Priority host plants for *Ceratitis capitata*, mediterranean fruit fly, based on the host reproduction number for surveillance, trade and eradication programs

B.C. Dominiak1 · R. Taylor-Hukins1

Received: 25 May 2022 / Accepted: 19 September 2022 / Published online: 3 October 2022
© Crown 2022

Abstract
Hosts of tephritids are known to vary in their capacity to support the life cycle from egg lay to adult. This capability is measured by the Host Reproduction Number (HRN) which the number of adults that emerge from one kg of fruit. Mediterranean fruit fly (Medfly) is one of the economically important fruit flies and is distributed worldwide. Many Medfly hosts are known but data to quantify their capacity to support the life cycle is scattered through many reports. Here, we reviewed published literature and found data on 146 potential hosts. We placed them in order of HRN and their Host Suitability Index. The HRN values ranged from bird plum (HRN = 1019) to three species of *Syzygium* which were non-hosts (HRN = 0). The HRN order will help to inform and triage hosts for targeted surveillance and eradication programs and inform disinfestation activities associated with incursion response management, and for trade and risk mitigation.

Keywords Trade · Incursion · Exotic

Introduction
Trade and tourism are key to the economies of many countries. However, increasing international trade of fruit and vegetables, and increasing tourist travel has led to more frequent incursions of invasive plant pests (Robinson and McNeill 2022). Tephritid fruit flies are one of the most important invasive and destructive crop pests (Follett et al. 2021). Endemic tephritids cause direct losses, making fruit inedible and adversely impacting the ability to feed a growing world population (Bebber et al. 2014). Additionally, detections of exotic tephritid infestations (eggs, larvae, pupae) trigger regulatory responses to eradicate or contain the incursion (Hancock 2013). Importing countries impose stringent quarantine restrictions to prevent entry of potentially infested fruit or vegetables. Therefore, tephritids have the potential to damage national economies and disrupt both domestic and international trade in fresh fruit.

Mediterranean fruit fly (Medfly), *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) is one of the world’s most serious plant pests (Woods et al. 2005). It is a native of Africa but has spread to many parts of the world. In Australia, it is restricted to Western Australia (Woods et al. 2005; Dominiak and Mapson 2017) but the eastern Australian states are free from Medfly. Additionally, Medfly is not established in New Zealand (MacLellan et al. 2021). Many regions, including New Zealand and eastern Australia, are sensitive to potential incursions of Medfly.

The actual risk posed by Medfly is largely influenced by host species. Hosts can be infested with eggs, larvae or pupae but not all of these life stages become adult flies, even under ideal mass rearing conditions (Fanson et al. 2014). Different hosts are known to have varying capacity to support the tephritid life cycle from egg laying stage to emerged adults. This is measured by the number of adults that emerge from one kilogram of fruit (Cowley et al. 1992) and this metric was termed the Host Reproduction Number (HRN) (Dominiak 2022). The HRN can range from 0 to >1000 (Dominiak 2022; Follett et al. 2021) placed these HRN into six major categories, based on the log of HRN and these categories were termed the Host Suitability Index (HSI). An additional category is non-host. In Australia, Hancock et al. (2000)
listed 53 species as hosts of Medfly, however, there was no ranking based on the HRN to quantify host risk. Here we found data on 146 potential hosts of Medfly and placed these hosts in the order of reproductive capacity (HRN).

**Materials and methods**

We followed the methodology described by Dominiak (2022). In summary, Google Scholar was used as a search engine because it yields more results than other databases (Pozsgai et al. 2021). The main research term used was “Ceratitis capitata”. Additional terms were added, such as “host” or “suitability” or “susceptibility” or “fruit” and similar terms in successive searches. We examined the results and we chose references if they provided useful data for HRN. Usually, useful references were contained in the first four pages of each search. The third search word was changed, based on the results in earlier searches.

To formulate the table containing hosts, HRN and HSI, we examined each reference for data of each host regarding the reproductive capacity to support adult fruit flies. Where possible, all fruit infestation results are standardized on an individual’s HRN. Most data were based on field sampling. Unfortunately, not all papers reported the information required. Some papers reported infestations per fruit and provided insufficient information to calculate the adults/kg metric. Some papers reported infestation rates in graphs or figures and accurate interpretation was too difficult to obtain reasonable estimates. Other papers reported infestations of larvae or pupae per kg and this information is not reported here. Different papers report a range of HRN figures. In plant biosecurity, the worst-case scenario is always assumed to be the case. Therefore, we did not include any references that reported a HRN lower than the eventual highest HRN in Table 1. Within Table 1, the HRN is followed by the equivalent index (HSI) proposed by Follett et al. (2021).

