Host Use of <I>Bactrocera latifrons</I>, a New Invasive Tephritid Species in Tanzania

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Host Use of *Bactrocera latifrons*, a New Invasive Tephritid Species in Tanzania

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ABSTRACT *Bactrocera latifrons* (Hendel) is a pest of Asian origin, first detected in Africa in 2006. We assessed the host utilization of this quarantine pest in Morogoro region, eastern central Tanzania, by collecting a wide range of cultivated and wild host plants of species belonging to Solanaceae and Cucurbitaceae from April 2007 to April 2008. Fruit were collected from 29 plant species and varieties (16 Solanaceae and 13 Cucurbitaceae) in all agroecological zones of Morogoro region. Twelve solanaceous fruit species yielded *B. latifrons* of which four are new host records: *Capsicum annuum* L. cov. *longum* A. DC., *Capsicum chinense* Jacq., *Solanum sodomeum* L., and *Solanum scabrum* Mill. Similarly, three cucurbitaceous fruit species provided positive rearings and are new host records: *Citrullus lanatus* (Thunb.) Matsum & Nakai, *Cucumis dipsaceus* L., and *Momordica* cf *trifoliata* L. The infestation rate and incidence of the pest was mainly high in the solanaceous hosts of nightshades (*Solanum nigrum* L. and *Solanum scabrum*) and African eggplants (*Solanum aethiopicum* Lam. and *Solanum anguivi*). In a host preference study involving limited number of cultivated solanaceous crops, *S. scabrum* was recorded as the most preferred host. The pest has been found to outnumber *Bactrocera invadens* (Drew et al.), *Bactrocera cucurbitae* (Coquillett), and *Ceratitis capitata* (Wiedemann) in most of the common solanaceous hosts.

KEY WORDS *Bactrocera latifrons*, host range, host preference, Africa, Solanaceae

Bactrocera latifrons (Hendel) (Diptera: Tephritidae) is indigenous to South and Southeast Asia but has an adventive population in the Hawaiian Islands (Vargas and Nishida 1985a, White and Elson-Harris 1994, Shimizu et al. 2006). It was detected for the first time in Morogoro region, eastern central Tanzania in 2006 (Mwatawala et al. 2007), this also being the first record of the pest in Africa. In 2007, *B. latifrons* was reported from southern Kenya near the border with Tanzania but so far, the species has not been reported from any other African country (De Meyer et al. 2007). The host range of *B. latifrons* is mainly limited to members of the Solanaceae and Cucurbitaceae, but the infestation is low for the latter (Vargas and Nishida 1985a, Liquido et al. 1994, White and Elson-Harris 1994, Carroll et al. 2004). In Asia, it has been occasionally reported from other plant families besides Solanaceae or Cucurbitaceae (Allwood et al. 1999). Despite having a narrow host range, *B. latifrons* is a pest of quarantine importance and has the potential to permanently establish itself and compete and/or coexist with other native and previously introduced tephritid species. Because of this, elements of its population biology and demography (Vargas and Nishida 1985b; Vargas et al. 1996, 1997; McQuate et al. 2007) and dispersal and host preference (Peck and McQuate 2004) have been studied extensively in Hawaii for more than two decades. Recently, control measures in this region through the use of parasitoids (Bokonon-Ganta et al. 2007) and fruit fly bait (McQuate 2009) were presented, and a specific lure was developed for its detection (McQuate and Peck 2001, McQuate et al. 2004).

We investigated the host range and preference of *B. latifrons* in Tanzania. The major aim of the study was to establish some ecological traits that may be used for developing management strategies for this pest. Field investigations were conducted to determine host use, preference, and niche overlap of *B. latifrons* with other tephritid fruit flies in Morogoro region, eastern central Tanzania.

Materials and Methods

Host Range of *B. latifrons*. Studies on host utilization of *B. latifrons* involved sampling fruit of cultivated and wild Solanaceae and Cucurbitaceae. Fruit were randomly and periodically collected between March 2007 and March 2008 from all three agroecological zones of Morogoro region, namely, river basin and valley (<300 m above sea level [asl]), plateau (300–600 m asl), and mountainous zones (> 600 m asl)

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(URT 2002). Fruit sampling largely followed the methodologies described by Copeland et al. (2002). In each locality, a minimum of 10 fruit were sampled for each host species, depending on the availability. Because of this, numbers and weights of fruit samples were not equal across species. Each collected fruit sample was placed in a uniquely labeled plastic bag; the fruit within each sample were not separated but kept bulked.

