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Alternate Host of *Diadegma insulare* (Hymenoptera: Ichneumonidae), a Parasitoid of Diamondback Moth (Lepidoptera: Plutellidae): A Preliminary Search

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Abstract: Potential alternate host larvae and pupae were collected from wild and cultivated *Brassica* plants, apple (*Malus domestica*) trees, ornamental honeylocust tree (*Gleditsia triacanthos*), and corn (*Zea mays*) plants for laboratory observations. Laboratory reared *Phthorimaea operculella* and *Sitotroga cerealella* were used for parasitism by *D. insulare*. There was no parasitism observed to all Lepidoptera except for *Plutella xylostella* L., suggesting that they are unlikely to be the hosts of *D. insulare*. *D. insulare* were observed to parasitize *Plutella porrectella*, but neither host pupae nor parasitoid pupae were formed. Interestingly, *Phthorimaea operculella* and *Sitotroga cerealella*, both gelechiids, were parasitized by *D. insulare* (new record). In contrast to the parasitized *P. xylostella*, the larval developmental time of gelechiids to pupation was prolonged. It is suggested that the search for alternate host of *D. insulare* should be continued and focused on the microlepidopterous larvae.

Key words: Diamondback Moth, *Diadegma insulare*, alternate hosts, overwintering, integrated pest management.

Introduction

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is a cosmopolitan insect and major pest of crucifer crops worldwide (Talekar & Shelton, 1993). It has been reported to be resistant to most of the pesticides (Cheng, 1988; Tabashnik *et al.*, 1990). Therefore, the control program of DBM has been focused on integrating all available methods including the use of biological agents such as bacteria, fungi, viruses and the parasitoids (Idris & Norhayati, 1997). *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae) is a major parasitoid of DBM in North and Central America (Harcourt, 1986; Biever *et al.*, 1994). In Michigan, DBM occurs at relatively low population densities, rarely reaching outbreak levels. This is probably due to the abundance of *D. insulare* population in the field (Idris & Grafius, 1983). The rate of parasitism of diamondback moth larvae by *D. insulare* have been reported between 70 and 100% during mid-July through October, but the rate is generally low (< 30%) in May and June (Harcourt, 1986; Idris, 1995). The low parasitism rate during early spring may be associated with the overwintering problem of this parasitoid. Putnam (1978) reported that *D. insulare* does not survive winter condition in Saskatchewan, Canada. Recent observations have indicated that DBM larvae successfully overwinter in western Canada and northern United States, but none of them formed *D. insulare* pupae. There was also no indication that *D. insulare* adults do migrate from southern United States in early spring as the DBM adults (Harcourt, 1986). Interestingly, we observed *D. insulare* adults in the field as early as mid-May for three consecutive years (1992 to 1994). As such, we hypothesized *D. insulare* has alternate hosts to survive the winter conditions in Michigan. This study was aimed to search for the potential alternate hosts (insects) of *D. insulare* that may associate them with the cultivated and wild Brassicaceae and non-host plants of DBM.

Materials and Methods

Insects associated with wild *Brassica* plants: Fifty to 100 wild *Brassica* plants per species per year were collected from Michigan State University (MSU) Research Farms and three other locations adjacent to MSU campus between April and

September 1993 and 1994 (Table 1). Each plant was hand-pulled and put on white papers placed on the ground. The plants were first shook over the papers for 3 min and then thoroughly inspected for left over larvae and pupae especially from the florets (Marsh, 1917). Larvae (fed leaves of the plants where they were collected) were brought to laboratory and kept at 25 ± 2°C and a photoperiod of 16:8 (L:D) h until adults emergence. We also put white sticky traps (Pherocon™ 1C - bottom, Trece, Inc., Salinas, CA) following the method of Idris (1995) at places where plants were collected to catch the possible *D. insulare* adult emergence from overwintering.

Ten to 15 leaves per plant (as above) were randomly selected and detached. They were brought to laboratory and placed in 10 x 7 x 5 cm³ rearing pans (3 x 4 cm² lid at the top), and kept as above for 8 - 10 d to allow eggs hatch. Leaves were kept fresh by putting wet paper towel under the leaves. Larvae were exposed for parasitism by *D. insulare* following the method of Idris and Grafius (1996). Presumably parasitized larvae were reared as above, until parasitoid pupae formed or host adults emerged.

Lepidopterous larvae in broccoli field: We collected all Lepidoptera larvae found in broccoli field between July to August 1993 and 1994. Thirteen larvae were also exposed for parasitism by *D. insulare* as above. Larvae were reared on the broccoli leaf (Idris & Grafius, 1996) until pupation.

