Insecticide Rotations for the Management of Lepidopteran Pests in Cabbage and Collards[1]

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J. Entomol. Sci. 49(2): 130-143 (April 2014)

Abstract Insecticide rotations for the management of the diamondback moth, *Plutella xylostella* (L), and other lepidopteran pests of cabbage and collard crops were evaluated in 2010, 2011, and 2012 at Tifton, GA, with the intent of identifying mode of action rotations equal in efficacy to single insecticide mode of action treatments. This was to demonstrate how insecticide rotations, which are purported to aid in the prevention of insecticide resistance, can be an economically-viable insect control option in *Brassica* crops. The insecticides and mode of actions tested included: chlorantraniliprole and flubendiamide (ryanodine receptor modulators), spinetoram (nicotinic acetylcholine receptor allosteric activator), indoxacarb (voltage-dependent sodium channel blocker), *Bacillus thuringiensis* subsp. aizawai (microbial disrupter of insect midgut membranes), novaluron (inhibitor of chitin biosynthesis) and zeta-cypermethrin (sodium channel modulator). The results demonstrated that all rotations were equally effective in the control lepidoteran pests in *Brassica* crops to the use of single insecticide treatments and that at least one rotation treatment provided the highest marketable yield each year.

Key Words insecticide resistance management, *Plutella xylostella*, *Trichoplusia ni*, *Pieris rapae*

The diamondback moth (DBM), *Plutella xylostella* (L.), has historically become resistant to every new insecticide mode of action that has ever been commercially marketed (544 cases listed by Anon. 2013). The mode of action corresponds with the Insecticide Resistance Action Committee [IRAC] Group number on every pesticide label. One of the newest modes of action groups, the diamides (IRAC Group 28, e.g. chlorantraniliprole and flubendiamide) has gained in popularity in use for the control of these pests because of its high level of efficacy. However, diamondback moth resistance to diamides already has been documented in Thailand and other overseas locations (Troczka et al. 2012), so if effective implement insecticide rotations to prevent the selection for resistance are not implemented, we may be faced with resistance to this group of insecticides in the USA in the near future. We know from recent studies that the rotation of mode of action groups, one group per diamondback moth generation, can prevent the selection for resistance compared with using a single mode of action across multiple generations of diamondback moth (Zhao et al. 2010). In the spring and fall in Georgia, there are typically 3 generations of diamondback moth during a cabbage or collard, *Brassica oleracea* L., crop growing season depending on temperature and the crop planting date (Riley and Sparks 2011). Thus, rotating at least 3

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insecticide modes of action in sequence should prevent or delay the selection of resistance to any one mode of action. If this strategy works as well as the best single mode of action, such as the new diamide insecticides, then there should only be benefit and no disadvantage to making mode of action rotations common practice in cabbage and collard production. The hypothesis was that insecticide rotations to subject each diamondback moth generation to a different mode of action was equal to single insecticide programs in *B. oleracea* crops in terms of lepidopteran-larval control and marketable yields. The generation time of diamondback moth populations was also estimated for each year of the study to see how well week-based rotation intervals aligned with actual generation times.

