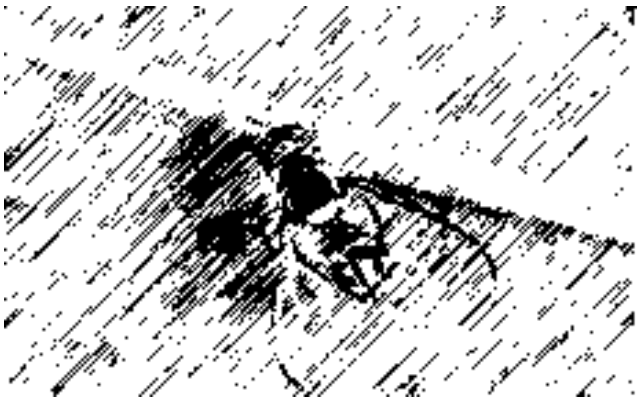
Action plan

for the control of the

African invader fruit fly

(*Bactrocera invadens* Drew, Tsuruta and White)



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REPUBLIC OF SOUTH AFRICA

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Contents

1 General information

(a) Action statement

The Action Plan is a recommended response for survey, containment and eradication following a find of Bactrocera invadens in an area having an existing trapping network for the above invasive fruit fly. The Action Plan was developed for the South African *B. invadens* Steering Committee, to be convened under the auspices of the South African department of Agriculture, but is available to any other SADC country (or the region) that may wish to make use of it.

(b) Background information

(i) *Origin and distribution*

Bactrocera invadens originates from Asia and has invaded various parts of Africa. The fruit fly officially occurs in Sri Lanka, India, Bhutan, Kenya, Uganda, Tanzania, Sudan, Democratic Republic of Congo, Congo, Nigeria, Angola, Sierra Leone, Senegal, Ghana, Togo, Niger, Ivory Coast, Mali, Guinea, Equatorial Guinea, Benin, Burkina Faso, Zambia, Mozambique and the Comoros Islands.

(ii) *Host range*

B. invadens is a polyphagous species and has to date been recorded from 74 host species belonging to 26 plant families. The host list in the table below has been compiled from published scientific papers. These hosts should therefore be inspected and regulated in the case of a *B. invadens* find. The host list presented in Table 1 below is not exhaustive and can still be expanded.

TABLE 1 Host plants of *B. invadens*

Scientific name	Common name	Scientific name	Common name
Achra sapota	Sapodilla tree	*Fortunella japonica*	Kumquat
Anacardium occidentale	Cashew	*Fortunella margarita*	Kumquat
Annona cherimola	Cherimoya	Garcinia mannii	Chewing stick
Annona diversifolia	Ilama fruit	*Irvingia gabonensis*	African wild mango
Annona montana	Mountain soursop	*Landolphia* sp.	
Annona muricata	Soursop	*Lycopersicon esculentum*	Tomato
Annona senegalensis	Wild custard apple	*Maerua duchesnei*	
Annona squamosa	Sugar-apple	*Malus domestica*	Apple
Averrhoa carambola	Carambola	*Mangifera indica*	Mango
Blighia sp.		*Momordica* cf *trifoliata*	
Capsicum annuum	Bell pepper	*Manilkara zapota*	Bully tree
Capsicum frutescens	Chilli pepper	*Musa* spp. (AAA)	Banana
Carica papaya	Papaya	*Musa* x *paradisiaca*	Plantain
Chrysophyllum albidum	White star-apple	*Persea americanum*	Avocado
Chrysophyllum cainito	Star apple	*Prunus persica*	each
Citrullus lanatus	Watermelon	*Psidium guajava*	Common guava
Citrus aurantium	Sour orange	*Psidium littorale*	Strawberry guava
Citrus grandis	Pomelo	*Richardella campechiana*	Yello Sapote
Citrus limon	Lemon	*Sarcocyphalus latyfolius*	African peach
Citrus paradisi	Grapefruit	*Sclerocarya birrea*	Marula
Citrus reticulata	Tangerine/mandarin	*Solanum anguivi*	Forest bitter berry
Citrus sinensis	Orange	*Solanum anthioticum*	Ethiopian eggplant