Cultivated broccoli remains: Six cages (180 x 165 x 165 cm³) were set in broccoli experimental plots at Michigan State University Collins Road Entomology Research Field on 28 October 1993. There were 10 - 12 broccoli plants per cage. In May 1994, four white sticky traps were hung (0.5 m from the ground) in each cage to trap the emerged or presumably overwinter *D. insulare* adults. To double check the presence of *D. insulare* adult six potted broccoli plants, grown in greenhouse and infested with DBM second and third instars, were also placed inside each cage starting on 7 May, 1994. Larvae were collected weekly, brought to laboratory and reared on broccoli leaves until adult emergence. The infested potted broccoli plants were replaced weekly, and larval

Idris and Grafius: Alternate host for *Diadegma insulare*

collection and rearing were continued until the end of June 1994. Number of *D. insulare* adults caught and types of pupae formed were recorded.

Insects associated with non-host plants of the diamondback moth: Ten insect species (six tortricids, two gelechiids, and one plutellid and pyralid) were sampled from fields or tested in laboratory. These insects were selected because their host plants are often planted close to *Brassica* fields in Michigan. Aside from this certain species of the tortricids and gelechiids were reported as potential alternate hosts for *Diadegma* (*Agitia cerophaga* Horstman (Hymenoptera: Ichneumonidae), a closely related species of *D. insulare*, which is also a parasitoid of DBM in England (Hardy, 1938).

Experiment 1: Potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae): Two one-month old potted potato plants grown in greenhouse were put in 45 x 40 x 40 cm³ cages in the laboratory. In first observation, 100 *P. operculella* eggs, donated by Walter Pett (Department of Entomology, Michigan State University), were placed on potato plants (four replicates, one plants per replicate) in the cages and kept at 25 ± 2°C with 16:8 (L:D) h photoperiod. After most eggs hatched, four 3-days old mated *D. insulare* female adults (from our laboratory cultures) were released into

the cages for 4 d to parasitize PTM first instar. The parasitoid adults were fed diluted honey, wetted on cotton wick placed in a 5 cm diam open petri dish.

In second observation, we put *P. operculella* eggs in 14.5 cm diam Petri dish, which was pre-filled with potato cut, until hatch. Forty second, third or fourth moth instars, which we consider as three treatments, were collected accordingly. They were released on potato plants in the cages (four replicates per treatment, one plant per treatment or cage) and kept for 24 h before exposed for parasitism by four 3-d old mated *D. insulare*. Presumably parasitized PTM larvae were collected from the leaves, stems and the tubers, put in 10 x 7 x 5 cm³ rearing pan that was half filled with clean non-infested potato tubers and kept as before. The numbers of moth and parasitoid pupae formed were recorded daily until all larvae pupated. The developmental time (day) of unparasitized and parasitized PTM larvae of each treatment was taken from the average time of the larvae to form pupae. Five parasitoid pupae per replicate were placed in 14.5 cm diam Petri dish for adult emergence. The sexes of the parasitoid adults were recorded. These adults were later used in our third observation.

In third observation, we cross-checked the occurrence of parasitism on DBM by *D. insulare* reared from *P. operculella* (above). Thirty DBM third instar were exposed to a 3-day old mated female *D. insulare* for 3 h in modified 400 ml transparent plastic cup following the method of Idris and Grafius (1996). For control, we exposed the same number of larvae to *D. insulare* reared from DBM larvae. The presumably parasitized larvae were reared as before except they were fed broccoli leaves raised in greenhouse. Number of *D. insulare* and diamondback moth pupae formed were recorded.

The percent parasitism was calculated by the numbers of parasitoid pupae divided by the total numbers of both moth and parasitoid pupae multiplied with 100. The time taken by unparasitized and parasitized *P. operculella* larvae to form pupae and the percentage of female parasitoid offsprings were analyzed by one-way ANOVA (Abacus Concept 1991).

Experiment 2: Angoumois grain moth, *Sitotroga cerealella* (Oliver) (Lepidoptera: Gelechiidae): The *S. cerealella* used in

this study was donated by Dr. D. K. Weaver, South Atlantic Area Stored-Product Insects Research and Development Laboratory, Georgia, USA. A folded black paper stapled at both ends (6 x 2 cm²) was placed in a 400 ml transparent plastic cup for oviposition. Ten pairs of *S. cerealella* were released into cup for 3 days after which they were taken out leaving the eggs on black paper. Five 3-days old mated *D. insulare* females were released into the cup for 4 d for parasitism (only when > 50% eggs were hatched). Food was added up to a three fourth of the cup after the parasitoid adults were taken out. The numbers of *S. cerealella* and *D. insulare* pupae formed, and the emerged adults of both insects were recorded.