Materials and Methods

Trials were conducted on the Lang-Rigdon Farm at the Coastal Plain Experiment Station at Tifton, GA. The full lists of treatments by year are given in Tables 1, 2, 3 and 4. These were selected to determine if currently recommended insecticide rotations with multiple modes of action were as effective as the best single insecticide spray programs. For each of the following trials the cabbage used was hybrid 'Cheers' (Siegers Seed Company, Holland, MI) and the collard used was variety 'Top Bunch' (Johnny's Selected Seeds, Winslow, ME). Cabbage and collards were tested in 2010 and 2011, and only cabbage was tested in 2012. The plants were transplanted with a Mechanical Transplanter™ (Mechanical Transplanter Company, Holland, MI) into 2 rows per 1.8 m beds with 30-cm spacing between plants and maintained with standard cultural practices. A total of 560 kg/ha of 10 - 10 - 10 fertilizer was applied to Tift pebbly clay loam field plots initially followed by 169 kg/ha of 10 - 10 - 10 at first side dressing and 169 kg/ha of ammonia nitrate at second side dressing. Irrigation was applied at 25 mm weekly with an overhead sprinkler system. All treatments were arranged into a randomized complete block design with 4 replicates per experiment. The insecticides used in these studies included chlorantraniliprole (Coragen®, IRAC Group 28, Dupont Crop Protection, Newark, DE), flubendiamide (Synapse®, IRAC Group 28, Bayer CropScience, Research Triangle Park, NC), spinetoram (Radiant®, IRAC Group 5, Dow AgroSciences LLC, INpolis, IN), indoxacarb (Avaunt®, IRAC Group 22A, Dupont Crop Protection, Newark, DE), *Bacillus thuringiensis* subsp. aizawai (Xentari®, IRAC Group 11B, Valent USA Corporation, Walnut Creek, CA), novaluron (Rimon®, IRAC Group 15, Chemtura AgroSolutions, Middlebury, CT) and zeta-cypermethrin (Mustang Max®, IRAC Group 3, FMC Corporation, Philadelphia, PA). The numbered experimental product DPX-KN128 used in the last test was a highly efficacious isomer of indoxacarb, a Dupont Crop Protection product. Two samples of 5 plants were scouted per plot per sample date (approx.. weekly) for diamondback moth larvae, imported cabbage worm, *Pieris rapae* (L.), cabbage looper, *Trichoplusia ni* (Hűbner), and cabbage webworm, *Hellula rogatalis* (Hulst). Damage ratings for larval damage to wrapper leaves and heads were recorded within 1 wk of harvest as 0 = none, 1 = slight, 2 = moderate and 3 = severe. A minimum of 10 heads per plot was assessed for yield quality and insect damage. Specific details by year are as follows.

In the 2010 trial, cabbage was transplanted into blocks (replicates) 1 and 2, and collards were transplanted into blocks 3 and 4 on April 13. Scouting was initiated on 15 April and continued weekly until a final damage rating and harvest on 7 June. Seven insecticides were applied on 14, 21, 28, April, 6, 12, 19 and 27 May corresponding to sprays 1 - 7, respectively. Single insecticide treatments occurred on all of

Table 1. Seasonal average control of lepidopteran larvae, resulting wrapper leaf and head damage and marketable yield over both cabbage and collards in spring 2010, Tifton, GA.

Treatment – Rate of active ingredient/ha (spray no.)	Avg. DBM* larvae and pupae	Avg. ICW larvae and pupae	Avg. wrapper leaf damage 0 - 3 none-severe	Avg. head damage 0 - 3 none-severe	Marketable wt. (lbs) per 10 plants
1. Untreated check	1.57 a**	1.32 a	2.85 a	2.35 a	5.2 d
2. Chlorantraniliprole 0.05 kg ai/ha (all)	0.04 c	0.14 b	0.60 c	0.25 c	26.7 ab
3. Flubendiamide 0.03 kg ai/ha (all)	0.07 c	0.14 b	1.60 b	0.88 b	24.4 abc
4. Spinetoram 0.04 kg ai/ha (all)	0.07 c	0.04 b	1.00 c	0.83 b	22.5 abc
5. *B. t.* aizawai 1.68 kg ai/ha (all)	0.82 b	0.25 b	1.60 b	1.15 b	14.3 cd
6. *B. t.* aizawai 1.68 kg ai/ha (1,2,7) Indoxacarb 0.05 kg ai/ha (3,4) Chlorantraniliprole 0.05 kg ai/ha (5, 6)	0.54 bc	0.14 b	1.65 b	0.93 b	21.5 abc
7. *B. t.* aizawai 1.68 kg ai/ha (1,2,7) Indoxacarb 0.05 kg ai/ha (3,4) Flubendiamide 0.03 kg ai/ha (5,6)	0.39 bc	0.04 b	1.55 b	0.93 b	19.2 bc
8. *B. t.* aizawai 1.68 kg ai/ha (1,2,7) Indoxacarb 0.05 kg ai/ha (3,4) Spinetoram 0.04 kg ai/ha (5,6)	0.39 bc	0.11 b	1.70 b	1.13 b	30.4 a

* Abbreviations: DBM = diamondback moth, ICW = imported cabbage worm.