Scientific name	Common name	Scientific name	Common name
Citrus tangelo	Tangelo	*Solanum nigrum*	Black nightshade
Coffea arabica	Arabica coffee	*Solanum sodomeum*	Apple of Sodum
Coffea canephora	Rubusta coffee	*Sorindeia madagascariensis*	Sondriry
Cordia spp.(*Cordia* sp.cf *myxa*)	Grey leaved saucer berry	*Spondias cytherea*	Jew plum
Cordyla pinnata	Cayor pear tree	*Spondias mombin*	Tropical plum
Cucumis pepo	Guard	*Strychnos mellodora*	Monkey orange
Cucumis sativus	Cucumber	*Syzygium cumini*	Jambolan
Cucumis sp nr *metuliferus*		Syzygium jambos	Rose apple
Cucurbita maxima	Pumpkin	Syzygium malaccense	Malay apple
Diospyros kaki	Japanese persimmon	*Syzygium samarangense*	Java apple
Diospyros montana	Mountain persimmon	*Terminalia catappa*	Tropical almond
Dracaena steudneri	Northern large leave dragon tree	*Thevetia peruviana*	Lucky nut
Eriobotrya japonica	Loquat	*Vitellaria paradoxa*	Sheanut
Ficus sycomorus	Wild fig	*Ziziphus mauritiana*	Indian jujube
Flacourtia indica	Governor's plum		

(iii) *Demography*

The mean generation time for *B. invadens* was found to be 30,7 days at 28 ± 1 °C. However, generation time is largely dependent on temperature. In order to determine phenological events in the field for monitoring and eradication purposes, it is important to determine the temperature-development rate of the pest. The developmental rates of *B. invadens* were determined at five constant temperatures of 15 °C, 20 °C, 25 °C, 30 °C and 35 °C and a photoperiod of L12:D12.

The table below gives the published mean total developmental time of immature stages (egg to pupa) (days) obtained at varying constant temperatures for *B. invadens*.

TABLE 2 Mean total developmental time for immature stages of *B. invadens* (Rwomushana et al., 2008)

Temperature (°C)	Mean total developmental time for immature stages (days)
15	75,74
20	31,45
25	21,19
30	17,76

To predict the developmental rate of individual life stages, a temperature summation model can be used. This approach is based on the assumption that above some lower threshold for development, temperature-developmental rate relationships are linear and, therefore, a constant number of heat units, expressed as day-degrees above this threshold are needed to complete the development.

To calculate developmental times in fluctuating daily temperature regimes, the number of day-degrees per day can be determined by the formula (Tmax + Tmin)/2 –t with Tmax being maximum temperature, Tmin minimum temperature and t, the lower development threshold. The lower development threshold of *B. invadens* was found to be 8,8°C, 9,4 °C and 8,7 °C for the egg, larva and pupa.

(iv) *Attractants*

B. invadens responds to methyl eugenol, which is a parapheromone and attracts only males. Attraction of both sexes of the fly to protein hydrolysate and the 3-component Biolure have also been reported.

2 Survey protocol

(a) Surveillance

A regular surveillance programme throughout the year should be in place to detect any incursion of *B. invadens* in high-risk areas, which include points of entry such as border posts, sea ports and international airports as well as in production areas of known hosts and cities/towns/villages close to the points of entry. Trapping with methyl eugenol and Biolure (3-component) should be carried out to determine pest absence or presence.

(b) Delimiting survey

When one *B. invadens* is collected in an area, a delimiting survey should be implemented immediately. The area immediately surrounding each fly find will be a core area of a 1 km x 1 km square grid. Methyl eugenol baited traps and Biolure (3-component) baited traps will each be placed at a density of 10 traps per km^2 within the core area (Fig. 1 and Table 3). Moving outwards from the core area, there will be three surrounding zones of sizes 8, 16 and 24 km2. In each of the surrounding zones, the trapping density will be 2 methyl eugenol baited traps per km.^{2}.

Additionally, radiating transects of about 100 km will be put into place from the third surrounding zone and will follow main road networks. Methyl Eugenol baited traps will be placed every 2 km for the first 10 km, every 5 km thereafter for the next 40 km and every 10 km for the 50 remaining km. Moreover, within 50 km radius of the core area, methyl eugenol baited traps will placed on farms with orchards or fields containing host material.

The density of traps in the farms will be determined by farm size, crops and extent of plantings. All traps will be serviced weekly, with core traps serviced daily for the first week. Traps will be maintained through three *B. invadens* generations (approx. 12 weeks) after the last fruit fly find.

If a fruit fly is found in an additional trap, a 1 km x 1 km core area will be established around the fly find and traps will be placed at the same rate as mentioned above.

