

***Bactrocera invadens* Drew Tsuruta and White**
The African Invader fly
ACTION PLAN



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Compiled by: Aruna Manrakhan (Citrus Research International),
Jan-Hendrik Venter (NPPOZA)
and Vaughan Hattingh (Citrus Research International)

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I. 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 & 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 25 host species belonging to 13 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 below is not exhaustive and can still expand.

Scientific name	Common name	Scientific name	Common name
<i>Mangifera indica</i>	Mango	<i>Carica papaya</i>	Papaya
<i>Anacardium occidentale</i>	Cashew	<i>Lycopersicon esculentum</i>	Tomato
<i>Sclerocarya birrea</i>	Marula	<i>Capsicum annum</i>	Bell pepper
<i>Sorindeia madagascariensis</i>	Sondriry	<i>Capsicum frutescens</i>	Chili pepper
<i>Spondias cytherea</i>	Jew plum	<i>Psidium guajava</i>	Common guava
<i>Spondias mombin</i>	Tropical plum	<i>Syzygium malaccense</i>	Malay apple
<i>Citrus aurantium</i>	Sour orange	<i>Syzygium samarangense</i>	Java apple
<i>Citrus sinensis</i>	Orange	<i>Annona cherimola</i>	Cherimoya
<i>Citrus limon</i>	Lemon	<i>Annona muricata</i>	Soursop
<i>Citrus reticulata</i>	Tangerine / mandarin	<i>Annona squamosa</i>	Sugar-apple
<i>Citrus paradisi</i>	Grapefruit	<i>Averrhoa carambola</i>	Carambola
<i>Fortunella japonica</i>	Kumquat	<i>Terminalia catappa</i>	Indian Almond
<i>Musa spp.</i>	Banana	<i>Flacourtia indica</i>	Governor's plum
<i>Musa x paradisiaca</i>	Plantain	<i>Cordia spp.</i>	Grey leaved saucer berry
<i>Prunus persica</i>	Peach	<i>Strychnos mellodora</i>	Monkey orange
<i>Eriobotrya japonica</i>	Loquat	<i>Dracaena steudneri</i>	
<i>Diospyros kaki</i>	Japanese persimmon	<i>Irvinia gabonensis</i>	African wild mango
<i>Diospyros montana</i>	Mountain persimmon	<i>Ficus sycomorus</i>	Wild fig
<i>Citrullus lanatus</i>	Watermelon	<i>Blighia sp.</i>	
<i>Cucumis sativus</i>	Cucumber	<i>Chrysophyllum albidum</i>	White star-apple
<i>Cucumis figarei</i>	Hyena's watermelon (direct translation)	<i>Vitellaria paradoxa</i>	Sheanut
<i>Cucurbita maxima</i>	Pumpkin	<i>Landolphia sp.</i>	
<i>Cucumis pepo</i>	Gourd	<i>Maerua duchesnei</i>	
<i>Persea americana</i>	Avocado	<i>Garcinia manii</i>	Chewing stick

Table 1. Host plants of *B. invadens*

iii. Demography

The mean generation time for *B. invadens* was found to be 30.7 days at $28 \pm 1^\circ \text{C}$. 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 1: 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 $(T_{\max} + T_{\min})/2 - t$ with T_{\max} being maximum temperature, T_{\min} 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.

II. 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 km² within the core area (Figure 1 & Table 2). 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 km². 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 be placed in 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 1km 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 annex

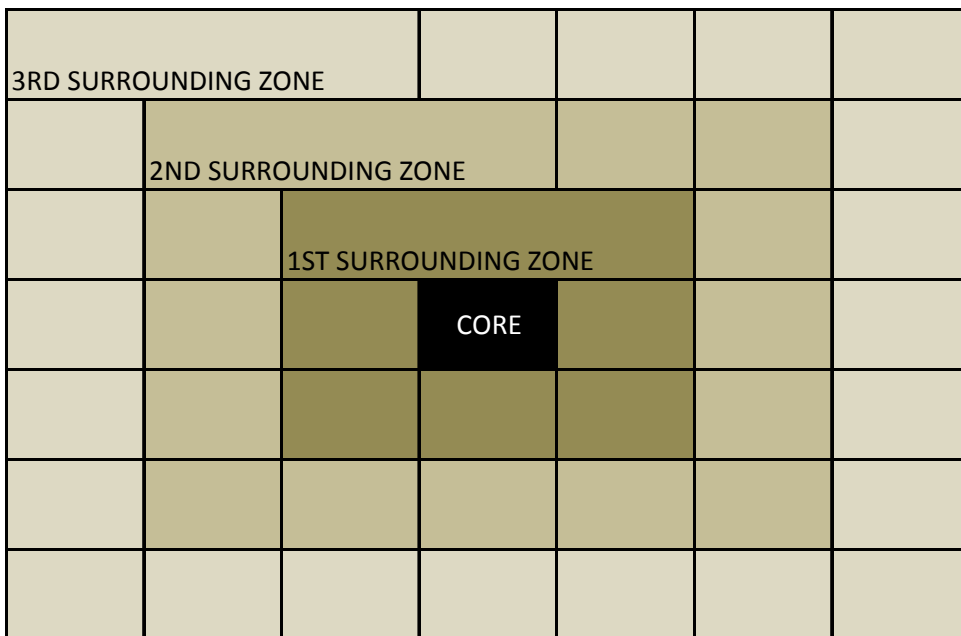


Figure 1. Delimiting survey with single km² core area and three surrounding zones

Table 2: 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
1 st	8	2
2 nd	16	2
3 rd	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 fruits from the core area will be surveyed, depending on host availability. Infested fruits 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 adult should be killed following emergence and preserved in alcohol or mounted for identification.