We examined the published literature covering the HRN for Medfly and ranked host plants in descending order based on published HRN (Table 1). Additionally, we assigned each host into one of the potential six HSI categories: HRN = 0 is non host (NH); HRN = <0.1 is very poor (VP); HRN = 0.1–1.0 is poor (P); HRN = 1.0–10.0 is moderately good (MG); HRN = 10.1–100 is good (G); and HRN = >100 is very good (VG) (Follett et al. 2021). In our review, numbers of HRN >20 were rounded out to the closest whole number. Numbers <20 were converted to one decimal point. We chose the higher HRN where different numbers were reported for a particular host, reflecting the worst-case scenario for biosecurity regulation considerations. There is a broad range within G and VG and there was merit in subdividing these two categories into high and low (Follett pers. comm.), based around the midpoint of the category. Therefore, we added H or L to the G and VG hosts in Table 1.

Africa is the ancestral home of Medfly and data primarily came from Copeland et al. (2002). This was supplemented mainly by Grove et al. (2017; 2019). Liquido et al. (1990) was the primary source for Medfly hosts in Hawaii. Woods et al. (2005) was the source for Medfly hosts in Australia.

**Results**

We found HRN for 146 potential hosts of Medfly (Table 1). Of these, there were 40 host plants were in the “very good” category (seven hosts were categorised as “very good-high” (VG-H) (HRN >500) and 33 hosts as “very good-low” (VG-L) (HRN between 100 and 500). We found 61 hosts as “good” (15 good-high (G-H) and 46 good-low (G-L)). Additionally, we found 34 hosts were “moderately good” host plants (MG), five as “poor” (P), zero host plants as Follett’s “very poor” and six host plants were categorised as non-hosts (NH) based on the available data.

**Discussion**

Two previous reviews were regionally based and examined many tephritids in the Pacific (Follett et al. 2021) and Africa (Dominiak 2022). Our review appears to be the first to propose using HRN on a particular species (Medfly) with the potential to inform a range of management options. Tephritid movements occur through long distance jumps followed by local diffusion (Sadler et al. 2011; Florec et al. 2013) found that it was economically better to invest in better exclusion techniques than enhanced surveillance or enhanced eradication capacity. Hence, importers can use HRN to identify higher risk importations and prepare better risk mitigation strategies to minimise or eliminate incursions of Medfly. However, incursions may still occur. Therefore, surveillance programs could consider HRN to identify the more ideal hosts in which to hang traps. Additionally, exotic incursions are more likely to establish quickly in hosts with a high HRN such as papaya (Carica papaya) with a HRN = 650. These hosts should be targeted with control measures to optimise eradication success. Therefore, if VG and G feral host fruit were removed or treated, pest populations are likely to decline quickly and the emergency response will have a shorter duration, decreasing the cost of the eradication program (Hancock 2013).

This targeting of host fruit based on HRN is particularly important in countries such as New Zealand which has no tephritids (MacLellan et al. 2021). It may be less important where exotic incursions have to compete with established
Table 1  List of hosts of Mediterranean fruit fly showing Host Reproduction Number (HRN), Host Suitability Index (HSI) and the source paper