Trapping details are outlined in the annexure

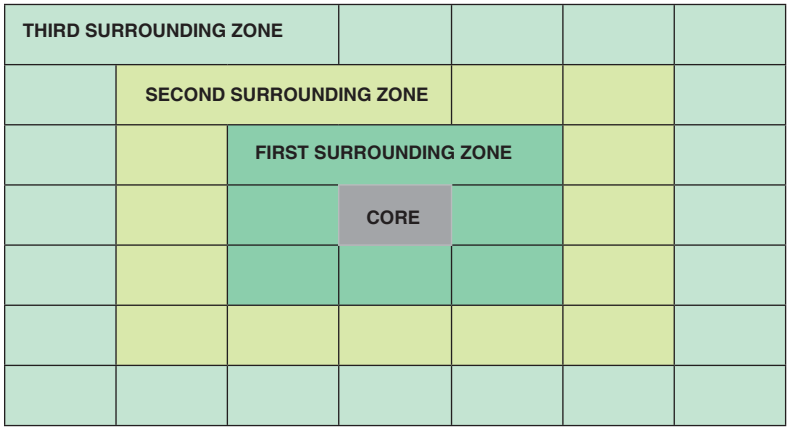


FIG. 1 Delimiting survey with single km.^{2} core area and three surrounding zones

TABLE 3 Trap density in core and surrounding zones

Zones	Area/km.^{2}	Number of traps per km.^{2}. Methyl eugenol + Biolure 3C (Biolure 3 C only in core area)
Core	1	10+10
1st	8	2
2nd	16	2
3rd	24	2

Record keeping is essential in a delimiting survey. The geographical coordinates of all traps should be taken and incorporated in a geographical information system. The location of traps should be geo-referenced with the use of global positioning system (GPS) equipment. Records of all trap inspections should be kept by the NPPO and should include trap number, date of servicing, outcome of servicing (catch/no catch), status of trap and replacement of trap in cases where it is gone or damaged, replacement of lure (yes/no).

(c) Fruit inspection

Host fruit from the core area will be surveyed, depending on host availability. Infested fruit will be collected and incubated for up to 6 weeks in sand in closed, aerated plastic containers in a facility within the core area. Any pupae, third instar larvae or adults should be killed following emergence and preserved in alcohol or mounted for identification.

3 Quarantine

Once a *B. invadens* sample is caught in a trap and the identification is done with reasonable confidence by a competent entomologist, the area of the fruit fly detection is quarantined with immediate effect to restrict movement of host material, in particular fruit types listed above as *B. invadens* hosts, cannery waste and soil, out of the area. The initial quarantine area will extend to a circular area of 5 km radius from the trapping point. The delimiting survey will also be implemented immediately to determine the area of the infestation and therefore any expansion of the initial quarantine area.

Movement of host material will be regulated in accordance with both relevant local legislation and international trade agreements.

Roadblocks should be implemented to regulate movement of fruit from the area. At any international point of entry or exit near a detection site, a mandatory check of passenger baggage should be implemented.

All local growers in the area of the fruit fly detection, establishments within the area in which fruit, cannery waste and soil are handled, as well as the organs of state that would implement roadblocks, should be notified of the threat posed by the fruit fly and actions that need to be taken.

An area may be removed from quarantine status after the pest has been declared eradicated or there has been no other *B. invadens* find for at least 3 generations (calculated from the local climate data, but generally around 12 weeks).

4 Eradication procedures

Eradication of *B. invadens* should be initiated following the detection of a second *B. invadens* fruit fly in the delimiting survey area. The total area of coverage will depend on the extent of spread. For each *B. invadens* fruit fly find, the area under eradication will be 25 km.^{2} surrounding the trap site. Duration of eradication measures should be planned for at least 2 generations of *B. invadens* (generation estimated based on local weather conditions but generally should be estimated for about 8 weeks). Trapping to verify eradication should continue for at least one *B. invadens* generation (generally 4 weeks) after eradication measures have stopped (no more bait spraying and placement of fresh male annihilation blocks).

A combination of ground applied male annihilation treatments and air/ground applied protein bait treatments (air/ground application in orchards and ground application in residential areas) should be carried out. Fruit stripping should be considered as a contributory measure, where appropriate.