** Means within columns followed by a same letter are not significantly different (LSD, $P < 0.05$).

Table 2. Seasonal average control of lepidopteran larvae, resulting Lepidoptera damage to wrapper leaves and heads and marketable weight of cabbage from 10 plants per plot in spring 2011, Tifton, GA.

Treatment – Rate of active ingredient/ha (spray no.)	Avg. DBM*larvae and pupae	Avg. CL larvae and pupae	Avg. ICW larvae and pupae	Avg. wrapper leaf damage 0 - 3 none-severe	Avg. head damage 0 - 3 none-severe	Marketable wt. (lbs) per 10 plants
1. Untreated check	1.98 a**	0.77 a	0.39 a	1.93 a	1.15 a	29.04 c
2. Chlorantraniliprole 0.05 kg ai/ha (all)	0.00 b	0.00 b	0.00 b	0.18 b	0.00 b	50.67 ab
3. Flubendiamide 0.03 kg ai/ha (all)	0.04 b	0.02 b	0.02 b	0.10 b	0.03 b	47.69 ab
4. Spinetoram 0.04 kg ai/ha (all)	0.06 b	0.02 b	0.00 b	0.08 b	0.00 b	42.83 ab
5. *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Chlorantraniliprole 0.05 kg ai/ha (6,7,8)	0.10 b	0.06 b	0.02 b	0.33 b	0.03 b	52.16 a
6. *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Flubendiamide 0.03 kg ai/ha (6,7,8)	0.19 b	0.06 b	0.00 b	0.25 b	0.13 b	40.47 bc

Table 2. Continued

Treatment – Rate of active ingredient/ha (spray no.)	Avg. DBM*larvae and pupae	Avg. CL larvae and pupae	Avg. ICW larvae and pupae	Avg. wrapper leaf damage 0 - 3 none-severe	Avg. head damage 0 - 3 none-severe	Marketable wt. (lbs) per 10 plants
7. *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Spinetoram 0.04 kg ai/ha (6,7,8)	0.08 b	0.10 b	0.00 b	0.25 b	0.05 b	47.70 ab
8. Chlorantraniliprole 0.07 kg ai/ha*** *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Novaluron 0.07 kg ai/ha (6,7,8)	0.00 b	0.00 b	0.00 b	0.45 b	0.05 b	44.90 ab

* Abbreviations: DBM = diamondback moth, CL = cabbage looper, ICW = imported cabbage worm.
** Means within columns followed by a same letter are not significantly different (LSD, $P < 0.05$).
*** Applied as a soil drench at transplant.

Table 3. Seasonal average control of lepidopteran larvae, resulting Lepidoptera damage to leaf heads and marketable weight of collards from 10 plants per plot in spring 2011, Tifton, GA.

Treatment – Rate of active ingredient/ha (spray no.)	DBM*larvae and pupae overall	CL larvae and pupae overall	ICW larvae and pupae overall	Avg. damage to collard foliage/head	Marketable wt (lbs) per 10 plants	Percent marketable weight
1. Untreated check	0.86 a**	0.19 a	0.19 a	2.25 a	3.26 b	12% b
2. Chlorantraniliprole 0.05 kg ai/ha (all)	0.00 b	0.00 b	0.00 b	0.73 b	22.73 a	87% a
3. Flubendiamide 0.03 kg ai/ha (all)	0.00 b	0.00 b	0.00 b	0.53 b	20.72 a	100% a
4. Spinetoram 0.04 kg ai/ha (all)	0.06 b	0.00 b	0.00 b	0.65 b	22.53 a	98% a
5. *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Chlorantraniliprole 0.05 kg ai/ha (6,7,8)	0.06 b	0.00 b	0.00 b	0.78 b	19.09 a	91% a
6. *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Flubendiamide 0.03 kg ai/ha (6,7,8)	0.14 b	0.00 b	0.00 b	0.98 b	18.00 a	84% a

