocera dorsalis Hendel (DIPTERA:Tephritidae)
Bactrocera tau Walker (DIPTERA:Tephritidae)
Bactrocera zonata (Saunders) (DIPTERA:Tephritidae)
Sternochetus frigidus (F.) (COLEOPTERA:Curculionidae)
Sternochetus mangiferae (F.) (COLEOPTERA:Curculionidae)
Aulacaspis tubercularis Newstead (HOMOPTERA: Diaspididae)
Parlatoria crypta Mckenzie (HOMOPTERA: Diaspididae)
Pseudaonidia trilobitiformis (HOMOPTERA: Diaspididae)
Ceroplastes rubens Maskell (HOMOPTERA: Coccidae)
Coccus viridis (HOMOPTERA: Coccidae)

Fungi:

Actinodochium jenkinsii Uppal, Patel & Kamat
Cytosphaera mangiferae Died,
Hendersonia creberrima Syd., Syd. & Butler,
Macrophoma mangiferae Higorami & Sharma
Phomopsis mangiferae Ahmad apud Petrak & Ahmad

Bacteria:

Xanthomonas campestris pv. *mangiferaeindicae* (Patel *et al*.) Robbs *et al*.

The proposed importation of mango fruit from India, if approved, would be regulated by an amendment to the existing fruits and vegetables regulations [7 CFR § 319.56]. This document outlines the phytosanitary measures that APHIS will require if the proposed importation of mango from India is approved and documents the evidence used by APHIS to conclude that these measures will effectively prevent the introduction of quarantine pests.

B. Proposed Risk Mitigation Measures for Mangoes

We propose that mango fruit from India may be imported into the United States only under the following conditions:

(a) The fruit must be commercially produced and part of a commercial shipment. A commercial shipment is defined in 7 CFR 319.56-1 as "a shipment containing fruits and vegetables that an inspector identifies as having been produced for sale and distribution in mass markets. Such identification will be based on a variety of indicators, including, but not limited to: quantity of produce, type of packaging, identification of grower or packing house on the packaging, and documents consigning the shipment to a wholesaler or retailer. The requirement that the fruit is commercially produced ensures that the fruit are subjected to standard commercial cultural and post harvest practices that reduce the risk associated with pathogens. While not specifically required by this proposal, standard cultural practices other than broad spectrum fungicides (*e.g.*, the regular use of sanitation measures, irrigation, fertilization and pest control) help to further ensure that the pests of concern do not follow the pathway (Ploetz, 2003; Agrios, 1997) All export orchards are registered production areas with traceback capability. Harvested fruit is moved to the packing houses in a manner that would preclude reinfestation by pests. Culling of blemished and damaged fruit occurs in the field and during the post-harvest commercial processing of the fruit. Risk mitigation options for pathogens are described in detail later in this document.

(b) The fruit must be treated by irradiation by receiving a minimum absorbed dose of 400 Gy and meet all other relevant requirements in 7 CFR 305.31 including monitoring of the treatment by APHIS inspectors.

(c) Either the fruit is treated with a post-harvest fungicidal dip or the orchard is inspected prior to harvest during the growing season and found free of *Cytosphaera mangiferae* and *Macrophoma mangiferae.* If during the pre-harvest inspection, the orchard is not found free of the above pathogens (and fungicidal spray is not to be applied after the harvest), the fruit must be free of the two pathogens and originate from an orchard that was treated with a broad-spectrum fungicide during the growing season.

(d) Each shipment of fruit must be inspected jointly by APHIS and Government of India (GOI) inspectors and accompanied by a phytosanitary certificate (PC) issued by the national plant protection service of India certifying that the fruit received the required irradiation treatment. The PC must also include two additional declarations (AD) that state:

(1) (a) That the mangoes were treated in accordance with a broad spectrum fungicide or otherwise meet the conditions of § 319.56-2tt(b) and

(2) "the shipment was inspected during pre-clearance activities and found free of *Cytosphaera mangiferae, Macrophoma mangiferae* and *Xanthomonas campestris pv. mangiferaeindicae*."