| Scientific name                  | Common name              | Host Reproduction Number | Host Suitability Index | Source               |
|----------------------------------|--------------------------|--------------------------|------------------------|----------------------|
| Berchemia discolor              | Bird plum                | 1019                     | VG-H                   | Grove et al. (2017)  |
| Carissa spinarum               | Bush plum                | 884                      | VG-H                   | Grove et al. (2017)  |
| Murrayana paniculata           | Mock orange              | 790                      | VG-H                   | Moquet et al. (2021) |
| Passiflora suberosa            | Corky passion vine       | 747                      | VG-H                   | Moquet et al. (2021) |
| Solanum pseudocapsicum         | Jerusalem cherry         | 664                      | VG-H                   | Lquirido et al. (1990)|
| Carica papaya                  | Papaya                   | 650                      | VG-H                   | Woods et al. (2005)  |
| Terminalia catappa             | Pacific almond           | 524                      | VG-H                   | Woods et al. (2005)  |
| Malpighia glabra               | Barbados cherry          | 434                      | VG-L                   | Woods et al. (2005)  |
| Juglans regia                  | Walnut                   | 367                      | VG-L                   | Lquirido et al. (1990)|
| Solanum melongena              | Eggplant                 | 354                      | VG-L                   | Lquirido et al. (1990)|
| Corallocarpus ellipticus       | Gourd                    | 348                      | VG-L                   | Copeland et al. (2002)|
| Prunus armeniaca               | Apricot                  | 341                      | VG-L                   | Lquirido et al. (1990)|
| Chrysoxyllyum cainito           | Star Apple               | 336                      | VG-L                   | Woods et al. (2005)  |
| Solanum seaforthianum          | Brazilian nightshade     | 333                      | VG-L                   | Copeland et al. (2002)|
| Annona muricata                | Soursop                  | 298                      | VG-L                   | Woods et al. (2005)  |
| Ekebergia capensis             | Cape ash                 | 297                      | VG-L                   | Grove et al. (2017)  |
| Carissa bispinoxa              | Karoo num-num            | 292                      | VG-L                   | Grove et al. (2017)  |
| Terminalia petiolaris          | Blackberry tree          | 276                      | VG-L                   | Woods et al. (2005)  |
| Coffea racemosa                | Rosemosa coffee          | 259                      | VG-L                   | Grove et al. (2017)  |
| Solanum torvum                 | Turkey berry             | 250                      | VG-L                   | McQuate (2008)       |
| Prunus serotine cf. capuli     | Capuli cherry            | 237                      | VG-L                   | Copeland et al. (2002)|
| Garcinia livingstonei          | Imbe                     | 235                      | VG-L                   | Grove et al. (2017)  |
| Mangifera indica               | Mango                    | 228                      | VG-L                   | Woods et al. (2005)  |
| Prunus persica                 | Peach                    | 204                      | VG-L                   | Lquirido et al. (1990)|
| Flueggea virosa                | Goowal                   | 188                      | VG-L                   | Copeland et al. (2002)|
| Fortunella japonica            | Kumquat                  | 178                      | VG-L                   | Lquirido et al. (1990)|
| Coffea arabica                 | Coffee                   | 176                      | VG-L                   | Lquirido et al. (1990)|
| Mimusops zeyheri               | Milk wood                | 171                      | VG-L                   | Grove et al. (2017)  |
| Opilia amentacea               | Opilia                   | 170                      | VG-L                   | Copeland et al. (2002)|
| Psidium guajava                | Guava                    | 160                      | VG-L                   | Woods et al. (2005)  |
| Thevetia peruviana             | Yellow oleander          | 148                      | VG-L                   | Woods et al. (2005)  |
| Carissa edulis                 | Bush plum                | 145                      | VG-L                   | Copeland et al. (2002)|
| Vepris simplicifolia           | *                        | 144                      | VG-L                   | Copeland et al. (2002)|
| Harpephyllum caffrum           | Wild plum                | 141                      | VG-L                   | Grove et al. (2017)  |
| Guettarda speciosa             | Beach gardenia           | 134                      | VG-L                   | Copeland et al. (2002)|
| Elaeodendron slucienfurthianum | *                        | 132                      | VG-L                   | Copeland et al. (2002)|
| Acokanthera schimperi          | Poison arrow tree        | 113                      | VG-L                   | Copeland et al. (2002)|
| Harrisonia abyssinia           | *                        | 122                      | VG-L                   | Copeland et al. (2002)|
| Juglans nigra                  | Black walnut             | 118                      | VG-L                   | Lquirido et al. (1990)|
| Eugenia uniflora               | Surinam cherry           | 111                      | VG-L                   | Grove et al. (2019)  |
| Mimusops obtusosofia           | Red milk wood            | 99                       | G-H                    | Copeland et al. (2002)|
| Azima tetracantha              | Bee sting bush           | 97                       | G-H                    | Copeland et al. (2002)|
| Manilkara sansiharensis        | *                        | 97                       | G-H                    | Copeland et al. (2002)|
| Antidesma venium               | Tassle berry             | 96                       | G-H                    | Copeland et al. (2002)|
| Clausena anisate               | Horsewood                | 94                       | G-H                    | Copeland et al. (2002)|
| Salacia elegans                | *                        | 88                       | G-H                    | Copeland et al. (2002)|
| Mimusops kunnem                | Red milk wood            | 87                       | G-H                    | Copeland et al. (2002)|
| Malus sylvestris               | Apple                    | 79                       | G-H                    | Lquirido et al. (1990)|
| Miliusa braheri                | *                        | 71                       | G-H                    | Woods et al. (2005)  |
| Prunus salicina x P. cerasifera | Methley plum             | 69                       | G-H                    | Lquirido et al. (1990)|
| Pentarthopailopia umbellulate   | False cluster pear       | 67                       | G-H                    | Copeland et al. (2002)|
| Vepris nobilis                 | White ironwood           | 56                       | G-H                    | Copeland et al. (2002)|
| Coffea sp.                     | Coffee                   | 53                       | G-H                    | Moquet et al. (2021) |
Table 1 (continued)