Table 3. Continued

Treatment – Rate of active ingredient/ha (spray no.)	DBM*larvae and pupae overall	CL larvae and pupae overall	ICW larvae and pupae overall	Avg. damage to collard foliage/head	Marketable wt (lbs) per 10 plants	Percent marketable weight
7. *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Spinetoram 0.04 kg ai/ha (6,7,8)	0.06 b	0.00 b	0.00 b	0.68 b	22.88 a	94% a
8. Chlorantraniliprole 0.07 kg ai/ha*** *B. t.* aizawai 1.68 kg ai/ha (1,2,9,10) Indoxacarb 0.05 kg ai/ha (3,4,5) Novaluron 0.07 kg ai/ha (6,7,8)	0.00 b	0.00 b	0.00 b	0.55 b	23.30 a	97% a

* Abbreviations: DBM = diamondback moth, CL = cabbage looper, ICW = imported cabbage worm.

** Means within columns followed by a same letter are not significantly different (LSD, $P < 0.05$).

*** Applied as a soil drench at transplant.

Table 4. Seasonal average control of lepidopteran larvae, resulting damage to wrapper leaves/heads and marketable weight of cabbage from 10 plants per plot in 2012, Tifton, GA.

Treatment – Rate of active ingredient/ha (spray no.)	Avg. CL* larvae and pupae	Avg. DBM larvae and pupae	Predatory insects over all dates	Avg. wrapper leaf damage	Avg. head damage rating	% marketable with slight damage allowed	Wt. of marketable heads per 10 plants
1. Untreated check	5.59 a**	1.31 a	0.72 a	2.92 a	2.70 a	13% b	20.7 c
2. Chlorantraniliprole 0.05 kg ai/ha (all)	0.06 b	0.06 b	0.25 a	0.18 c	0.00 b	100% a	57.8 ab
3. Spinetoram 0.04 kg ai/ha (all)	0.00 b	0.16 b	0.47 a	0.20 bc	0.08 b	98% a	51.7 b
4. Indoxacarb 0.07 kg ai/ha (all)	0.04 b	0.09 b	0.28 a	0.50 b	0.05 b	100% a	52.2 b
5. Indoxacarb 0.15 kg ai/ha (all)	0.00 b	0.09 b	0.44 a	0.20 bc	0.03 b	100% a	64.4 a
6. DPX-KN128 30WG 0.07 kg ai/ha (all)	0.09 b	0.22 b	0.28 a	0.40 bc	0.08 b	100% a	57.5 ab
7. DPX-KN128 30WG 0.15 kg ai/ha (all)	0.00 b	0.06 b	0.31 a	0.35 bc	0.00 b	100% a	56.1 ab
8. Chlorantraniliprole 0.05 kg ai/ha*** Indoxacarb 0.07 kg ai/ha (3, 4, 5) Spinetoram 0.04 kg ai/ha (6, 7, 8) Zeta-cypermethrin 0.03 kg ai/ha (9)	0.19 b	0.13 b	0.28 a	0.23 bc	0.00 b	100% a	57.9 ab

* Abbreviations: DBM = diamondback moth, CL = cabbage looper, ICW = imported cabbage worm.
** Means within columns followed by a same letter are not significantly different (LSD, $P < 0.05$).
*** Applied as a soil drench at transplant.

these dates, and rotation applications were changed every two weeks as indicated in Table 1.

In the 2011 trial, two separate experiments were transplanted on 3 March, one cabbage and one collard experiment. Scouting was initiated on 8 March and continued weekly until a final damage rating on 1 June just before harvest on 2 June. Ten applications of insecticide were made on 15, 23, 28 March, 4, 11, 18, 26 April, 3, 10 and 17 May using the treatments listed in Tables 2 and 3 and corresponding to sprays 1 - 10, respectively. The rotation treatments changed after 2 weeks, 3 weeks and 3 weeks, respectively, to more closely align with a diamondback moth generation (Fig. 1).