Collected fruit were transported within a day to the rearing unit in the Horticulture Unit at Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Fruit were weighed, counted, and placed in rearing cages similar to those described by Copeland et al. (2002). Holding cages were made of two rectangular transparent plastic containers (23 by 16 cm [top] and 21 by 13 cm [bottom]). One container perforated with ellipsoid holes at the bottom and with polythene mesh-covered top for ventilation was tightly fitted on top of the second container. The latter contained a thin layer (1 cm) of moistened sterile sandy soil to hold exudates dripping from the rotting fruit. Sandy soil also served as pupation substrate for the "popping" larvae as they left the fruit. Ellipsoid holes prevented fruit from clogging the holes and allowed mature larvae to fall into the soil after leaving the host fruit. Rearing of fruit flies followed procedures outlined by the African Fruit Fly Initiative (Ekesi 2006). After 10–12 d of incubation at room temperature (23- 25°C), containers were examined daily for adult fruit flies emergence until no more flies emerged. Emerged adult flies were removed from rearing cages by aspirator (pooter) and preserved in vials containing 70% alcohol for identification. Fly identification was accomplished with the aid of keys by White and Elson-Harris (1994), CABI (2005), and White (2006). For each sample, we recorded the number of flies emerging for each species of fruit fly. The results were expressed as infestation rates i.e., number of adult tephritids obtained per unit weight of a fruit species (only samples positive for *B. latifrons* were included). A positive sample meaning thus that the bulk of the fruit produced fruit flies but not taking into account how many fruit within a sample produced flies. Therefore, the weight of the total sample is used in calculating the infestation rate). Incidence was expressed as the percentage of infested samples to the total number of samples for a particular fruit species.

Niche overlap of *B. latifrons* and coemerged fruit fly species was studied by first determining the infestation rate of each fruit fly species in each common host. These infestation rates were then pooled and percentage for each fruit fly species was determined (Liquido et al. 1994). Furthermore, the average infestation rates of fruit fly species in the common solanaceous hosts was analyzed using Kruskal–Wallis, a nonparametric one-way analysis of variance (ANOVA) test. The fruit fly species was the source of variation and the common hosts (seven) were the replicates. The analysis was carried out using GENSTAT (VSN International Ltd., Hemel Hempstead, Hertfordshire, United Kingdom).

Host Preference of *B. latifrons* Among Cultivated Solanaceous Crops. Host preference of *B. latifrons* in selected solanaceous crops was studied in a randomized complete design (RCD), with three replications. The source of variation was solanaceous species, and five species in total were compared: *Solanum aethiopicum* L., *Lycopersicon esculentum* L., *Capsicum frutescens* L., *Capsicum annuum* L. cov. *longum* (hereafter referred to as paprika), and *Solanum scabrum* Mill. The three replications were at least 5 km apart, all in the plateau agroecological zone, within Morogoro municipality. All the different crops were established in each of the replicates following standard agronomic practices and were left to be naturally infested. At ripening, fruit were harvested randomly every week and handled as described in section on *Host Range.* Infestation rate and incidence were computed as for the host range study (cf. above). One-way ANOVA was used to compare mean infestation rates of solanaceous crops by *B. latifrons* as well as their incidence. However, for incidence, the data were first converted to ratios and then log transformed to improve normality. The data were analyzed using GENSTAT (VSN International Ltd.).

Results

Host Range. In total, 56,200 fruit (351 kg) were collected from 1,606 samples representing 16 solanaceous and 13 cucurbitaceous plant species (Table 1). Twelve solanaceous fruit species yielded *B. latifrons*, whereas only three cucurbit species provided positive results. Of the positive solanaceous plants, *Solanum sodomeum* L., *Solanum incanum* L., and *Lycopersicon pimpinellifolium* (Jasl.) Mill., were recorded as wild hosts. The rest were cultivated hosts (Table 1). Only *Citrullus lanatus* (Thunb.) Matsum & Nakai was found to be a host plant among the cultivated cucurbitaceous species sampled, whereas *Cucumis dipsaceus* L. and *Momordica* cf *trifoliata* were the positive wild cucurbitaceous hosts. Quantitative data on random collection of host plants of *B. latifrons* in Morogoro region shows that, of all solanaceous hosts, *Solanum nigrum* L. yielded the highest number of *B. latifrons* flies per kilogram when looking at positive samples only, followed by *Solanum anguivi* Lam. and *S. scabrum* (Table 1). Paprika, *Solanum macrocarpon* L., and *S. sodomeum* had the lowest infestation rates. Hosts with high infestation rate usually also had a high incidence, with *S. anguivi* recording the highest value (93%). Among the cucurbitaceous fruit, only *C. dipsaceus* had a relatively high infestation rate. However, incidence for cucurbit hosts was very low (5.36% maximum, for *M.* cf *trifoliata*, and only single positive samples for the other positive hosts).