| Scientific name                  | Common name                  | Host Reproduction Number | Host Suitability Index | Source               |
|----------------------------------|------------------------------|--------------------------|------------------------|----------------------|
| Prunus domestica                 | Plum                         | 51                       | G-H                    | Liquido et al. (1990) |
| Parinaric curatellifolia        | *                            | 50                       | G-H                    | Grove et al. (2017)   |
| Bourreria petiolaris            | *                            | 42                       | G-L                    | Copeland et al. (2002) |
| Capparis sandwichiana          | Puapilo                      | 41                       | G-L                    | Liquido et al. (1990) |
| Polysphaeria parvifolia         | *                            | 40                       | G-L                    | Copeland et al. (2002) |
| Capsicum annuum                 | Bell pepper, capsicum        | 39                       | G-L                    | Liquido et al. (1990) |
| Manilkara sulcate               | *                            | 39                       | G-L                    | Copeland et al. (2002) |
| Gmelina arborea                 | Snapdragon tree              | 39                       | G-L                    | Woods et al. (2005)   |
| Artabotrys monteiroae          | Red hook-berry               | 34                       | G-L                    | Copeland et al. (2002) |
| Syzygium cordatum              | Water berry                  | 32                       | G-L                    | Grove et al. (2017)   |
| Syzygium jambos                 | Jambos                       | 27                       | G-L                    | Liquido et al. (1990) |
| Ficus decipiens                | Treefern                     | 27                       | G-L                    | Copeland et al. (2002) |
| Grewia trichocarpa             | *                            | 25                       | G-L                    | Copeland et al. (2002) |
| Lycopersicon lycopersicum      | Common tomato                | 23                       | G-L                    | Liquido et al. (1990) |
| Pimento dioica                 | Allspice                     | 22                       | G-L                    | Grove et al. (2019)   |
| Manikara butugi                | *                            | 22                       | G-L                    | Copeland et al. (2002) |
| Psidium littorale              | Strawberry guava             | 21                       | G-L                    | Liquido et al. (1990) |
| Euclea dinorum                 | Toothbrush bush             | 21                       | G-L                    | Copeland et al. (2002) |
| Eriobotrya japonica           | Loquat                       | 20                       | G-L                    | Liquido et al. (1990) |
| Wikstroemia phillyreifolia     | Akia                         | 19.8                     | G-L                    | Liquido et al. (1990) |
| Ficus carica                   | Common fig                   | 18.6                     | G-L                    | Liquido et al. (1990) |
| Ludia mauritiana              | *                            | 18                       | G-L                    | Copeland et al. (2002) |
| Syzygium cumini                | Java plum                    | 17.9                     | G-L                    | Liquido et al. (1990) |
| Inga laurina                   | Inga                         | 17.4                     | G-L                    | Moquet et al. (2021) |
| Diospyros kaki                 | Oriental persimmon          | 17.2                     | G-L                    | Liquido et al. (1990) |
| Drypetes gerrardii            | Forest iron plum            | 17                       | G-L                    | Copeland et al. (2002) |
