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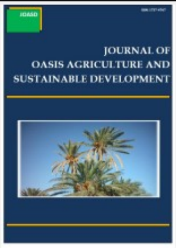

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The Pumpkin fruit fly *Dacus frontalis* (Becker) (Diptera: Tephritidae): A review of its bio-ecology and control strategy

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Abstract

The pumpkin fly *Dacus frontalis* (Becker) is already ranked as one of the most economically damaging pest of cucurbits in North Africa, South Africa, and the Middle East. The exact identification of this fruit fly can be delicate because of the similarities at the species level. Thus, molecular biology can easily classify and control fruit fly pests. *D.frontalis* favorite hosts are Pumpkin, Watermelon, Sweet melon, Cucumber and Squash. Infested fruits usually present oviposition or exit holes and direct damage is caused by the larval stage which, decreases quality and quantity of fruits and provoke high losses in yield. The Control strategy of this pest varies from biological control to chemical pesticides in addition to the bait traps.

1. INTRODUCTION

The Tephritidae fruit flies are one of the most prominent pests on a wide range of crops in many parts of the world (Dhillon et al., 2005; Elfékih and Haymer, 2010; Layodé et al., 2020; Boulahia-Khedher, 2020) and have a vast capacity for being invasive in new areas (Elfékih and Haymer, 2010). Almost 250 species belong to Dacinae subfamily (Dhillon et al., 2005), which cause enormous economic losses in grown fruits and vegetables (Dhillon et al., 2005; Ekesi et al., 2016; Maronsy & Al-Muffti, 2019) including cucurbit crops (Dhillon et al., 2005; Badii et al., 2015; Sapkota et al., 2016; Layodé et al., 2020). Few studies were devoted to the fruit flies in North African countries including Morocco, Algeria, Tunisia, Libya, Mauritania and Egypt. Dacinae fruit flies are recorded as economic importance pests in much horticultural production (Christenson & Foote, 1960).

The pumpkin fly *Dacus frontalis* (Becker) is already ranked as an exotic, invasive (Hafsi et al., 2015; Ekesi et al., 2016) and one of the most economically damaging pests of cucurbits in many countries in Africa, (Hafsi et al., 2015; Ekesi et al., 2016; Layodé et al., 2020) and the Middle East (Ekesi & Billah, 2007). This species could be arranged as a highly serious agricultural quarantine pests under rank A1 (Howarth, 1991 and Hafsi et al., 2015). About North of Africa, this pest has recently been detected in Morocco (Elharym & Balqat, 2017), identified in Tunisia (Hafsi et al., 2015), Libya, Egypt (Fetoh, 2009) and it's mentioned that it exists in Algeria (Hafsi et al., 2015).

2. TAXONOMY AND IDENTIFICATION

Identification of insect pest species is necessary for quarantine restrictions, studying ecology, biology, and control methods (Fetoh, 2009). Dacinae flies are phenotypically very similar and they are known as one of the most complicated groups of Tephritidae to exact species-level identification (Ekesi & Billah, 2007; Virgilio et al., 2014; Doorenweerd et al., 2018; Hafsi et al., 2015).

Dacus frontalis adults have a mostly orange coloration. All tergites are combined into a single plate with a sleeker transverse line and without overlapping sclerites. The basal part of the scutum has two black rounded spots. The majority of the anatergite and katatergite are covered with a yellow stripe. The wings are characterized by the presence of an apical spot (Ekesi & Billah, 2007; Hafsi et al., 2015).

The examination of body color patterns to separate species is very confounded by considerable intraspecific variation (Leblanc et al., 2015). Else, it's impossible to distinguish the immature stages, larvae or pupae, from each other (Virgilio et al., 2008).

All these traditional taxonomic limitations cause an unstable history of classification (Allwood et al., 2002; Doorenweerd et al., 2018). Thus, as a new approach, molecular biology can easefully identify and classify these pests (Fetoh, 2009) by simplifying their phylogenetic relationships and taxonomic status, using sequences of mitochondrial and nuclear markers (Virgilio et al., 2008; Elfékih & Haymer, 2010). This approach was reported by many several authors. For example, Fetoh (2009) stated differentiation between *Dacus frontalis* and *Dacus ciliatus* in Egypt specimens by comparative taxonomy throughout molecular characterizations and variations in proteins using sodium Dodecyl Sulphate-Polyacrylamide gel electrophoresis (SDS-PAGE) and Esterase Profile using Electrophoresis (EST-PAGE). This work aims to facilitate identification methods and control measures.