The current study puts on record for the first time *S. sodomeum*, *S. scabrum*, paprika, *Capsicum chinense* Jacq., *C. lanatus*, *C. dipsaceus*, and *M.* cf *trifoliata* as new host records of *B. latifrons* worldwide. In addition,

Table 1. Positive and negative hosts of *B. latifrons* including new host records and coemergence

Host latin name	Host common name	Total no. fruits	Total wt (Kg)	Total no. samples	No. positive samples	Infestation rate		Incidence	Other emerged tephritids
						Positive samples only	All samples		
Capsicum annuum var. *longum**	Paprika	1754	22.316	148	5	0.51	0.063	3.38	None
Capsicum annuum var. yellow wonder	Bell pepper	419	4.159	29					Cc
*Capsicum chinense**	Habanero pepper	82	1.559	82	22	53.04	15.9	26.83	Cc
Capsicum frutescens var. *tabasco*	Tabasco pepper	16	0.021	1					Cc
Capsicum frutescens (cayenne)	Cayenne pepper	564	1.267	23					None
*Citrullus lanatus**		42	0.432	42	1	1.61	0.04	2.38	Bc, Dp, Dc
Cucumis melo L.	Wild cucumber	79	2.664	6					Bc
Cucumis sativus (local variety)	Local cucumber	15	0.523	3					Dc, Dv
*Cucumis dipsaceus**	Teasel gourd	394	5.938	42	1	45.45	0.17	2.38	Dc
Cucumis ficifolius		50	0.83	8					Dc, Dp
Cucumis sativus cv. *Ashley*	Cucumber	342	25.743	46					Bc, Db, Dc, Df, Dp
Cucurbita moschata	Pumpkin	707	29.286	83					Bc, Db, Dc, Df, Dp Dv
Cucurbita pepo	Zucchini	7	0.519	1					Db
Lagenaria siceraria	Calabash	55	0.795	7					Bc, Db, Dc, Df
Luffa acuntangula	Angled luffa	110	7.996	23					Bc, Db, Dc, Dp
Luffa aegyptica	Smooth luffa	4	0.109	1					None
Lycopersicon esculentum	Tomato	3578	8.827	145	25	12.56	1.56	17.24	Bi, Dv
Lycopersicon pimpinellifolium	Cherry tomato	293	61.724	67	19	44.2	14.5	28.36	Dc
*Momordica cf trifoliata**		1085	8.814	56	3	7.8	0.45	5.36	Bc
Momordica charantia	Bitter gourd	58	0.588	4					None
Nicandra physalodes	Apple of Peru	72	0.096	4					None
Solanum aethiopicum	African eggplant	3411	61.179	228	157	44.97	36.94	68.86	Bi, Bc, Cc, Db, Dc
Solanum anguivi	African eggplant	6003	10.269	70	65	124.34	118.71	92.86	Bc, Bi, Dc
Solanum incanum		3892	28.682	166	28	33.44	4.99	16.87	Bi
Solanum macrocarpon	African eggplant	208	21.23	42	3	8.11	0.52	7.14	None
Solanum melongena	Eggplant	141	5.993	23	4	17.99	1.17	17.39	None
Solanum nigrum	Black nightshade	4785	2.016	44	21	136.74	98.21	47.73	Bi
*Solanum scabrum**		27698	29.343	175	115	61.73	63.12	65.71	Bc, Dc, Cc
*Solanum sodomeum**	Sodom apple	336	8.086	37	19	13.2	8.78	51.35	Bi

Bi, *Bactrocera invadens;* Bc, *Bactrocera cucurbitae;* Cc, *Ceratitis capitata;* Db, *Dacus bivittatus;* Dc, *Dacus ciliatus;* Df, *Dacus frontalis;* Dp, *Dacus punctatifrons;* Dv, *Dacus vertebratus.*

* New host record.