| Englerophyllum magalismontanum | *                            | 17                       | G-L                    | Grove et al. (2017)   |
| Vepris trichocarpa             | Furry fruited teclea        | 16.6                     | G-L                    | Copeland et al. (2002) |
| Capparis sepiaria              | Wild caper bush             | 16                       | G-L                    | Copeland et al. (2002) |
| Capsicum frutescens           | Chilli pepper                | 17.7                     | G-L                    | Moquet et al. (2021) |
| Strychnos henningsii          | Red bitter berry            | 15.4                     | G-L                    | Copeland et al. (2002) |
| Sideroxylon inerme             | White milkweed              | 14.1                     | G-L                    | Copeland et al. (2002) |
| Minusops elengi                | Spanish cherry               | 13.9                     | G-L                    | Moquet et al. (2021) |
| Momordica charantia           | Bitter melon                | 13.8                     | G-L                    | Liquido et al. (1990) |
| Scaevola plumieri             | Gullfeed                     | 13.7                     | G-L                    | Copeland et al. (2002) |
| Malpighia punicifolia         | Acerola                      | 13.1                     | G-L                    | Liquido et al. (1990) |
| Olea woodiana                 | Forest olive                | 13                       | G-L                    | Copeland et al. (2002) |
| Drypetes natalensis           | Natal iron plum             | 13                       | G-L                    | Copeland et al. (2002) |
| Doxyalis caffra                | Kei-apple                    | 12                       | G-L                    | Grove et al. (2017)   |
| Flacourtia indica              | Batoko plum                 | 12                       | G-L                    | Copeland et al. (2002) |
| Cascabela thevetia             | Yellow oleander             | 11.9                     | G-L                    | Moquet et al. (2021) |
| Rubus lucidus                 | Blackberry                  | 11.9                     | G-L                    | Liquido et al. (1990) |
| Santalum sp.                  | Sandalwood                  | 11.1                     | G-L                    | Liquido et al. (1990) |
| Cordia sebestena              | Scarlet cordia              | 11                       | G-L                    | Woods et al. (2005)   |
| Physalis peruviana            | Poha                         | 11                       | G-L                    | Liquido et al. (1990) |
| Pithecellobium dulce          | Madras thorn                | 10.9                     | G-L                    | Moquet et al. (2021) |
| Scaevola sericera             | Beach naupaka               | 10.5                     | G-L                    | Copeland et al. (2002) |
| Pouteria viridis             | Green sapote                | 10.2                     | G-L                    | Liquido et al. (1990) |
| Flagellaria guineensis        | Bababia                      | 9.6                      | MG                     | Copeland et al. (2002) |
| Ximenia caffra                | Sour plum                    | 9.4                      | MG                     | Copeland et al. (2002) |
| Annona cherimola             | Cherimoya                    | 8.9                      | MG                     | Liquido et al. (1990) |
| Eugenia uniflora             | Surinam cherry               | 8.1                      | MG                     | Liquido et al. (1990) |
| Cyphomandra betacea          | Tree tomato                 | 8.1                      | MG                     | Liquido et al. (1990) |
tephritids with higher HRNs in those same hosts (Copeland et al. 2006; Dominiak and Mapson 2017).