(e) Fruits imported into the United States would also be subject to inspection at the port of entry should inspectors determine that such inspection is necessary.

C. Historical Performance of Importing Irradiated Mangoes

Current regulations 7CFR 305.31 and 7CFR.319-56.2(k) allow the use of irradiation to treat fruit for importation into the United States. Since publication of the final rule allowing use of irradition for imported commodities in 2002, no country has taken advantage of the technology to import mangoes or any other fruits into the United States with this treatment. Regulations 7CFR318.13-4f allow interstate movement of fifteen different fruit, including mango, from Hawaii using a minimum absorbed dose of 150 Gy to 400 Gy. There are four fruit flies and one seed weevil associated with mango fruit from Hawaii: *Bactrocera cucurbitae* (melon fruit fly), *B. dorsalis* (oriental fruit fly), *B. latifrons* (Malasian fruit fly), *Ceratitis capitata* (Mediterranean fruit fly) and *Sternochetus mangiferae* (mango seed weevil). The 300 Gy dose is considered adequate to mitigate mango seed weevil while oriental fruit fly, Mediterranean fruit fly, melon fruit fly and Malasian fruit fly, all require a lesser dose of 150 Gy (USDA 2006b). No live pests of quarantine significance have been intercepted from fruits and vegetables treated with irradiation in Hawaii and moved to the mainland U.S. (Uyeda 2005).

D. Evidence for the Effective Removal of Pests of Concern from the Pathway

The following paragraph summarizes key mitigation measures for mango fruit from India and provides a general discussion of their efficacy. The evidence APHIS uses to determine that the measures described above in Section B effectively remove pests of concern from the pathway are also discussed. The FAO (2002) defines “pathway” as “Any means that allows the entry or spread of a pest.”

Insect Pests:

Fourteen of the twenty pests likely to follow pathway are insect pests. There are no records of importing irradiated mangoes from India, but records since 2000 of interstate movement of mangoes from HI to the U.S. after treatment with 300 Gy irradiation show no interceptions of quarantine pests (Uyeda 2005). Additionally, reports of twelve shipments of mangoes irradiated with 150 Gy imported from Australia into New Zealand since 2004 provide no record of quarantine pest interceptions from the irradiated mangoes (Edwards 2005). Although the pest complex in Hawaii or Australia may be different from that described for Indian mangoes, the 400 Gy minimum absorbed dose which Indian mangoes will be treated

with has been determined to be effective against all insect pests except adults and pupae of the order Lepidoptera (USDA 2006b).

As part of the U.S. requirements (7CFR305.31) governing the use of irradiation as a phytosanitary treatment, APHIS and the national plant protection organization (NPPO) of India will jointly develop an operational work plan. The work plan shall incorporate details of treatment and preclearance activities including inspection of articles that APHIS may perform before or after the treatment. Inspection of the mango fruit for the presence of pests not targeted by irradiation during preclearance activities will further ensure that the pests of concern are removed from the pathway.

Risk Mitigation Options:

A minimum absorbed dose of 400 Gy is required by U.S. regulations 7CFR305.31 and has been determined by APHIS to be adequate to neutralize or mitigate risks of all insect pests excluding adults and pupae in the order Lepidoptera. None of the fourteen insect pests identified as likely to follow the pathway belong to the order Lepidoptera. Therefore the generic irradiation treatment is a valid treatment for all of these insect pests.