III. 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 fruits 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 also 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.

Road blocks should be implemented to regulate movement of fruits 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 that handle fruits, cannery waste and soil, as well as the organs of state that would implement road blocks, 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).

IV. 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 km² surrounding the trap site. Duration of eradication measures should be planned for at least 2 generations of *B. invadens* (generation estimated based on local climatic 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 km², either nailed to poles or hung from trees (10 000 blocks per 25 km² 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 (Hym lure 425 g/L) in combination with malathion UL (1130 g/L) is registered for aerial application as a bait using Hym lure 750 ml and malathion UL 250 ml/ha (75 + 25 L per km² and 1 875 + 625 L per 25 km²). 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 km² and 2500 L per 25 km²). 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 Hym lure and 175 ml Malathion EC (500 g/l) in 100 L of water per ha (40 L + 17.5 L per km² and 1000 L + 437.5 L per 25 km²) 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 km² and 2500 L in 50 000 L per 25 km²).

Supplemental eradication treatments

Fruit stripping. If fruit stripping is undertaken in the core area, stripped fruits 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.

V. IDENTIFICATION & 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.

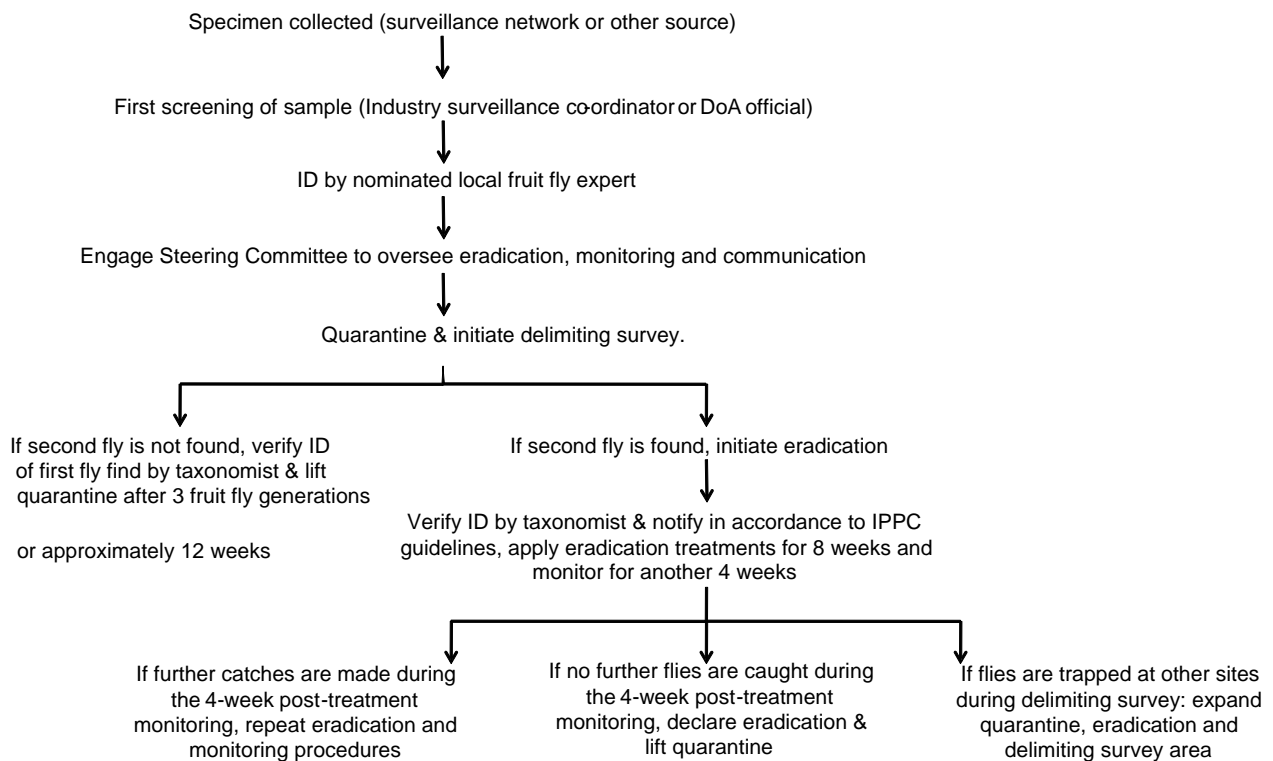
For final confirmation of the fruit fly ID, the specimen should be sent to a fruit fly taxonomist. Care should be taken to ensure that reference samples are preserved in accordance with acceptable scientific procedures.

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

The SA *B. invadens* Steering Committee will oversee communication, co-ordination 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, with 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 fruits). The Steering Committee will be chaired by the Directorate Plant Health.

VI. SEQUENCE OF EVENTS



VII. STOCK OF MATERIALS REQUIRED IN PREPAREDNESS OF ERADICATION AND MONITORING

Materials should be kept in a designated facility in preparedness 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 km² as mentioned previously. The extent of stock piling (in multiples of single detection site units) is to be determined by the Steering Committee. The following will therefore 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

VIII. REFERENCES

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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 since 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 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 on 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 labeled and fitted with other labels indicating the presence of an insecticide. Once the trap is placed, the co-ordinates 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 labeled 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. Dates of rebaiting should be noted.