Experiment 3: European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Pyralidae): Forty of the *O. nubilalis* first instar (donated by Dr. Douglas A. Landis, Department of Entomology, Michigan State University) were divided into two groups (five larvae per group per replicate). Group-1 larvae were tested, while they were still in first instar. However, the group-2 larvae were tested only after they became second instar. Larvae of each group were exposed for parasitism by *D. insulare* as before. The presumably parasitized larvae of both groups were reared on artificial diet until pupation. The pupae of *O. nubilalis* or parasitoid formed were recorded and percent parasitism was calculated as before. We also collected 100 *O. nubilalis* larvae (20 larvae per instar) from field of Michigan State University to determine in-field parasitism by *D. insulare*. However, larvae collected were reared on corn's cobs until pupation.

Experiment 4: Tortricids in Apple Orchard: We collected tortricids larvae from apple leaves and 1000 fruits at the Entomology Research Field beginning 2 July through September 1994. Larvae collected were reared in rearing pan as above and fed with apple shoot or cut off apple fruit until pupation. We also collected leaves and shoots that had moth eggs, brought to the laboratory, separated according to specific species eggs, and kept as before until 80% hatched. A total of 10 first instar larvae of each tortricid species were placed in modified plastic container following the method of Idris and Grafius (1996). Larvae were immediately exposed to one-day old mated *D. insulare* for 4 h inside the container for parasitism. Presumably parasitized tortricids larvae were fed on apple leaf or fruit slices placed in the rearing pan until pupation. The numbers and type of pupae formed were recorded.

Experiment 5: Mimosa webworm, *Homadaula anisocentra* Meyrick (Lepidoptera: Plutellidae): Larvae of *H. anisocentra* were collected from 250 - 300 *Gleditsia triacanthos* L. trees around the campus and the nursery of the Forestry Department Michigan State University in June and July 1994. They were then reared in laboratory, fed *G. triacanthos* leaves, and kept as before until pupation. The numbers of parasitoid and moth pupae formed were recorded.

Results and Discussion

Insect associated with wild Brassicaceae: Insects associated with wild Brassica in present study were the Lepidoptera (DBM, *P. xylostella*; imported cabbage worm, *Pieris rapae* L.; cabbage looper, *Trichoplusia ni* L.; *P. porrectella* L. and the unidentified microlepidopterans and macrolepidopterans), Diptera (*syrphid* spp.) and Coleoptera (coccinellids, lady bird beetles) (Table 1). There were no *D. insulare* pupae formed from field collected insect larvae other than DBM (50 - 94%). This indicated that insect other than DBM are unlikely the

Idris and Grafius: Alternate host for *Diadegma insulare*

Table 1: Insects collected from wild Brassicaceae in the summer of 1993 and 1994¹

Weed Species	Common Name	Lepidoptera ²	Diptera	Coleoptera
<i>Barbarea vulgaris</i> R. Br.	Yellow rocket	ICW, DBM, CL	S	LB
<i>Berteroa incana</i> (L.) DC	Hoary alyssum	DBM	N	LB
<i>Brassica nigra</i> (L.) Koch	Black mustard	DBM	S	LB
<i>Brassica kaber</i> (DC) Wheeler	Wild mustard	DBM, ICM, UL*	S	LB
<i>Capsella bursa-pastoris</i> (L.) Medic	Shepard's purse	DBM	N	N
<i>Erysimum cheiranthoides</i> (L.)	Wormseed mustard	DBM	N	N
<i>Lepidium campestre</i> (L.) R. Br.	Field pepperweed	DBM	S	LB
<i>Lepidium densiflorum</i> (Schard)	Greenflower	DBM	S	LB
<i>Lepidium virginicum</i> L.	Virginia pepperweed	DBM	N	N
<i>Neslia paniculata</i> (L.) Desv.	Ball mustard	N	N	LB
<i>Raphanus raphanistrum</i> L.	Wild radish	DBM, ICW, CL	S	LB
<i>Sisymbrium altissimum</i> L.	Tumble mustard	DBM	N	LB
<i>Sisymbrium officinale</i> (L.) Scop.	Hedge mustard	DBM, ICW	S	N
<i>Thlaspi arvense</i> L.	Field pennycress	DBM	S	LB
<i>Hesperis matronalis</i> (L.)	Dame's rocket	PP, DBM*, UML, CL	S	N

¹ICW, Imported cabbageworm (*Pieris rapae*); DBM, Diamondback moth (*Plutella xylostella*); UL, Unidentified microlepidopteran; PP, *Plutella porrectella*; CL, Cabbage looper; UML, unidentified macrolepidopteran; S, Syrphid larvae; N, none; LB, Lady bird beetle; *, **, less than five DBM individuals larvae were collected.