3. GLOBAL DISTRIBUTION

Dacus frontalis has been reported in South Africa, Kenya, Zimbabwe, Namibia, Tanzania, Eritrea, Angola, Lesotho, Congo, Botswana, Nigeria, Cape Verde and Benin. It has also been detected outside Africa in the Middle East in Yemen, the United Arab Emirates, Saudi Arabia (Ekesi & Billah, 2007; Hafsi et al., 2015) and Iraq (Shawkit et al., 2011).

In North Africa, this pest has been recorded in Libya, Egypt (Fetoh, 2007 and Elharym & Balqat, 2017) and it has been mentioned that it exists in Algeria (Hafsi et al., 2015 and Elharym & Balqat, 2017). Recently, the fly has been detected in Tunisia (Hafsi et al., 2019) and more recently in Morocco for the first time (Elharym & Belqat, 2017).

4. HOST PLANTS

D. frontalis is one of the most destructive fruit fly species damaging all cucurbits crops, preferred hosts are pumpkin (*Cucurbita pepo*), watermelon (*Citrullus lanatus*), sweet melon (*Cucumis melo*), cucumber (*Cucumis sativus*) and squash *(Cucurbita* sp.). It attacks also some wild cucurbitaceae as colocynth (*Citrullus colocynthis*) and bur cucumber (*Cucumis anguria*). Some plants are known as rest plants where adults mate (example: *Citrus spp*., maize (*Zea mays*) and pigeon pea (*Cajanus cajan*) (Steffens, 1983; Ekesi & Billah, 2007; Hafsi et al., 2015).

The recent investigations in Libya confirmed the same cucurbits host range species by adding Eggplant species *Solanum melongena* L. (Solanaceae) as a new fly host (Elghadi, 2016).

5. LIFE HISTORY

D. frontalis has similar damage symptoms and life cycle of other species belonging to the Dacinae fruit flies (Steffens, 1983).

After emerging and feeding, adult females lay their eggs just under the skin of the fruit. Eggs and larvae develop inside the fruit and relatively protected from direct application of insecticides except systemic ones. The larvae consume pulp, feed and develop inside destroying the host. Then, mature larvae drop into the soil to pupate (Christenson & Foote, 1960; Hafsi et al., 2015).

Rounded white eggs (Hafsi et al.,2015) have been laid daily by *D. frontalis* females after inserting the ovipositor into the skin of the cucurbit fruit to a depth of 3 mm (Elghadi, 2016).

Depending on environmental conditions, the eggs hatch in 2 to 4 days into white milky larvae which develop through three larval instars, feed on the host fruit and inducing decomposition of the host. The mature larvae emerge from the fruits and pupate on the ground. The newborn pupae are cylindrical and have a yellow-brown coloration, develop and emerge into adults. *D. frontalis* adults are small flies with a body length of 8-9 mm, orange to brown, with four yellow spots on the thorax and another at the wing connection. For morphological differentiation, females have ovipositor in the abdomen and their body size is bigger than males (Elghadi, 2016). Generally, adults are active in the afternoon (mating and laying). Fly life stages from eggs to adult emergence are dependent on climate change. Dry conditions are generally suitable for high infestations; however, cold conditions cause the fly population to decrease (Steffens, 1983; Hafsi et al., 2015). Field observations from Tunisia showed that the fly was detected from September to December (Hafsi et al., 2015). In Iraq, various field infestations on cucumber fruits were observed from May to October but the highest level was recorded between August and October.

6. SYMPTOMS AND DAMAGE

Infested fruits usually contain egg-laying or exit holes (Hafsi et al., 2015). Pale yellow coloration generally is observed around the egg-laying holes, which then turn brownish-yellow (Elghadi, 2016).

Direct damage of *D.frontalis* is caused by the larval stage, which decreases the quality and quantity of fruit production, making the fruit unsalable (Elghadi and Port, 2019). Emerged larvae cause rot by consuming the fruit from the inside (Hafsi et al., 2015) and facilitate infection by pathogens (Elghadi, 2016) (Fig. 1).

In the Cape Verde Islands, with the absence of good control strategy, *D.frontalis* attacks all cultivated cucurbits and causes high yield losses, sometimes reaching one hundred percent (Steffens, 1983).

7. CONTROL STRATEGY

The development of sustainable management strategies obliges the collection of good information of pest communities and factors controlling larvae being as temperature, rainfall and host range species (Layodé et al., 2020). Published studies on *D.frontalis* control strategies are very limited (Elghadi, 2016). Few procedures have been recommended to reduce the fruit fly's population, which vary from chemical treatments, to biological control in addition to the bait traps.