L. pimpinellifolium, S. anguivi, S. nigrum, S. melongena, S. incanum, and *L. esculentum,* which were reported previously by Vargas and Nishida (1985a), Liquido et al. (1994), White and Elson-Harris (1994), and De Meyer et al. (2007) as hosts in Asia and Hawaii, are new records for Africa; *S. macrocarpon* and *S. aethiopicum* were earlier reported by Mwatawala et al. (2007).

The highest diversity of fruit fly coemergence (Table 1) was observed in *S. aethiopicum* where *B. latifrons* coemerged with *Bactrocera invadens* Drew, Tsuruta & White, *Bactrocera cucurbitae* (Coquillett), *Dacus ciliatus* Loew, *Dacus bivittatus* (Bigot), and *Ceratitis capitata* (Wiedemann). Of all positive hosts, *B. latifrons* coemerged with at least one other fruit fly, except for paprika, *S. macrocarpon,* and *S. melongena. B. latifrons* was predominant in the majority of hosts (Fig. 1). Only in *C. chinense,* there was a large coemergence with *C. capitata.*

Further analysis indicates that the highest mean infestation rate of fruit flies in these fruit was that of *B. latifrons,* followed by *B. invadens, C. capitata,* and *B. cucurbitae* (Fig. 2). The differences in infestation rates were significant between *B. latifrons* and the other two species, *C. capitata* and *B. cucurbitae,* whereas the difference between *B. latifrons* and *B. invadens* was not significant.

Host Preference of *B. latifrons* Among Cultivated Solanaceous Crops. The study revealed that *S. scabrum* was the most preferred host plant by *B. latifrons* in terms of infestation rates (Fig. 3), whereas paprika was the least preferred. The infestation rate of *B. latifrons* in *S. scabrum* was significantly higher than that of all other solanaceous species. The infestation rates of *B. latifrons* in the remaining solanaceous species were not significantly different (Fig. 3). Similarly, the incidence of *B. latifrons* was highest in *S. aethiopicum* and *S. scabrum* and was lowest in paprika (Fig. 4). *S. scabrum* observed to be an important host of *B. latifrons* among the cultivated solanaceous hosts, although it is not widely grown and consumed in Tanzania.

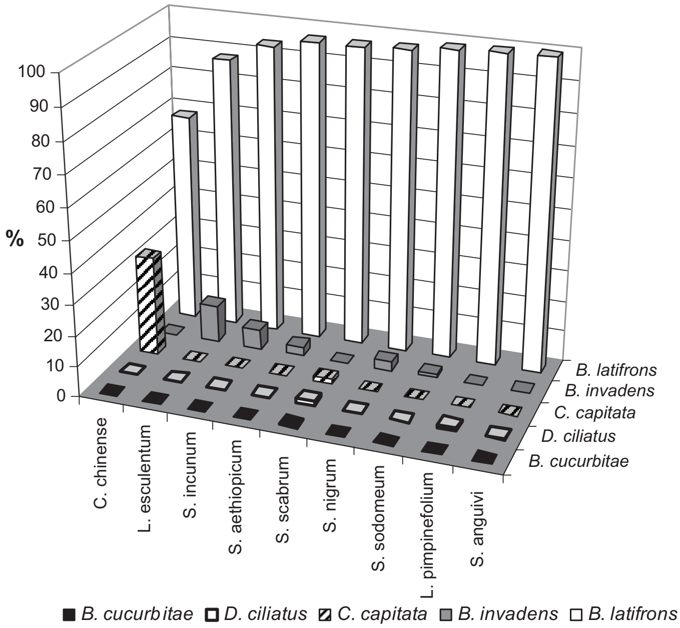

Fig. 1. Coemergence of *B. latifrons* with other fruit fly species from solanaceous hosts.