²The first and last mentioned Lepidoptera larvae were the most and least numbers collected respectively. There was no *Diadegma insulare* pupae formed from all lepidoptera larvae except DBM. It was observed that neither PP nor *D. insulare* pupae formed from PP's larvae exposed to parasitism by *D. insulare*.

Table 2: Lepidoptera larvae collected from the broccoli field in summer 1993 and 1994, and percent parasitism by *Diadegma insulare*

Insect Species or family	Common Name	Numbers Collected	Percent parasitism
<i>Plutella xylostella</i> L.	Diamondback Moth	100	89.5 (93.4) ¹
<i>Pieris rapae</i> L.	Imported Cabbageworm	70	0 ^a
<i>Trichoplusia ni</i> L.	Cabbage looper	30	0 ^a
Tortricidae	-	10	0 ^a
Lymantridae	-	20	0 ^a
Arctiidae	-	10	0 ^b
Noctuidae	-	8	0 ^b
Unidentified microlepidopteran	-	2	0 ^c
Unidentified macrolepidopteran	-	4	0 ^c

¹ Percent parasitism of unexposed and exposed (in parenthesis) for parasitism by *D. insulare* in laboratory

^a There was no parasitism even though all larval stages were exposed for parasitism by *D. insulare*

^b Only late instar larvae were exposed to parasitism but fed broccoli leaves

^c Died because of food problem (did not feed on broccoli leaf offered) even though they were collected from the broccoli leaves.

Table 3: Percent parasitism of *Phthorimaea operculella* (Zeller) by *Diadegma insulare* (Cresson), the male to female sex ratio of *D. insulare* and the cross-check parasitism

Observation	Instar of <i>P. operculella</i> (\pm S. E.)				Cross-check parasitism (\pm S. E.) ¹	
	First	Second	Third	Fourth	<i>P. operculella</i>	<i>P. xylostella</i>
% Parasitism	34.3 \pm 4.8c	25.3 \pm 3.4b	8.8 \pm 1.2a	0a	88.9 \pm 10.5	90.6 \pm 11.4
Sex Ratio ² (male: female)	5.4 : 1	4.5 : 1	3.5 : 1	-	3.2 : 1	3.0 : 1

Means in row with same letters are not significantly different (Fisher's Protected LSD, $P > 0.05$)

¹ Parasitism of diamondback moth larvae by *D. insulare* emerged from *P. operculella* or *P. xylostella*

² The male to female sex ratio was not significantly different (χ^2 , $P > 0.05$)

Table 4: Tortricids (Lepidoptera) larvae collected from apple orchards in spring 1994¹

Scientific names ²	Common Name
<i>Cydia pomonella</i> (L.) (50)	Codling moth
<i>Grapholita molesta</i> (Busck) (50)	Oriental fruit moth
<i>Archips argyrospila</i> (Walker) (50)	Fruit tree leaf roller
<i>Choristoneura rosaceana</i> (Harris) (40)	Olivebanded leaf roller
<i>Platynota idaeusalis</i> (Walker) (20)	Tufted apple bud moth
<i>Platynota flavedana</i> (Walker) (25)	Variagated leaf roller

¹ No parasitism recorded to all six species of the tortricid (Lepidoptera) larvae

² Number in parenthesis indicates the number of larvae collected for that particular species.

hosts of *D. insulare*.

In laboratory, there was no parasitism on larvae of insect species other than DBM, when exposed to *D. insulare*. It was also observed that neither *P. porrectella* nor *D. insulare* pupae formed from parasitized DBM larvae. Although the external appearance of early pupal stages of the parasitized *P. porrectella* and DBM was similar, the parasitized DBM completely formed the parasitoid pupae (88% parasitism)

while the presumably parasitized *P. porrectella* body shrunk, failed to produce cocoon and died. This result somewhat support earlier report in Ontario, Canada, that there was no parasitism observed on the field collected *P. porrectella* (Smith & Sears, 1984).