7.1. Cultural practices

Cultural practices are based on traditional techniques that can minimize fly infestations (Elghadi, 2016) and reduce the emergence of fruit fly's adults from the soil (Christenson & Foote, 1960) by collecting and destroying all infested fruit that can be deeply buried in the soil (>30 cm) in order to prevent larvae and pupae to emerge. For example, the experience carried out in Indonesia shows that catch males of *Bactrocera tau* species were 20 % inferior in plots with field sanitation compared with plots without. For other methods, infested fruits can be collected, placed in plastic bags and exposed to the sun. Also, the early harvesting of fruits can reduce fruit damage (Ekesi et al., 2016).

7.2. Attract and kill technique

Fruit fly detection and population monitoring are essential for any management program (IAEA, 2003). Bait-trapping has a long, well documented history that result from the development of various trap and lure combinations used to trap Tephritidae fruit flies (Moreno & Mangorn, 2007). In Africa, Cue-lure is used for attracting male specimens of *Dacus frontalis*, *Bactrocera cucurbitae* and several Dacus species (Ekesi & Billah, 2007; Ekesi et al., 2016; Hafsi et al., 2015 and Doorenweerd et al., 2018). In another way, females and males of some fruit flies have been captured in food-baited traps. For the population monitoring of Pumpkin fruit fly in Tunisia, Hafsi et al., (2015). has deployed in the study area the Cue-lure bait trap for male attracting and the Di-ammonium Phosphate (DAP) as a food baited-trap to catch the both sexes.

(a) (b)

Fig.1. Symptomatic cucurbit fruits were sampled in southern Tunisia, on October 2020 (Photographs © were taken by the first author, on October 2020).
(a): Infested Pumpkin fruit presenting exit holes. (b): Third instar larvae inside the cucumber fruit.

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7.3. Sterile Insect Technique (SIT)

It is a friendly method that respects the environment and is applied to limit the populations of Tephritidae fruit flies. This technique involves releasing a large number of sterile males into the infested area, which will mate with fertile females with the aim of laying sterile eggs (Duyck & Robinson, 2005). The hugest successful program using this technique in Africa has been applied in South Africa's Western Cape Province in order to eradicate *Cératitis capitata* species (Barnes & Venter, 2006).

7.4. Chemical pesticide

Until now, the use of chemical pesticides dominates the approach of pest control despite the negative environmental impact of these treatments (Rizvi et al., 2009). However, some insecticides have successfully limited some Tephritidae population species when combined in Attract and Kill method (Elghadi and Port, 2019) and Sterile Insect Technique (Allwood et al., 2002). Three insecticides Dimethoate, Fenthion and Diazinon added to the protein hydrolysate were tested for the control of *Dacus frontalis* on watermelon and sweet melon field crops in Yemen. After seven days, insecticide treatments lowered infestation levels in the experimental area. Also, these insecticides were used to control other pests of cucurbits (Ba-Angood, 1997).

7.5. Biological Control

Biological control is an economical method that respects humans and the environment (Rizvi et al., 2009) and uses biological agents as an alternative to pesticide control (Howarth ,1991; Hoddle, 2004).

Parasitoids: Manoukis et al., (2014) have claimed that the Hymenopteran parasitoids have been classified as the most efficient bio-control agents against Tephritidae species. They have the capacity to lay eggs into a live stage (eggs, larvae or pupae) and achieve their larval development before the death of hosts (Abram et al., 2019). For example, the African parasitism rate of *Psyttalia fletcheri*, which has been introduced into La Réunion in 1995 to control Bactrocera cucurbitae in bitter gourd, reached 75 % (Quilici et al., 2002). In 2006, *F. arisanus* and *D. longicaudata* has been imported from Hawaii and introduced into Kenya, Tanzania, Mozambique, Cameroon, Benin, Togo, and Senegal, to control *B.dorsalis*. Thus, the parasitism rate reached up to 40 %, depending on host species (Ekesi et al., 2016).

Entomopathogenic nematodes: *Heterorhabditis* and *Steinernema* species have been reported to cause mortality in some Tephritidae life stages in the soil (Pupae) (Langford et al., 2014). Larvae and adults of cucurbit fly, *Dacus ciliatus* were also attacked by *S. carpocapsae* under laboratory and greenhouse conditions (Kamali et al., 2020).

Entomopathogenic fungi: These types of pathogens are capable of killing pupae and adult stages of different Tephritidae species. The first study of the efficacy of a commercial strain of *Metarhizium anisoplae* as entomopathogenic fungi against the pumpkin fly *Dacus frontalis* (Becker) in Libya has demonstrated that this pathogen was an effective biological control agent. The research has also shown that just one single application of this fungus has been able to reduce the adult emergence and persist in soil for more than two months (Elghadi & Port, 2019).