Fungal Pathogens:

The PRA determined that the three fungi, *Actinodochium jenkinsii, Hendersonia creberrima* and *Phomopsis mangiferae*, have a low pest risk potential and according to our 5.02 guidelines do not require mitigation measures beyond port of entry inspection. Two other fungi, *Cytosphaera mangiferae* and *Macrophoma mangiferae* are rated in the PRA as having a medium pest risk potential and according to our 5.02 guidelines may require special measures beyond port of entry inspection

Infection by *C. mangiferae* in the field causes a tan lesion to emerge and develop at the stem end of the fruit after a "zonate" leaf spot initially appears on the leaves (Johnson *et al.*, 1992; Peterson, 1986; MAF 2003). The leaf spot symptoms first appear as water-soaked circular spots that later develop tan centers with dark brown borders. On the fruit, this fungus causes slow-spreading, tan lesions that form initially on the stem end of the fruits and eventually spreads onto the shoulder of the fruit. It can be distinguished from other fungi by the conidiomata it produces which appear as dark pinpoints within the tan lesions (Ploetz et al, 1994).

The only plausible pathway for the pathogen to become established in the United States is via discarded fruit or unused portions of the fruit or peel. Disease spread can only occur if temperature and moisture conditions are favorable for spore germination. Infected discarded fruit would need to be disposed in or near mango orchards or areas with suitable host material at a time when susceptible tissue is available and in a stressed conditon. (Johnson *et al.*, 1993; Johnson *et al.*, 1989; Kishun and Chand, 1989; Pruvost *et al.*, 1990; Pruvost and Luisetti, 1991). The

probability of discarded infected fruit being in close proximity to a cultivated mango tree with favorable environmental conditions for spore germination is low.

In addition to mango, the host range of *C. mangiferae* also includes *Aquilaria agallocha* Roxb., *Artocarpus frengenifolia*, *Macadamia integrifolia* and *Sabal palmetto* (Johnson & Hyde, 1992). Of these species, while *Sabal palmetto* is a native plant throughout the Southeastern United States, the other three species (*Aquilaria* spp., *Artocarpus* spp. or *Macadamia* spp.) have a very limited production in the continental United States (occuring primarily in Florida and California) (USDA-NRCS, 2003). The requirement for tropical temperatures by *Cytosphaera mangiferae* (the fungus is found in regions which roughly correspond to the USDA Plant Hardiness Zone 11) will limit its survival potential even in Florida and California, which correspond to Plant Hardiness Zone 10b. In India, spraying of mango plants with broad-spectrum fungicides during the growing season is a common practice to control fungal diseases. Additionally, the fruit that are blemished and damaged are culled by hand in the field and during the processing of the commercial mango fruit. These practices effectively remove the pathogen from the pathway.

Macrophoma mangiferae causes a leaf and stem blight and postharvest rot of mango (Hingorani, et al., 1960). In nature the host for this pathogen is mango. *Macrophoma mangiferae* has been found to weakly infect additional hosts but only when artificially inoculated. In a study by Hingorani, et al, 1960, *Ficus carica*, *Eryobotrya japonica*, *Eugenia jambolina* and *Vitis vinifera* leaves were inoculated after injury and became weakly infected. Infected discarded fruit or unused portions of fruit or peel are the only plausible pathway for this pathogen to become established in the United States. The spores must be dispersed from infected discarded fruit into mango orchards at a time when susceptible tissue is available and in a stressed condition (Johnson *et al.*, 1993; Johnson *et al.*, 1989; Kishun and Chand, 1989; Pruvost *et al.*, 1990; Pruvost and Luisetti, 1991). Disease spread can only occur if temperature and moisture conditions are favorable for spore germination. The probability that infected discarded fruit would be in close proximity with a cultivated mango in favorable environmental conditions for spore germination is low. Additionally, applications of fungicides during the growing season and culling of the fruit by hand in the field and during the processing of the commercial mango fruit will effectively remove any blemished or suspicious fruit from the pathway.

In the field, *M. mangiferae* also causes a spot on the leaves although symptoms begin as small yellowish pin-head like spots. These spots gradually enlarge and become irregularly shaped and dark brown with raised margins. On fruits, water soaked circular lesions are produced which enlarge rapidly and cause rotting. (Hingorani, et al 1960).