Lepidoptera larvae in the broccoli field: Except for DBM larvae, none of the 150 field-collected Lepidoptera larvae, both exposed and non-exposed *D. insulare*, formed parasitoid pupae (Table 2). In laboratory, *D. insulare* females were never observed attacking Lepidoptera larvae other than DBM. This suggests that, at least in Michigan, common Lepidoptera feed on *Brassica* crops are unlikely to act as the alternate hosts of *D. insulare*.

Remains of the cultivated broccoli: There was no DBM or *D. insulare* adults observed or caught on the sticky traps placed in the emergence cages. However, three *Microplitis plutellae* (Muesbeck) adults were caught from one of the cages. A total of 20 pupae of *Microplitis plutellae* (Muesbeck) (Hymenoptera: Braconidae), but none for *D. insulare*, were produced from

Idris and Grafius: Alternate host for *Diadegma insulare*

DBM larvae exposed for parasitism in the cages. This implies that *D. insulare* did not use DBM for overwintering or DBM does not overwinter in the cabbage remains.

Insects associated with non-host plants of DBM:

Potato tuber moth (PTM), *P. operculella* (Gelechiid): The mean percent parasitism was 38.4 ± 6.8 in the first observation. In the second observation, percent parasitism was significantly different among PTM instars ($F = 7.52$; $df = 3, 9$; $P < 0.05$) (Table 3). Percent parasitism was significantly higher in early than in the later instars (Fisher's Protected LSD, $P < 0.05$). Results indicated that PTM could be an alternate host of *D. insulare* even though parasitism rate was comparatively lower (highest was 34.3%, Table 3) than that of DBM (up to 80%) (Harcourt, 1986; Idris & Grafius, 1993). Unlike DBM larvae, we observed that the larger *P. porrectella* larvae spent relatively very little time outside host plant (tuber, stem or leaf) than the smaller larvae (Bolter & Laing, 1983; Harcourt, 1986). This suggests that the exposure time for parasitism is less for larger than the smaller larvae, and this explains why parasitism rate on larger larvae was lower than those of smaller ones. In contrast, percent parasitism of DBM larvae by *D. insulare* is higher on the second and third instars than on first or fourth instars (Bolter & Laing, 1983). There was no significant difference in male to female sex ratio of *D. insulare* produced from various larvae stages of *P. operculella* (Table 3). Apparently, the number of males produced was less than females when larger larvae were parasitized.

Our cross-checked experiment (third observation) showed that there was no significant difference in percent parasitism of DBM larvae irrespective of the source of *D. insulare* (Table 3). This indicates that potato-*Brassica* intercropping would sustain the *D. insulare* population in the field. The potato field can act as refuge for *D. insulare* and may allow us, if necessary, to use pesticides for controlling DBM in *Brassica* field. *D. insulare* adults from potato field could provide control on DBM larvae that survived pesticide treatments. This could indirectly slow down insecticide-resistance development in the field populations of DBM.

In contrast to parasitized DBM larvae (Idris & Grafius, 1993; Bolter & Laing, 1983), the developmental time of parasitized *P. operculella* larvae to form *D. insulare* pupae was 14 - 16 d, 4 - 6 d shorter than the developmental time of unparasitized larvae to form host pupae. This suggests that the parasitoid larvae were able to control the physiological development of host larvae to suit their own developmental time. It was observed that parasitized *P. operculella* larvae pupated more openly or without full cover of frass on the outside of potato tubers, than that of unparasitized larvae. These two intriguing behaviour may have some biological significance for the pests itself, such as exposing the parasitoid pupae more to predation as compared to its own hidden and protected pupae.

Angoumois grain moth, *S. cerealella* (Gelechiid): There were only two *D. insulare* males produced from > 1000 first instar *S. cerealella* exposed for parasitism. In Egypt, *Diadegma semiclausum* (Hellen) is reported to have emerged from *S. cerealella* infesting stored wheat grains (S. F. Mahmoud Moussa, Plant Protection Research Institute, Egypt - personal communication). In Michigan, however, there was no *S. cerealella* found in the stored grains (Russell, 1980), suggesting that this insect host is not common in Michigan and that it may not be the alternate host of *D. insulare*.