7. CONCLUSION

In North African countries, the fruit flies quarantine system must be urgently modified and consolidated in the face of new exotic introductions since it is confirmed that, actually, *Bactrocera zonata* (Libya), *Bactrocera cucurbitae*, *Dacus ciliatus* (Egypt) and *Dacus frontalis* (Egypt, Libya, Algeria, Morrocco and Tunisa) have been invading the North African countries. Thus, a search for control measures is necessary to develop an effective integrated pest management strategy that is more respectful of the environment and can even lead to their eradication.

REFERENCES

Abram, P. K., Brodeur, J., Urbaneja, A., & Tena, A. (2019). Non reproductive effects of insect parasitoids on their hosts. Annual Review of Entomology, 64, 259–276.

Allwood, A. J., Vueti, E. T., Leblanc, L., & Bull, R. (2002). Eradication of introduced Bactrocera species (Diptera: Tephritidae) in Nauru using male annihilation and protein bait application techniques. Turning the tide: the eradication of invasive species, 19–25.

Ba-Angood, S. A. S. (1977). Control of the melon fruit fly, Dacus frontalis Becker (Diptera: Trypetidae), on cucurbits. Journal of Horticultural Science, 52(4), 545–547.

Badii, K. B., Billah, M. K., Afreh-Nuamah, K., Obeng-Ofori, D., & Nyarko, G. (2015). Review of the pest status, economic impact and management of fruit-infesting flies (Diptera: Tephritidae) in Africa. Journal of Entomology and Nematology, 7(10), 1488–1498.

Barnes, B. N., & Venter, J. H. (2006). The South African fruit fly action plan: area-wide suppression and exotic species surveillance. In: Proceedings of the 7th International Symposium on Fruit Flies of Economic Importance, 271–283.

Boulahia-Kheder, S. (2020). Review on major fruit flies (Diptera: Tephritidae) in North Africa: Bio-ecological traits and future trends. Crop Protection, 105416.

Christenson, L. D., & Foote, R. H. (1960). Biology of fruit flies. Annual Review of Entomology, 5(1), 171–192.

Dhillon, M. K., Singh, R., Naresh, J. S., & Sharma, H. C. (2005). The melon fruit fly, Bactrocera cucurbitae: A review of its biology and management. Journal of Insect Science, 5(1), 40.

Doorenweerd, C., Leblanc, L., Norrbom, A. L., San Jose, M., & Rubinoff, D. (2018). A global checklist of the 932 fruit fly species in the tribe Dacini (Diptera, Tephritidae). Zookeys, (730), 19.

Dyck, V. A., Hendrichs, J., & Robinson, A. S. (2005). Sterile Insect Technique: Principles and practice in area-wide integrated pest management. Springer. 1216 p.

Ekesi, S., & Billah, M. K. (2007). A field guide to the management of economically important tephritid fruit flies in Africa (2nd ed.). ICIPE Science Press, Nairobi, Kenya. 104 p.

Ekesi, S., De Meyer, M., Mohamed, S. A., Virgilio, M., & Borgemeister, C. (2016). Taxonomy, ecology, and management of native and exotic fruit fly species in Africa. Annual Review of Entomology, 61, 219–238.

Elfékih, S., & Haymer, D. S. (2010). Molecular taxonomic identification of Dacus and Ceratitis species from Sub-Saharan Africa using mitochondrial haplotypes. Journal of Economic Entomology, 103(5), 1842–1847.

Elghadi, E., & Port, G. (2019). Use of entomopathogenic fungi for the biological control of the greater melon fly Dacus frontalis in Libya. pp. 251–265.

Elghadi, E. O. A. (2016). Entomopathogenic fungi as a biological control for the greater melon fly Dacus frontalis (Becker) (Diptera: Tephritidae) (Doctoral dissertation, Newcastle University), 163 p.

Elharym, Y., & Belqat, B. (2017). First checklist of the fruit flies of Morocco, including new records (Diptera, Tephritidae). Zookeys, (702), 137.

Fetoh, B. E. S. A. (2009). Molecular, morphological and histological differentiation between the lesser pumpkin fly, Dacus ciliatus (Loew) and the greater pumpkin fly, Dacus frontalis Becker. Egyptian Journal of Genetics and Cytology, 38(2).

Fletcher, B. S. (1987). The biology of Dacine fruit flies. Annual Review of Entomology, 32(1), 115–144.