In the 2012 trial, one cabbage experiment was transplanted on 2 March. Scouting was initiated on 15 March and continued weekly until a final damage rating at harvest time on 23 May. Nine calendar applications of insecticide were made on 16, 28 March, 3, 11, 19, 25, April, 1, 8 and 16 May using the treatments listed in Table 4 and corresponding to sprays 1 - 9, respectively. In this third year, the alignment insecticide rotations with diamondback moth generation times was based on temperature and degree-day accumulation (Fig. 1).

To demonstrate when the generations of diamondback moth were likely to occur, degree day (DD) based generation times for diamondback moth were estimated. The lower development threshold used by Butts and McEwen (1981) of 7.3°C (45.1°F) and their total DD value of 293°C (527.4°F) was used for this calculation. January 1 was arbitrarily set with an estimated one third of a diamondback moth generation completed based on observations of the last flight of diamondback moth adults in late November and the typical DD accumulation from that period. Also, DD accumulation values were not added above a maximum development threshold of 27.5°C (81.5°F) as suggested by Koshihara (1986). Thus, using the simple averaging method days with average temperatures, i.e., (Max+Min)/2, below 7.3°C (45.1°F) equaled zero DD whereas days with averages above 27.5°C (81.5°F) equaled a maximum of 20.2 DD °C

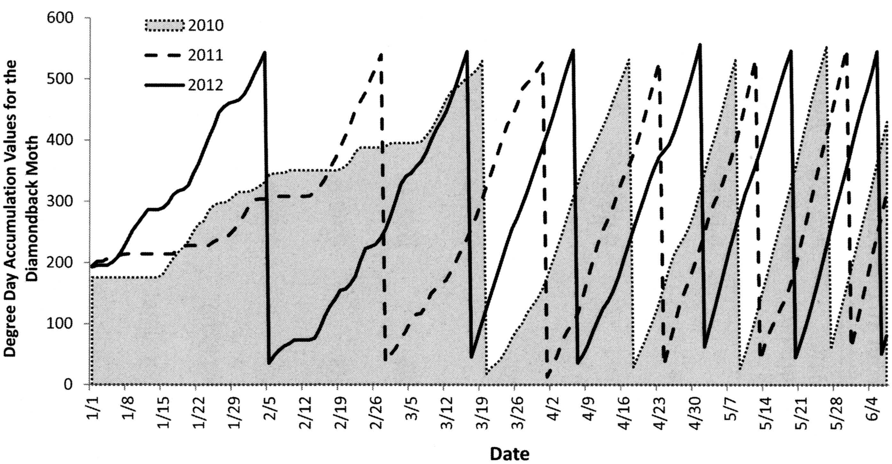

Fig. 1. The number of diamondback moth generations in the spring of 2010, 2011, and 2012, at Tifton, GA, USA, based on degree day cumulative values were four, five and six, respectively.

(36.4 DD °F). Degree day accumulation from transplant to last application in the first rotation and then from that date to the last application in the second rotation, etc., was used to estimate diamondback month generation times per calendar insecticide rotation interval (Table 5).

Analysis of variance was conducted using PROC GLM (SAS Institute 2003), and separation of means for individual pest species over all sample dates was determined by LSD tests. Damage ratings were analyzed by wrapper leaves and head in cabbage and only the leaf head in collards. Marketability was estimated as the number of heads and total weight of heads with a rating of 1 or less per plot. The data on diamondback moth generation times at Tifton, GA were estimated using temperature data from the Georgia Automated Environmental Monitoring Network (http://www.griffin.uga.edu/aemn/) from the University of Georgia Tifton Campus weather recording site 5 km from the Lang-Rigdon Farm site.