European corn borer, *O. nubilalis* (pyralid): Neither first nor second instars larvae exposed to *D. insulare* were parasitized. Similarly, there was no parasitism recorded for field-collected larvae of *O. nubilalis*. The parasitoid was observed not

attracted at all to the larvae even though we had added larval faeces in parasitism cage. Two pyralids, *Hellula undalis* L., a pest of *Brassica* crops, and *H. rogatalis* that feed on Portulacaceae and Amaranthaceae were parasitized by *D. insulare* (Carlson, 1979). However, they were not recorded in Michigan and northern states of USA (Heppner, 1987).

Tortricids of apple: There was no *D. insulare* adults produced from both field-collected and laboratory-reared larvae of six common tortricids of apple trees (Table 4). In contrast, more than 60% of DBM larvae fed on potted broccoli plants placed in apple orchard for 28 h were parasitized by *D. insulare* (Idris, 1995). Three *Diadegma* species were reported to parasitize *Grapholita molesta* (Busk), the oriental fruit moth attacking apple fruit (Allen, 1962), but they are not important parasitoids of this tortricid (N.J. Mills, University of California Berkeley - personal communication). The closely related species of *D. insulare*, *D. fenestralis* (Hellen), was also reported to parasitize tortricids of apple in Oregon (Carlson, 1979). In Michigan, there are 47 species of microlepidoptera coexist in apple ecosystem, and of these 27 are tortricids (Strickler & Whalon, 1985). This suggests that further investigation, both in the field and laboratory, is needed as we had investigated only six out of 27 tortricid species infesting apple orchard. In addition, field collection of tortricid larvae in early spring and at the end of the summer may increase the possibility of getting overwinter parasitized tortricids larvae.

Mimosa webworm, *H. anisocentra* (Plutellid): We were able to get only seven *H. anisocentra* larvae on 6 and 11 May 1994 from flowers of *G. triacanthos* trees. Although *Diadegma* spp. are reported as the primary parasitoids of this moth in Iowa and southern Illinois (Peacock, see Miller *et al.*, 1987), there were none of the larvae collected from *D. insulare* pupae; all seven larvae formed moth pupae and three males *H. anisocentra* were emerged. The combination of increased parasitism from other parasitoids, heavy rains, and cold winter perhaps reduce the local *H. anisocentra* populations nearly to zero (E. R. Hart., Entomology Department, Iowa State University, personal communication).

Other plutellids, feeding on non-brassicaceous plants that occur in Michigan are *Plutella armoraciae* Busk (Museum of Department of Entomology, Michigan State University) and *Ypsolopha dentiferella* (F.) (Profant, 1991). However, their populations are very rare because of the host plants scarcity. Therefore, it is unlikely that *D. insulare* use them for overwintering. The closely related plutellid, yponomeutids, have three species being reported in Michigan (Profant, 1991) and that *D. insulare* may used them as its alternate host. However, further study is needed to confirm this speculation. In Netherland, *Diadegma armillata* (Gravenhost) was reported to parasitize six species of Yponomeutidae (Dijkerman, 1990). Results of our preliminary search indicated that *D. insulare* has no insect host other than DBM in Michigan. Although *P. operculella* and *S. cerealella* cannot overwinter in Michigan and probably in other states of the United States, and Canada, this is the first report that *D. insulare* parasitizes gelechiids moth, adding two more species to the current list of Lepidoptera that can be the alternate hosts of *D. insulare* (Carlson, 1979). However, what insect species could act as the alternate host of *D. insulare* is still a mystery question.

In Michigan, our results suggested that further search should be focused on the microlepidopterans since large Lepidoptera are unlikely to be the alternate host of *D. insulare*. The plutellids other than *P. xylostella* and its closely related yponomeutids should be studied for possible alternate hosts of *D. insulare*. Other insect especially the pyralids, tortricids and gelechiids also have great possibility to serve as alternate

Idris and Grafius: Alternate host for *Diadegma insulare*

hosts of *D. insulare*. Unlike DBM larvae, many of these insect larvae, especially during the later stages, may have very short exposure time for parasitism by *D. insulare* since they are concealed in the leaves, grains or stem. Therefore, if the parasitism occurred then the parasitism rate could be very low. Subsequently, the chances to get parasitized larvae are not easy and surely time consuming. To overcome this problem the larvae collected are the best to be exposed for parasitism in the laboratory.

A quick identification of the alternate host will speed up the integration of factors responsible for *D. insulare* overwintering population into the total DBM management program. For instance, intercropping of host food plant in *Brassica* crop agroecosystem could increase the parasitism efficiency of *D. insulare*. This is because *D. insulare* does not need to spend more time traveling from its main host habitats to its alternate host habitats particularly when host habitat is sprayed with pesticides or for overwintering.

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