Discussion

Host Range of *B. latifrons*. The invasive *B. latifrons* was reared from 15 potential host plant species in the Solanaceae and Cucurbitaceae. Most of these crops are widely cultivated by small-scale-growers year-round in commercial and backyard gardens. The study further shows that *B. latifrons* prefers plants belonging to solanaceous rather than cucurbitaceous plants. This is in agreement with the reports by Vargas and Nishida (1985a) and White and Elson-Harris (1994) that *B. latifrons* uses solanaceous host plants and occasionally attacks cucurbitaceous plant species with low infestation rate. This observation validates the information provided by Vargas and Nishida (1985a) that *B. latifrons* exhibits oligophagous feeding habit under natural conditions. In Asia, Allwood et al. (1999) reports the species from other plant families. A parallel study in the Morogoro region, and covering a wider spectrum of potential fruit hosts, including representatives of several other plant families such as Annonaceae, Myrtaceae, Rubiaceae, and Rutaceae, did not yield any positive results for *B. latifrons* (Mwatawala et al. 2009). This indicates that, at least in this region, the species is restricted to these two host families. Such specialized behavior enables *B. latifrons* to establish in niches less occupied by other frugivorous tephritids and therefore exacerbates the damage and losses contributed by fruit flies in horticultural industry. It should be noted that infestation rates, as used in this study, does not allow us to differentiate between actual hosts maintaining a population or population sinks whereby the net reproductive rate is less than one

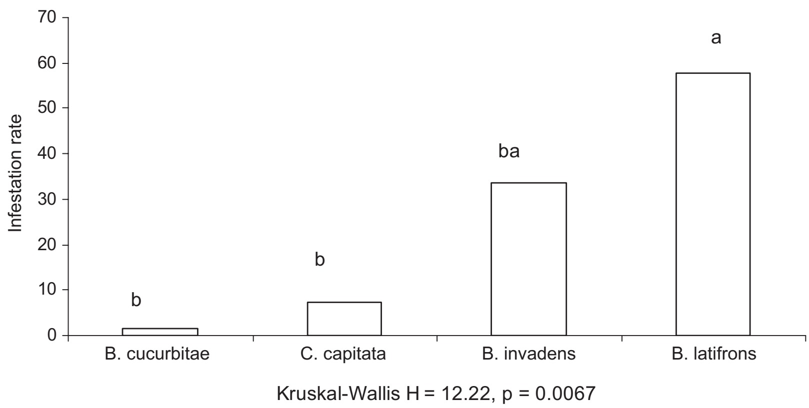

Fig. 2. Mean infestation rates of *B. latifrons* and coemerged fruit fly species from solanaceous fruit (means with same letters are not significantly different).

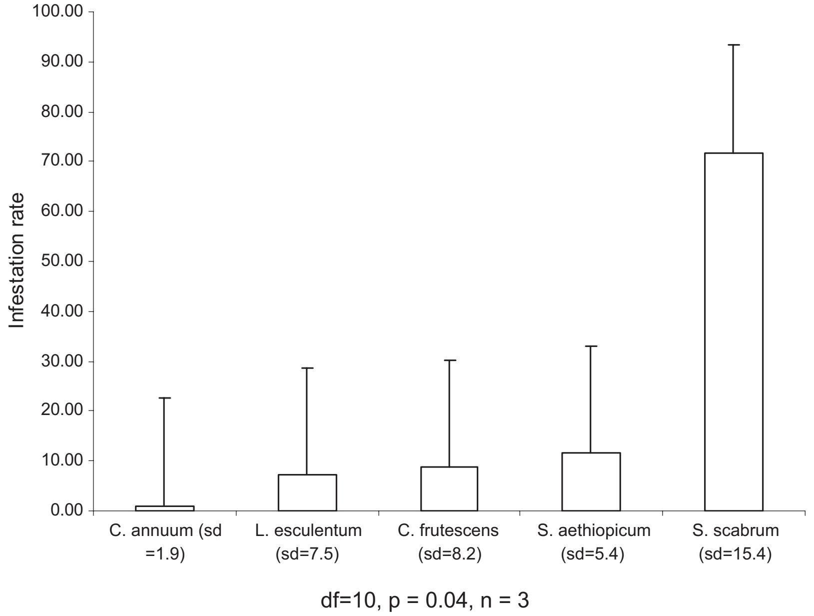

Fig. 3. Mean infestation rate of *B. latifrons* in cultivated solanaceous hosts.

because of a high mortality rate in the juvenile stage. Caution should be taken, therefore, to imply that particular hosts recognized here can in fact sustain a fruit fly population on their own.