Results and Discussion

Diamondback moth was the more prevalent lepidopteran species in two of the three years, but imported cabbage worm and cabbage looper larvae were present in damaging levels in at least 2 of the years (Tables 1, 2, 3 and 4). The lepidopteran larvae as a group provided the only significant crop damage in these tests. There were no significant treatment effects on total beneficial predators over all sample dates in these tests (2010: $F = 0.77$, df = 7, 213, $P = 0.6$; 2011 cabbage: $F = 0.68$, df = 7, 373, $P = 0.7$; 2011 collard: $F = 1.15$, df = 7, 277, $P = 0.3$; 2012: $F = 1.15$, df = 7, 245, $P = 0.3$). All of these selected synthetic insecticides significantly controlled lepidopteran larvae as expected, and the insecticide rotations, treatments, were statistically the same in diamondback moth, cabbage looper, and imported cabbage worm control over all. This was also reflected in the average damage rating to wrapper leaves and heads. Finally, most rotations were not significantly different from most single insecticide treatments in terms of marketable yields, and one of the rotations resulted in the numerically highest marketable yield in 2010 - 2012 (Tables 1, 2, 3 and 4). Specific, yearly results were as follows.

In 2010, diamondback moth varied significantly across treatments ($F = 4.88$, df = 7, 213, $P < 0.001$), as did imported cabbage worm ($F = 3.28$, df = 7, 213, $P < 0.01$) over all dates. The lepidopteran pests provided the only significant crop damage in this test although tobacco thrips and aphids were present in low numbers on the foliage. All treatments significantly controlled lepidopteran larvae, and the insecticide rotations, treatments 6 - 8, were statistically similar to the best single insecticide treatment (Table 1). The rotation ending with flubendiamide tended to be slightly weaker in terms of marketable yield, but the rotation ending with spinetoram performed best with significantly greater yield than the check and a straight *B. thuringiensis* program. All rotations were not significantly different from the single insecticide treatments in terms of marketable yields (Table 1). The total number of generations of diamondback moth for the duration of this test was 2.26 and so the last two rotation intervals coincided with approximately ¾ of a generation interval (Table 5), which was not ideal.

In 2011, diamondback moth again varied significantly across treatments in both cabbage ($F = 14.7$, df = 7, 373, $P < 0.0001$) and collards ($F = 8.9$, df = 7, 277, $P < 0.0001$), but cabbage loopers and imported cabbage worm were also present in significant numbers in both the cabbage (Table 2) and collard test (Table 3). All treatments significantly controlled lepidopteran larvae as expected, and the insecticide

Table 5. Spray rotation schedules and accumulated degree days for diamond back moth in 2010, 2011, and 2012, Tifton, GA.

2010 Rotation-Application dates	2010 DBM generations accumulated per rotation*	2011 Rotation-Application dates	2011 DBM generations accumulated per rotation*	2012 Rotation-Application dates	2012 DBM generations accumulated per rotation*
1 - 4/13	0.00	1 - 3/3	0.00	1 - 3/2	0.00
1 - 4/14	0.04	1 - 3/15	0.28	1 - 3/16	0.46
1 - 4/21	**0.32**	1 - 3/23	**0.62**	1 - 3/28	**1.02**
2 - 4/28	0.29	2 - 3/28	0.18	2 - 4/3	0.30
2 - 5/6	**0.72**	2 - 4/4	0.38	2 - 4/11	0.59
3 - 5/12	0.31	2 - 4/11	**0.68**	2 - 4/19	**0.93**
3 - 5/19	**0.73**	3 - 4/18	0.27	3 - 4/25	0.21
4 - 5/27	0.49	3 - 4/26	0.74	3 - 5/1	0.54
		3 - 5/3	**1.09**	3 - 5/8	**0.96**
		4 - 5/10	0.34	4 - 5/16	0.40
		4 - 5/17	0.70		

* The degree day values in bold are the total accumulated values for a give spray rotation.

rotations were statistically the same in insect control and in the average damage rating to cabbage wrapper leaves and heads to the single insecticide treatments in both cabbage (Table 2) and collards (Table 3). All rotations were not significantly different from the single insecticide treatments in terms of marketable yields and again the rotation ending with spinetoram resulted in the highest marketable yield in collards. The average number of diamondback moth generations during this test was 3.09 (Table 5), closer to what was expected, but the first two rotation intervals were still short of a full diamondback moth generation period.