We found 40 VG hosts capable of supporting >100 adults per kg of fruit. Within this group, papaya, Pacific almond, mango, coffee and guava were major hosts. Good hosts was the largest category (41.7%) with 61 hosts. Surveillance and incursion managers should be aware of these species to optimise surveillance or eradication activities. Additionally, the use of HRN to inform and triage surveillance targets should consider factors such as typical size (kg) of fruit. Also, it is unclear whether the HRN translates to the attractiveness of the fruit and preferential selection by Medfly.

The seven hosts with the highest HRN (HRN = VG-H) would be preferred hosts for surveillance including bird plum, bush plum, mock orange, corky passion vine, Jerusalem cherry and Pacific almond (Table 1). However, any host with a HRN > 100 would be ideal hosts for surveillance (40 hosts). In any incursion, these hosts should be fruit stripped to prevent any further rapid Medfly population development. For domestic and international trade, the HRN could

Table 1 (continued)

| Scientific name | Common name | Host Reproduction Number | Host Suitability Index | Source |
|-----------------|-------------|--------------------------|-----------------------|--------|
| Solanum muricatum | Pepino       | 8.0                      | MG                    | Liquido et al. (1990) |
| Monodora grandidieri | *           | 7.7                      | MG                    | Copeland et al. (2002) |
| Mimusops bagshavei | *           | 7.7                      | MG                    | Copeland et al. (2002) |
| Coccinia microphylla | Red gourd   | 7.7                      | MG                    | Copeland et al. (2002) |
| Lamprothamnus zanquebaricus | *           | 6.9                      | MG                    | Copeland et al. (2002) |
| Prunus africana  | African cherry | 6.5                     | MG                    | Copeland et al. (2002) |
| Euphoria longan | Longan       | 6.3                      | MG                    | Liquido et al. (1990) |
| Acokanthera oppositifolia | Bushman’s poison | 5.5                 | MG                    | Copeland et al. (2002) |
| Casimiroa edulis | Sapote       | 5.4                      | MG                    | Liquido et al. (1990) |
| Spondias cytherea | Wi apple     | 5.3                      | MG                    | Liquido et al. (1990) |
| Citrus x tangelo | Tangelo      | 4.4                      | MG                    | Liquido et al. (1990) |
| Clausena lanatus | Wampi        | 4.2                      | MG                    | Liquido et al. (1990) |
| Psidium cattleianum | Strawberry guava | 4.1                 | MG                    | Grove et al. (2019) |
| Citrus maxima    | Pummelo      | 4.1                      | MG                    | Liquido et al. (1990) |
| Citrus x paradisi | Grapefruit   | 3.9                      | MG                    | Liquido et al. (1990) |
| Citrus reticulata | Tangerine orange | 3.7             | MG                    | Liquido et al. (1990) |
| Persea americana | Avocado      | 3.2                      | MG                    | Liquido et al. (1990) |
| Phyllanthus acidus | Otaheite gooseberry | 2.9            | MG                    | Liquido et al. (1990) |
| Annona reticulata | Custard apple | 2.6                      | MG                    | Liquido et al. (1990) |
| Blighia sapida   | Akee         | 2.2                      | MG                    | Liquido et al. (1990) |
| Citrus sinensis  | Orange (Navel and Valencia) | 2.2             | MG                    | Liquido et al. (1990) |
| Parinaric macrophylla | Nonda          | 2                        | MG                    | Woods et al. (2005)  |
| Passiflora ligularis | Sweet granadilla | 1.8                   | MG                    | Liquido et al. (1990) |
| Calophyllum inophyllum | Kamani       | 1.8                      | MG                    | Liquido et al. (1990) |
| Opuntia ficus-indica | Cactus     | 1.8                      | MG                    | Liquido et al. (1990) |
| Musa x paradisiaca | Banana       | 1.4                      | MG                    | Liquido et al. (1990) |
| Syzygium malaccense | Mountain apple | 1.4               | MG                    | Liquido et al. (1990) |
| Oxyanthus zanquebaricus | *           | 1.2                      | MG                    | Copeland et al. (2002) |
| Pyrus communis  | Pear         | 1.1                      | MG                    | Liquido et al. (1990) |
| Artocarpus altilis | Breadfruit   | 0.9                      | P                     | Liquido et al. (1990) |
| Citrus limon      | Lemon        | 0.8                      | P                     | Liquido et al. (1990) |
| Averrhoa carambola | Star fruit   | 0.7                      | P                     | Moquet et al. (2021) |
| Citrus aurantiifolia | Lime         | 0.6                      | P                     | Liquido et al. (1990) |
| Citrus australasia | Finger lime  | 0.2                      | P                     | Follett et al. (2022) |
| Acca sellowiana  | Feijoa       | 0                        | NH                    | Grove et al. (2019)  |
| Plinia caujifora | Jaboyicaba   | 0                        | NH                    | Grove et al. (2019)  |
| Psidium friedrichshilianum | Costa Rican guava | 0         | NH                    | Grove et al. (2019)  |
| Syzygium guineense | Water berry  | 0                        | NH                    | Grove et al. (2019)  |
| Syzygium paniculatum | Magenta cherry | 0                      | NH                    | Grove et al. (2019)  |
| Syzygium samarangense | Java plum     | 0                        | NH                    | Grove et al. (2019)  |

* = no common name
be used to vary disinfestation protocols, particularly in a Systems Approach (Dominiak 2019). For instance, should limes (HRN = 0.6) be required to undergo the same treatment as papaya (HRN = 650) where the risk is about 1000 times greater. Additionally, the temperature mediated disinfestation period might be shortened for low HRN commodities to achieve the same biosecurity outcome (e.g. - a given probit level in a Systems Approach). Shorter treatment times would result in a lower carbon footprint of commodities and minimise the impact on global climate change.