Niche overlap among *B. latifrons* and other aggressive and destructive frugivorous tephritid species was observed. *B. latifrons* was found to coexist with *B. invadens, B. cucurbitae C. capitata, D. ciliatus,* and *D. bivittatus* in some commercial and wild solanaceous and cucurbitaceous host plants. Generally, *B. latifrons* was predominant in the solanaceous host plants. Its presence in cucurbitaceous hosts is minimal in comparison with *B. cucurbitae,* which is the predominant infesting species of this host family in this region (M.M. et al., unpublished data). In addition, there is a high number of indigenous *Dacus* species (such as *D. bivittatus, D. ciliatus,* or *D. punctatifrons*) that are known to attack Cucurbitaceae (White 2006). The ability of *B. latifrons* to coexist with highly aggressive invasive species (such as *B. invadens, B. cucurbitae*) as well as major indigenous pests (such as *C. capitata* and *Dacus* spp.) is of ecological interest. Apparently

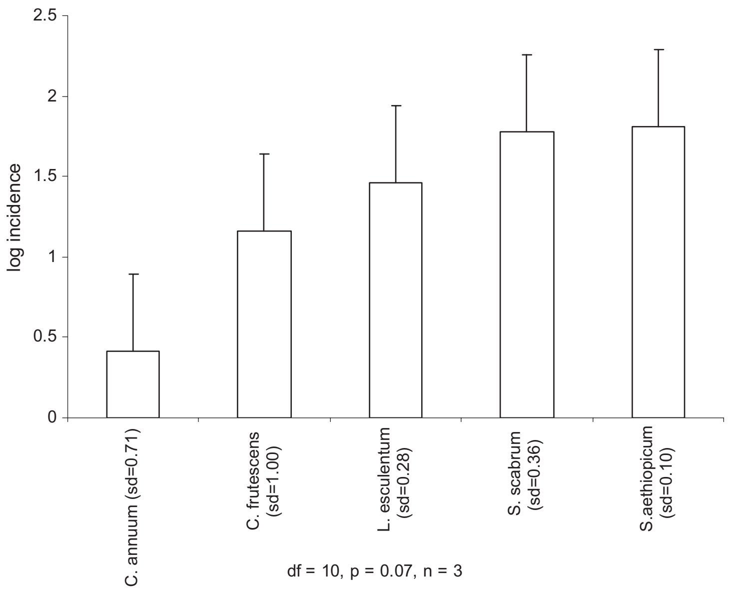

Fig. 4. Mean incidence of *B. latifrons* in cultivated solanaceous hosts.

the ability of *B. latifrons* to use certain solanaceous host plants allowed it to fill niches under used by other fruit fly species in certain localities.

Host Preference of *B. latifrons* Among Cultivated Solanaceous Crops. Among the cultivated solanaceous hosts, *B. latifrons* seems to prefer *S. scabrum* and *S. aethiopicum.* The incidence of the pest in *S. scabrum* is very high, and Liquido *et al.* (1994) reported highest infestation rate of *B. latifrons* in another nightshade, *S. nigrum,* in Hawaii. However, it is the leaves of nightshades and not fruit that are consumed by people in some parts of Tanzania; hence, the economic loss might not be very high. However, the presence of nightshades in the fields/backyards can lead to a build up of the population of the pest that can then attack other edible solanaceous fruit and cause significant losses. M.M. et al. (unpublished data) pointed out that agricultural practices prevalent in Tanzania, play a role here. Several solanaceous crops, such as tomato, are heavily sprayed preventing them from being infested heavily. In the case of local eggplants such as *S. aethiopicum,* it is the unripe fruit that are consumed. Only the mature, red fruit, were found infested when left in the field until they have ripened for seeds extraction by local farmers, and the economic loss might not be so high. The infestation rate of *B. latifrons* in *C. annuum* is very low but could be more important compared with *S. scabrum* and *S. aethiopicum.* Because this is a crop with export potential, further information should be obtained on the effect of infestation by *B. latifrons.* With this regard, more surveys are needed to cover much of the country where potential hosts of *B. latifrons* are available. The exact impact of this species on cultivated solanaceous crops will only be fully understood when more data are collected on farms throughout the range. The ability of *B. latifrons* to use wild host plant species in marginalized and less managed areas can favor the build up of population and spread of *B. latifrons* in the country. This suggests that wild host plant species should not be overlooked when designing an integrated pest management program for the pest.

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