Male Annihilation Technique (MAT)

This will involve the distribution of square (5cm x 5 cm) 1,3 cm thick fibre-board/soft board blocks soaked in a mixture of methyl eugenol and malathion EC (500g/ℓ) at a ratio 3: 1 for a minimum of 24 hours and placed at a density of 400 per km.^{2}, either nailed to poles or hung from trees (10 000 blocks per 25 km.^{2} fly-detection unit). A single application of MAT blocks will cover a period of 8 weeks.

Protein baiting

Protein bait sprays should be carried out weekly. The toxicants that may be used in combination with the protein hydrolysate are malathion and spinosad. Spinosad in combination with an attractant is commercially available as the organically certified product GF120.

In production areas, aerial bait sprays will be the most viable and effective option. Protein hydrolysate (Hymlure 425 g/ℓ) in combination with malathion UL (1130 g/ℓ) is registered for aerial application as a bait using Hymlure 750 mℓ and malathion UL 250 mℓ/ha (75 + 25 ℓ per km.^{2} and 1 875 + 625 ℓ per 25 km.^{2}). This amount will be required every week. Alternatively, GF 120 can now be used at 1 ℓ per ha in a spray mix with 1–3 ℓ of water (100 ℓ per km.^{2} and 2500 ℓ per 25 km.^{2}). Where possible, applications in an eradication programme should favour the use of GF120 when certified organic farms are treated.

If protein bait is applied from the ground, it should preferably be applied on host trees. The registered bait mixture is 400 mℓ Hymlure and 175 mℓ Malathion EC (500 g/ℓ) in 100 ℓ of water per ha (40 ℓ + 17,5 ℓ per km.^{2} and 1000 ℓ + 437,5 ℓ per 25 km.^{2}) and for GF-120, the registered dilution is 1–1,2 ℓ in 19–29 ℓ water which is then applied to every hectare (100 ℓ in 2000 ℓ per km.^{2} and 2500 ℓ in 50 000 ℓ per 25 km.^{2}).

Supplementary eradication treatments

Fruit stripping. If fruit stripping is undertaken in the core area, stripped fruit should be placed in plastic bags, fumigated if possible and removed to a landfill site for burial under at least 1 m of fill. The burial site should be located within the quarantined area.

5 Identification and information flow

(a) Identification

During surveillance, specimens should be collected and first screened by a local designated identifier. Any suspect specimen should be forwarded immediately to the local fruit fly expert in vials of at least 70% alcohol for confirmation.

If a positive ID is obtained from the local fruit fly expert, a Steering Committee should oversee the implementation of the quarantine, delimiting survey and eradication measures as described above. The effectiveness of the programme should be monitored periodically by the NPPO through review of documentation and procedures.

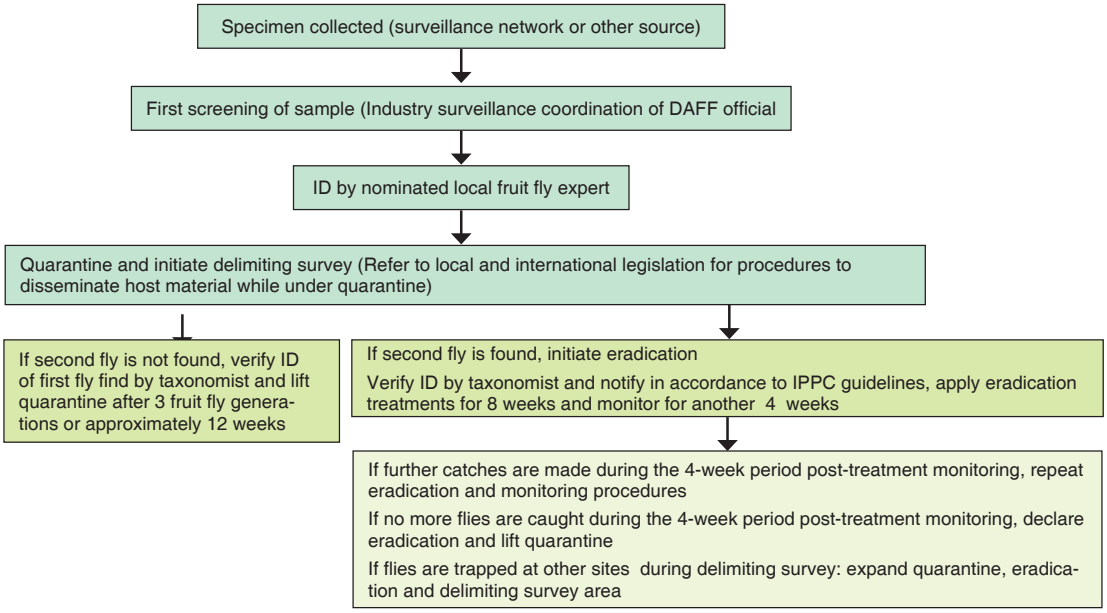
For final confirmation of the fruit fly ID, the specimen should be sent to a fruit fly taxonomist. Care should be taken to ensure that reference samples are preserved in accordance with acceptable scientific procedures.