In Australia, Hancock et al. (2000) listed 53 potential hosts of Medfly, but there was virtually no ranking of HRN. Based on our review (see Table 1 for details), ten of these hosts were VG hosts, seven were G hosts, 12 were MG hosts and one was a NH. Many authors report hosts of Medfly but not all record the HRN metric: many authors report adults per fruit with no reference to weight of individual fruit. The HRN metric needs to be included in future reports if trade, surveillance and eradication programs are to be optimised. Additionally, knowledge of high HRN hosts would inform eradication managers to rapidly reduce endemic Medfly populations.

It is important to reflect that this host list is not exhaustive. There are many hosts of Medfly referenced in literature that have not been included in this review due to unavailability of data to quantify reproductive capacity. Also, it is important to acknowledge that even though the data suggests that some are potential NH hosts, these hosts need to be considered carefully. For example, feijoa is commonly considered a Medfly host (Argov and Gazit 2008) but we could not find HRN data for feijoa in Africa. Therefore, NH should not be ruled out as a host based on the presented data alone. It is known that factors such as climate, altitude, competition with other fruit fly species and time of year of sampling can influence number of flies found and may account for some NH results.

Here, we have reported the worst-case HRN however these number may not apply to all circumstances. Medfly are found in abundance at lowland and high elevation sites (>2,100 m ASL) however Medfly were seldom found in lowland areas after the introduction of Bactrocera dorsalis (Hendel) (Copeland et al. 2002). Medfly has a high tolerance of dry conditions compared to B. dorsalis (Hassani et al. 2016) and is capable of withstanding low temperatures (Badil et al. 2015). Therefore, the HRN may be lower than our reported figures based on the local environment, particularly at the margins of its range. Conversely, the HRN may be higher in ideal environmental situations. We encourage all fruit fly researchers to report, where possible, the HRN for all tephritids so that management and trade can be optimised. For example, commercial consignments of papaya, egg plant, apricot, mango and peach needs to be treated before export because of their high HRN. Conversely, based on our findings, low HRN commodities such as feijoa, finger lime, star fruit, pear and banana may require minimum disinfestation before export. Alternatively, these commodities would be suitable for a Systems Approach to production and not require any disinfestation due to their low HRN (Dominiak 2019).

Acknowledgements Louise Rossiter and Lloyd Kingham reviewed an earlier version of the manuscript. Two anonymous journal reviewers further improved the submitted manuscript.

Author contribution Both authors conceived the review and reviewed and approved the final manuscript. Bernie Dominiak created the first draft of the manuscript.

Funding NSW Department of Primary Industries funded this review. There were no specific grants or funded projects. Open Access funding enabled and organized by CAUL and its Member Institutions

Declarations

Conflict of interest The authors declared that there are no conflicts of interest.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

Argov Y, Gazit Y (2008) Biological control of the Mediterranean fruit fly in Israel: Introduction and establishment of natural enemies. Biol Control 46:502–507
Badil KB, Billah MK, Afreh-Nuamah K, Obeng-Ofori D, Hyarko G (2015) Review of the pest status, economic impact and management of fruit-infesting flies (Diptera: Tephritidae) in Africa. Afr J Agric Res 10:1488–1498
Bebbert PD, Holmes T, Smith D, Gurr SJ (2014) Economic and physical determinants of the global distributions of crop pests and pathogens. New Phytol 202:901–910
Copeland RS, Wharton RA, Luke Q, De Meyer M (2002) Indigenous hosts of Ceratitis capitata (Diptera: Tephritidae) in Kenya. Ann Entomol Soc Am 95:672–694
Copeland RS, Wharton RA, Luke Q, De Meyer M, Lux S, Zenz N, Machera P, Okumu M (2006) Geographic distribution, host fruit, and parasitoids of African fruit fly pests Ceratitis anonaee, Ceratitis cosycra, Ceratitis fasciventris, and Ceratitis rosa (Diptera: Tephritidae) in Kenya. Ann Entomol Soc Am 99: 261–278
Cowlby JM, Baker RT, Harte DS (1992) Definition and determination of host status for multivoltine fruit fly (Diptera: Tephritidae) species. J Econ Entomol 85:312–317

Dominiak BC, Mapson R (2017) Revised distribution of Bactrocera tryoni in Eastern Australia and effect on possible incursions of Mediterranean fruit fly: Development of Australia’s Eastern Trading Block. J Econ Entomol 110:2459–2465