A pre-harvest field inspection, a post-harvest fungicidal dip or an orchard application of broad spectrum fungicide as discussed below is included to mitigate the risk that these fungal pathogens may cause post-harvest infections.

Risk Mitgation Option A:

The fruit is subject to a broad spectrum fungicidal dip during the 52ºC water bath used during the commercial post harvest processing in India (Johnson, 1994b).

Risk Mitigation Option B:

Both *Cytosphaera mangiferae* and *Macrophoma mangiferae* can be easily seen and detected in the field on mango leaves and fruit during the preharvest inspection. Postharvest diseases do not occur without the presence of fungal symptoms on leaves in the field.

A preharvest or growing season inspection of the orchard is required. The inspection will occur at a time prior to the beginning of harvest as determined by mutual agreement between APHIS and the Indian NPPO for symptoms of *Cytosphaera mangiferae* and *Macrophoma mangiferae.*

Risk Mitigation Option C:

Orchard application of broad spectrum fungicide sprays protects fruit from infection by aerial spores produced on leaves or stems (Jarvis, 1992).

An orchard treatment and orchard inspection, when coupled with a pre-export inspection of the fruit are considered sufficient to mitigate the pathway risk of these fungal pathogens.

Bacteria:

Bacterial black spot or black canker caused by *Xanthomonas campestris* pv *mangiferaeindica*, occurs in India, Australia, Brazil, Pakistan, Taiwan, Reunion, Sudan and South Africa (CPC, 2005). Since the pathogen moves only short distances in wind-blown aerosols (usually within orchards), the long-distance spread of the pathogen depends almost entirely upon the movement of infected plants (Manicom and Pruvost, 1994).

Symptoms of *Xanthomonas campestris* pv *mangiferaeindica* on mango fruit consist of fruit lesions that develop into water-soaked halos, become raised, blacken and crack open (Ploetz, *et al*. 1994). These conspicuous lesions usually produce gummy exudates and are discernible with the naked eye (Johnson et al, 1989). Fruit susceptibility increases over time and is highest during the month preceding harvest (Gagnevin and Pruvost, 2001). Visual inspection of the fruit at the packinghouse would most likely detect this pathogen. This pest is rated as medium risk in the PRA. According to our 5.02 guidelines pests rated as medium may require specific mitigation measures beyond port of entry inspection.
This bacterial pathogen is not generally considered as a post harvest disease (Johnson, G.I., 1994; Singh, R.S. 2000). "The pathogen is an epiphytic colonist of leaves

(Manicom, 1986; Pruvost et al., 1990), buds (Pruvost et al., 1993) and fruit (Pruvost and Luisetti, 1991). Infection occurs through wounds and, less often, stomata..."(Ploetz, 1992, p. 334).

Risk Mitigation Option:

Inspection of the fruit during preclearance activities for evidence of *Xanthomonas campestris* pv *mangiferaeindica.*

Additional Declarations:

All shipments require the following statements on the phytosanitary certificate:

"The mangoes were treated in accordance with a broad spectrum fungicide or otherwise meet the conditions of § 319.56-2tt(b)" and

"The fruit in this shipment was inspected during pre-clearance activities and found free of *Cytosphaera mangiferae*, *Macrophoma mangiferae*, and *Xanthomonas campestris pv. mangiferaeindicae*."

E. Conclusion

The phytosanitary requirements described above include treatment in India of mango fruit with irradiation using a minimum absorbed dose of 400 Gy and preclearance inspections for pests not targeted by the irradiation treatment. The risk management document concludes that based on the evaluation of effectiveness of these measures directed against the pests of concern, APHIS finds that the safeguards of 7 CFR § 319.56 and the additional mitigations described here will result in the effective removal of the pests of concern identified by the pest risk analysis from the pathway of the importation of fresh mango fruit from India.

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