Hafsi, A., Abbes, K., Harbi, A., Ben Othmen, S., Limem, E., Elimem, M., & Chermiti, B. (2015). The pumpkin fly Dacus frontalis (Diptera: Tephritidae): A new pest of cucurbits in Tunisia. EPPO Bulletin, 45(2), 209–213.

Hoddle, M. S. (2004). Restoring balance: Using exotic species to control invasive exotic species. Conservation Biology, 18(1), 38–49.

Howarth, F. G. (1991). Environmental impacts of classical biological control. Annual Review of Entomology, 36(1), 485–509.

IAEA. (2003). Trapping guidelines for area-wide fruit fly programmes. Vienna: International Atomic Energy Agency.

Kamali, S., Karimi, J., Hosseini, M., Campos-Herrera, R., & Duncan, L. W. (2013). Biocontrol potential of the entomopathogenic nematodes Heterorhabditis bacteriophora and Steinernema carpocapsae on cucurbit fly, Dacus ciliatus (Diptera: Tephritidae). Biocontrol Science and Technology, 23(11), 1307–1323.

Langford, E. A., Nielsen, U. N., Johnson, S. N., & Riegler, M. (2014). Susceptibility of Queensland fruit fly, Bactrocera tryoni (Froggatt) (Diptera: Tephritidae), to entomopathogenic nematodes. Biological Control, 69, 34–39.

Layodé, B. F. R., Onzo, A., & Karlsson, M. F. (2020). Watermelon-infesting Tephritidae fruit fly guild and parasitism by Psyttalia phaeostigma (Hymenoptera: Braconidae). International Journal of Tropical Insect Science, 40(1), 157–166.

Leblanc, L., San Jose, M., Barr, N., & Rubinoff, D. (2015). A phylogenetic assessment of the polyphyletic nature and intraspecific color polymorphism in the Bactrocera dorsalis complex (Diptera, Tephritidae). Zookeys, (540), 339.

Manoukis, N. C., Geib, S. M., & Vargas, R. I. (2014). Effect of host Bactrocera dorsalis sex on yield and quality of the parasitoid Fopius arisanus. BioControl, 59(4), 395–402.

Maronsy, G. H., & Al-Mufti, S. A. (2019). Molecular identification of cucurbit fly Dacus ciliatus (Diptera: Tephritidae) infesting Cucurbitaceae family based on mitochondrial gene in Kurdistan region-Iraq. Journal of Duhok University, 22(2), 229–238.

Moreno, D. S., & Mangan, R. L. (2007). Bait matrix for novel toxicants for use in control of fruit flies (Diptera: Tephritidae). IAEA.

Quilici, S., Hurtrel, B., Messing, R. H., Montagneux, B., Barbet, A., Gourdon, F., ... & Simon, A. (2002, May). Successful acclimatization of Psyttalia fletcheri (Braconidae: Opiinae) for biological control of the melon fly, Bactrocera cucurbitae (Diptera: Tephritidae), on Reunion Island. In Proc. 6th Int. Symp. Fruit Flies of Economic Importance, Stellenbosch, South Africa (pp. 6–10).

Rizvi, P. Q., Choudhury, R. A., & Ali, A. (2009). Recent advances in biopesticides. In Microbial Strategies for Crop Improvement (pp. 185–203). Springer, Berlin, Heidelberg.

Sapkota, R., Dahal, K. C., & Thapa, R. B. (2010). Damage assessment and management of cucurbit fruit flies in spring-summer squash. Journal of Entomology and Nematology, 2(1), 007–012.

Shawkit, M. A., Basam, A. N., Hussian, F., Edan, L. H., & Mahmood, A. R. (2011). Population density and biological studies of two cucurbit fly's species: Dacus ciliatus Loew and Dacus frontalis Becker (Diptera: Tephritidae). Journal of Madenat Alelem University College, 3(2), 78–84.

Steffens, R. J. (1983). Ecology and approach to integrated control of Dacus frontalis on the Cape Verde Islands. In: Cavalloro, R. (Ed.), Fruit Flies of Economic Importance, pp. 632–638. Proceedings of the CEC/IOBC International Symposium, Athens, Greece, 16–19 November 1982.

Virgilio, M., Backeljau, T., Barr, N., & De Meyer, M. (2008). Molecular evaluation of nominal species in the Ceratitis fasciventris, C. anonae, C. rosa complex (Diptera: Tephritidae). Molecular Phylogenetics and Evolution, 48(1), 270–280.

Virgilio, M., White, I., & De Meyer, M. (2014). A set of multi-entry identification keys to African frugivorous flies (Diptera, Tephritidae). Zookeys, (428), 97–112.