(b) Steering Committee (coordination, communication and decision making)

The SA *B. invadens* Steering Committee (BiSC) will oversee communication, coordination of actions and decision making in response to a *B. invadens* detection. Notifications to the international community will be done in consultation with this Steering Committee and in accordance with the requirements of the WTO SPS Agreement, the IPPC and relevant ISPMs, to which the national phytosanitary standard and operating procedures for pest reporting are aligned.

The Steering Committee will consist of officials from the Department of Agriculture (representatives from each of the following: Directorate Plant Health, Directorate Agricultural Product Inspection Services, Directorate Plant Production Systems or equivalents) and representatives from each of the major affected industries (e.g. citrus, deciduous fruits and subtropical fruit). The Steering Committee will be chaired by the Directorate Plant Health.

6 Sequence of events

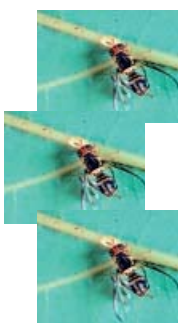


7 Materials required for eradication and monitoring

Materials should be kept in a designated facility in preparation for a potential outbreak of *B. invadens*. The stock is essential to be able to initiate a delimiting survey and eradication procedures without delay. In the event of an incursion and eradication actions being initiated, replacement of such stock must commence immediately. In the absence of an outbreak, stock of attractants and insecticides should be replaced every 2 years.

For eradication, the quantity of materials to be stockpiled in preparation will be based on units of one fly detection site and 2 months of eradication (which might be for 2 generations of *B. invadens* if temperature is at 28 °C). The area of coverage around each fly detection site will be 25 km.^{2} as mentioned previously. The extent of stockpiling (in multiples of single detection site units) is to be determined by the Steering Committee. The following will be required per detection site (one unit):

1. 10, 000 fibre board blocks (5 cm x 5 cm x 1,3 cm)
2. 150 ℓ methyl eugenol
3. 5000 ℓ of UL malathion
4. 500 ℓ of malathion EC (500 g/ℓ)
5. 15 000 ℓ of hymLure



For monitoring, the amount of materials required would be based on one fly detection and 3 months of trapping. Four radiating transects will be calculated from the zone surrounding the core area.

1. 200 Bucket traps
2. 400 methyl eugenol dispensers
3. 20 Biolure 3C dispensers
4. 450 DDVP strips

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Annexures

Annexure 1

Methyl eugenol baited trap

The locally available (RSA) Chempac bucket trap can be used. This is a yellow, cylindrical container with an opaque lid. A plastic basket can be fitted in the lid of the trap to contain a methyl eugenol dispenser. A 1 cm x 1 cm dichlorvos DDVP block should be placed at the bottom of the trap to kill any attracted flies.

Biolure 3-component baited trap

The locally available Chempac bucket trap or the less conspicuous Moroccan type trap (in areas more prone to trap theft) can be used. Biolure 3-component consists of ammonium acetate, trimethylamine and putrescine commercially available in the form of membrane dispensers. These dispensers should be stripped open and placed at the bottom of the trap (avoid sticking the dispenser to the trap because flies can be trapped on the sticky materials) and a 1 cm x 1 cm dichlorvos block should also be placed at the bottom of the trap to kill off any attracted flies.

Trap handling and placement

Maximum precaution is required to avoid contamination on the outside of the trap. A wire should be used to suspend the trap from a tree. The trap should be placed at 1,5 m above ground, preferably on a host tree. The wire should be coated with a sticky material (e.g. Stickem, Tanglefoot) or grease to avoid entry of ants. Foliage touching the trap should also be removed to prevent entry of ants. For both attractants mentioned above and insecticides, a period of 6 weeks is optimum before replacement.

The trap should be placed preferably in a secure location (e.g. back garden, hotel compound) following arrangements with the owner. Good public relations are important. The trap should be labelled and fitted with other labels indicating the presence of an insecticide. Once the trap is placed, the coordinates of the trap must be taken and details of its location (e.g., province, town, habitat type).