In 2012, imported cabbage worm was the most prevalent larvae over all dates and significantly affected by the treatments (F = 16.2, df = 7, 245, P < 0.0001), but cabbage looper (F = 39.3, df = 7, 245, P < 0.0001) and diamondback moth (F = 9.6, df = 7, 245, P < 0.0001) were also significant (Table 4). The Lepidoptera pests as a group provided the only significant crop damage in this test although tobacco thrips were present on the foliage and significantly affected by the treatments (F = 2.0, df = 7, 245, P = 0.05) with the indoxacarb treatments significantly increasing thrips compared with spinetoram. All treatments significantly controlled lepidopteran larvae, including the rotation treatment (Table 4). This was reflected in the average damage rating to cabbage wrapper leaves and heads. Finally, all treatments were significantly different from the check in terms of producing higher marketable yields (Table 4). The high rate of indoxacarb provided the highest weight of marketable yield. Under low damage tolerance, i.e., not even slight damage to the head, there was no marketable yield in the check, which demonstrates how devastating imported cabbage worm can be in a high population year. The average number of generations of diamondback moth during this test was 3.31 and the rotations intervals averaged 97% of the generation intervals (Table 5).

The degree day value changed dramatically over the 3 yr test period, from 4 diamondback moth generations in the spring of 2010 - 6 generations in 2012 (Fig. 1). Consequently, the attempted alignment of the calendar spray rotations with diamondback moth generations times was close only one year, 2012 (Table 5). Thus, some overlap in different mode of action rotations on a single generation of diamondback moth occurred. Assuming that calendar rotations are going to be more commercially used than rotations based on degree day accumulations, it will be important to have at least three distinct mode of action rotations in the spring in Georgia to attempt to "clean up" individuals that might have been selected for resistance by both the previous two mode of action groups.

Insecticide resistance in diamondback moth has been documented for many decades for the organophosphates, carbamates, organochlorines and pyrethroids (Liu et al. 1981, 1984, Sun et al. 1986) and *B. thurengiensis* (Heckel et al. 2004). More recently, resistance has been reported for the spinosyns (Zhao et al. 2002, Sparks et al. 2012), indoxacarb (Sayyed and Wright 2006), emamectin benzoate (Zhao et al. 2006), abamectin (Pu et al. 2010), fipronyl (Li et al. 2006), and others (Anon. 2013). One of the reasons for this widespread adaptation to insecticides is the range of resistance mechanisms occurring diamondback moth populations (Cheema et al. 2011). With the recent occurrence of resistance to the newest insecticide mode of action on the market, the diamides (Temple et al. 2009, Troczka et al. 2012), there is immediate need for implementation of insecticide resistance management techniques wherever this insect occurs. One of the best techniques we have available is the rotation of insecticide mode of action between diamondback moth generations (Zhao et al. 2010).

The cabbage and collard trial results for spring 2010 - 2012 at the UGA Tifton Campus confirmed that rotations work as well as single mode of action treatments for the control of lepidopteran pests of cabbage and collards. Insecticide rotations based on Insecticide Resistance Action Committee group numbers are strongly recommended to cabbage and collard farmers and pest managers to prevent the development of insecticide resistance. Insecticide resistance diamondback moth in Georgia stemming from the use of the same mode of action season-long across multiple diamondback moth generations is currently considered a manageable problem (Riley and Sparks 2011).

Acknowledgments

We acknowledge the UGA technical assistance of Jackie Davis (deceased) and Donnie Cook. This work was supported in part by Dupont Crop Protection and Bayer Crop Science. This study was supported by the Georgia Agricultural Experiment Stations.

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