Dominiak BC (2019) Components of a systems approach for the management of Queensland fruit fly Bactrocera tryoni (Froggatt) in a post dimethoate fenthion era. Crop Prot 116:56–67

Dominiak BC (2022) The use of Host Reproduction Number and Host Suitability Index to rank hosts of Fruit Flies in Africa. Int J Trop Insect Sci. doi:https://doi.org/10.1007/s42690-022-00804-8

Fanson BG, Sundaralingam S, Jiang L, Dominiak BC, D’Arcy G (2014) A review of 16 years of quality control parameters at a mass-rearing facility producing Queensland fruit fly, Bactrocera tryoni. Entomol Exper Appl 151:152–159

Florec V, Sadler RJ, White D, Dominiak BC (2013) Choosing the battles: the economics of area wide pest management for Queensland fruit fly. Food Policy 38:203–213

Follett PA, Haynes FEM, Dominiak BC (2021) Host Suitability Index for polyphagous tephritid fruit flies. J Econ Entomol 114:1021–1034

Follett PA, Asmus G, Hamilton LJ (2022) Poor host status of Australian finger limes, Citrus australasica, to Ceratitis capitata, Zeugodacus cucurbitae, and Bactrocera dorsalis (Diptera: Tephritidae) in Hawai‘i. Insects 13:177

Grove T, De Jager K, De Beer MS (2017) Indigenous hosts of economically important fruit fly species (Diptera: Tephritidae) in South Africa. J Appl Entomol 141:817–824

Grove T, De Jager K, Theledi ML (2019) Fruit flies (Diptera: Tephritidae) and Thaumatosibia leucotreta (Meyrick) (Lepidoptera: Tortricidae) associated with fruit of the family Myrtaceae Juss. in South Africa. Crop Prot 116:24–32

Hancock DL, Hamacek EL, Lloyd AC, Elson-Harris MM (2000) The distribution and host plants of fruit flies (Diptera: Tephritidae) in Australia. Queensland Department of Primary Industries, Brisbane

Hancock DL (2013) A revised checklist of Australian fruit flies (Diptera: Tephritidae). Aust Entomol 40:219–236

Hassani IM, Raveloson-Ravaomanarivo LH, Delatte H, Chiroleu F, Allibert A, Nouhou S, Quilici S, Duyck PF (2016) Invasion by Bactrocera dorsalis and niche partitioning among tephritid species in Comoros. Bull Entomol Res 106:749–758

Liquido NJ, Cunningham RT, Nagawa S (1990) Host plants of Mediterranean fruit fly (Diptera: Tephritidae) on the island of Hawaii (1949–1985) survey. J Econ Entomol 83:1863–1878

MacLellan R, King K, McCarthy B, France S (2021) National fruit fly surveillance programme annual report. Surve 48: 131–134

McQuate GT (2008) Solanum torvum (Solanaceae), a new host of Ceratitis capitata (Diptera: Tephritidae) in Hawaii. Proc Hawaii Entomol Soc 40:71–75

Moquet L, Payet J, Glenac S, Delatte H (2021) Niche shift of tephritid species after the Oriental fruit fly (Bactrocera dorsalis) invasion in La Reunion. Divers Distrib 27:109–129

Pozsgai G, Lovei GL, Vasseur L, Gurr G, Batary P, Korponal J, Littlewood NA, Liu J, Mora A, Obrycki J, Reynolds O, Stockan JA, VanVolkenburg H, Zhang J, Zhou W, You M (2021) Irreproducibility in searches of scientific literature: a comparative analysis. Ecol Evol 11:14658–14668

Robinson AP, McNeill MR (2022) Biosecurity and post-arrival pathways in New Zealand: relating alien organism detections to tourism indicators. NeoBiota 71:51–69

Sadler RJ, Florec V, White B, Dominiak BC (2011) Calibrating a jump-diffusion model of an endemic invasive: metamodels, statistics and Qfly. In Sustaining our Future: Understanding and Living with Uncertainty, MODSIM 2011 International Congress on Modelling and simulation. 7–11 December. 2011. Eds Chan F & Marinova D). Modelling and Simulation Society of Australia and New Zealand, Perth, Australia

Woods B, Lacey IB, Brockway CA, Johnstone CP (2005) Hosts of Mediterranean fruit fly Ceratitis capitata (Wiedemann) (Diptera: Tephritidae) from Broome and Broome Peninsula, Western Australia. Aust J Entomol 44:437–441

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.