Trap servicing

A fine hairbrush should be used to collect specimens from the trap. Separate hairbrushes should be used for Biolure baited and methyl eugenol baited traps in order to avoid contamination between trap types. The specimens should be collected into a vial that is properly labelled with a pencil and preserved in 70% alcohol before shipping for screening/identification.

During rebaiting, old attractants, insecticides and packaging materials must be collected and disposed of in bins far away from the trapping site. the dates of rebaiting should be noted.

Annexure 2

Bactrocera invadens trapping survey

This annexure describes how trapping surveys on *Bactrocera invadens* would progress over time relative to changing status of the pest in the country. The information provided has been based on existing fruit fly trapping guidelines (IAEA 2003, FAO 2008).

Different trap densities (Table 3) would be applied under four different scenarios for the *B. invadens* population and control measures are defined below:

(a) Exclusion (*B. invadens* not in the country). The pest population is absent from the country and surveys are required to detect the entry of pest and for establishment of the pest-free areas.

(b) Eradication of incursion (*B. invadens* only in the country as point incursions that are under quarantine and subject to eradication). When one *B. invadens* fly is detected in an area, a delimiting survey will be implemented immediately in the outbreak area to determine the extent of spread and should be carried out for three generations past the last fly find (approximately 12 weeks). Eradication will be conducted if there is a second fly find. Trapping to verify eradication in the outbreak area will be carried out for one generation (4 weeks) after eradication measures have stopped. The detection area will be quarantined until the pest has been declared eradicated or there is no other fly find for 3 generations (12 weeks). Following confirmation of eradication and lifting of quarantine restrictions, surveys for detection with trapping densities similar to (A) will be resumed in the affected area. Detection surveys would be ongoing in other non-affected areas.

(c) Eradication of established population (*B. invadens* is established in a small part of the country and subject to containment). The pest population is present in a small part of the country and subject to eradication and surveys required to monitor the progress of the control measures. Trapping in the affected area will be at a higher density compared to detection surveys are and trap densities in the affected areas will be similar in different sub-areas (production, marginal, urban and points of entry). The affected area will be subject to quarantine restrictions until eradication is confirmed to prevent the spread of the pest throughout the country. Surveys for detection with trapping densities similar to (A) will be ongoing in the non- affected parts of the country.

(d) Monitoring of established population in part of the country no longer subject to containment. The pest population is established in part of the country and no longer subject to containment. Trapping surveys to determine the pest population level in the established area must be carried out. Monitoring for suppression activities in production areas would be implemented following the determination of the pest population level. Detection surveys in other parts of the country will be ongoing.

Trapping records

All trapping records must be kept and made available to the NPPO of the importing country on request. The following information must be included: trap location, plant where trap is placed, trap and attractant type, date trap was set, servicing and inspection dates and target fly catches. Fly catches should be expressed as flies per trap per day (FTD) which is the average number of flies of the target fly (*B. invadens*) captured per trap per day during a specified period in which the trap was exposed in the field.

FTD of an area at any specified time is obtained by dividing the total number of target flies captured by the product of the total number of inspected traps in the area and the average number of days that the traps were exposed.

FTD = F/T x D
where
F = total number of flies
T = number of inspected traps
D = average number of days traps were exposed in the field.

Trap densities for *Bactrocera invadens* under different scenarios of pest population and control measures. Methyl eugenol will be used as attractant in all trapping surveys. The Biolure 3 component will also be used in detection survey (A) at points of entry, in delimiting surveys (B) in the core outbreak area and in affected areas (C and D). When two attractants are used, different attractants can be combined to reach the total number.

Areas	Trap density per km2 under different scenarios						
	A. Exclusion	B. Eradication of incursion		C. Eradication of established population		D. Establishment of pest in part of country	
		Outbreak area	Non-affected areas	Eradication area	Non-affected areas	Affected area	Non-affected area
Production	1	20 in core area (1 km.^{2}) and 2 in each of three surrounding zones (8, 16 and 24 km.^{2})	1	3–5	1	2–4	1
Marginal	1		1	3–5	1	1–2	1
Urban	1–5		1–5	3–5	1–5	0,25–0,5	1–5
Points of entry	3–12		3–12	3–5	3–12	0,25–0,5	3–12

References

IAEA. 2003. *Trapping guidelines for area-wide fruit fly programmes*. Joint FAO/IAEA Division, Vienna, Austria.

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