

Threecornered Alfalfa Hopper (TCAH)

Spissistilus festinus (Say)

See Page 12 for Model Summary

Phenology/Degree-Day Model for USPEST.ORG

Synthesis analysis by Len Coop, Oregon State University IPPC Dec 29, 2016

Data contributing most directly to model(s) with yellow background

Apparent outlier; not included in Calculations

Final "best estimate" model parameter values



Working estimates:	Tlow	52 F
	Tupper	100 F
	egg devel	310 DD F
	nymph devel	670
	Pre-OV	340
	Egg to Adult	1060
	Gen Time	1400

Sources of phenological data/observations (in no particular order)

Source #1: Wistrom, C., M.S. Sisterson, M.P. Pryor, J.M. Hashim-Buckey, and K.M. Daane. 2010. Distribution of glassy-winged sharpshooter and threecornered alfalfa hopper on Plant hosts in the San Joaquin Valley, California. *J. Econ. Entomol.* 103: 1051-1059.

-Factors of new growth of shoots or suckers, presence of ground vegetation, lack of pruning, and mature fruit all resulted in higher sample numbers of TCAH

Therefore best to a) control suckers; b) not use a ground cover; c) prune vigorously; and monitor more vigorously when fruit matures

-Collected in white flowered sweet clover in May; called a "breeding host" by authors

-in 5 crops numbers peaked Nov-Dec and lowest from Feb through Oct.

-Observed pop. decreases after cold temps between Jan 12-23 2007, when daily low temps avg -3.1C vs. avg temps +3C (CIMIS Arvin Station)

-Southern San Joaquin Valley; CIMIS station Arvin-Edison CI125

-Alfafa sampled was mowed 7.3 times per season on average.

-TCAH commonly collected from citrus, jojoba, oleander, grape, and eucalyptus

-TCAH nymphs rarely collected on non-alfalfa host plants (only 1% of all specimens) indicating that these were colonized by adults for the most part

-potential 1st generation adults ca. Jun 20 2007 (Fig. 3 combined 5 field sites and all non-alfalfa crops)

-also potential 3rd gen adults starting ca. Oct 20 2007 (Fig. 3A)

Analysis: assume above is correct: F1 and F3 adults appear Jun 20 and Oct 20 2007; assume gen time=1400 DD F; see below

(Tlow=52F, Tupper=100F, S1 or single-sine DD calculations) Weather Station: CI125

Est. Gen	Date	Dds F	Weather Station: CI125
F3	10/20/07	4577	
F2	08/09/07	3177 (subtr. 1400=)	
F1	06/20/07	1777 (subtr. 1400=)	bold=starting value(s)

OW oviposit: 03/23/07 377 < - - plausible approx. 1st Spring OV

Interpretation: The F1 and F3 adult peaks in accordance is appears implausible in S. Calif. Alfalfa; only makes sense if perhaps OW as eggs

Generation Analysis:

Total Dds Jan 1 – Sept 20 (assumed enter reproductive diapause by this time):

CI12507 4247

CI12508 4230

CI12509 4300

Avg 4259

3.04 no. gens/yr = 4259/1400; appears to be sufficient DDs for ca. 3 complete generations in S. CA

Source #2: Macmillan, C. 2016. Three-cornered alfalfa hopper: A known vector of red blotch. Vineyard Team.

<http://www.vineyardteam.org/files/resources/Technical%20Articles/TCAH%20Article.pdf>

-Minor pest of vineyards in N. California; late instar nymphs can cause girdling of leaf petioles and lateral stems

-Found year-round in CA and has 3-4 gen/year in S. CA; Generation analysis above indicates 3 generations/yr

-Usually OW as adults

-Associated with vineyards with nearby alfalfa fields

-Shown to vector Red Blotch in winegrapes but takes ca. 4 MONTHS

Source #3: Brendan Beyer, B. 2015. Establishment of threecornered alfalfa hopper (*Spissistilus festinus*) as a pest of peanut (*Arachis hypogaea*). U. Georgia. PhD Thesis 2015

https://getd.libs.uga.edu/pdfs/beyer_brendan_a_201512_ms.pdf

-females capable of laying 6-7 eggs/day (Mitchell & Newsom 1984; Rice & Drees 1985)

-Nymph numbers rose rapidly within 2-3 weeks after initial invasion of adults in 2015

-Matches reported average egg devel time of 13-16 days (Meisch & Randolph 1965)

-2 nymph pop peaks observed in peanut, 1 in late June and another in late Aug (similar to findings of Rahman et al. 2007)

-appearance of nymphs may precede appearance of girdle damage of stems

-yellow sticky traps not reliable for use in a sampling program; trap numbers not a good predictor of field numbers

-traps to indicate presence or absence of adults in the field; but walking the field easily detects adults

-best time to treat in peanut may be 1st gen nymphs; which is in last 2 weeks in July

-data in Figs. 3.1A&B indicate the following:

1) Two gens/yr: 2014 “Early” field adults 1st peak around July 25-Aug 10, 2nd peak around Sept 8-18th

2014 nymphs present entire season (July-mid Sept), 2nd gen. Seemed to peak half way between 2 adult peaks, or Aug 20-Sept 2

2014 “Late” field similar but with gradual increase adults July – Sept with peak ca. Sept 5-12

2014 “Late” nymphs apparent peaks ca. July 30-Aug 3 and Aug 27-Sept 2

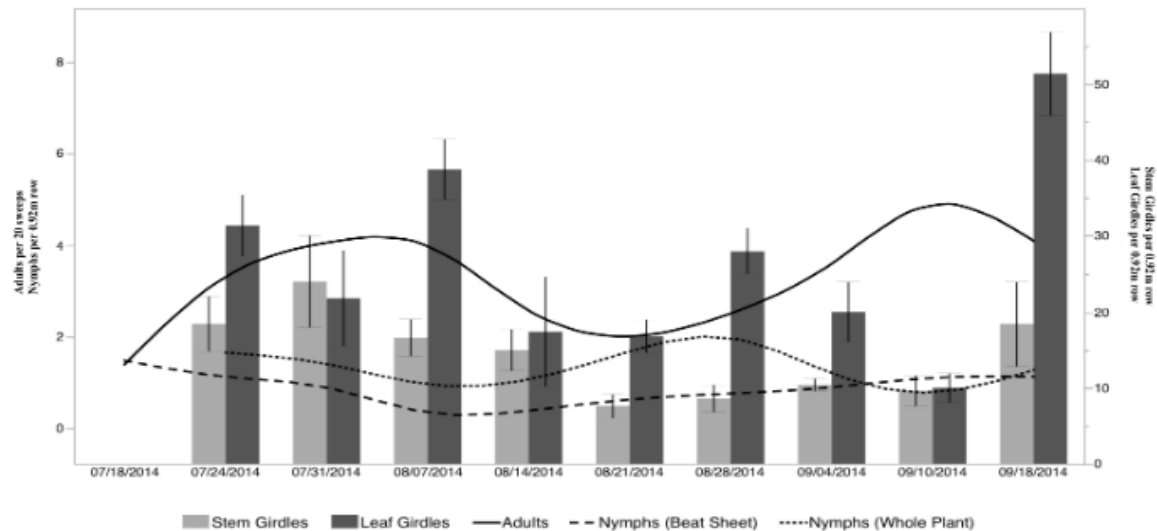


Figure 3.1A: Change over time of *S. festinus* adult and nymph means, in context of the means \pm SEM of stem and leaf girdles in the “Early” field at Lang-Rigdon farm 2014.

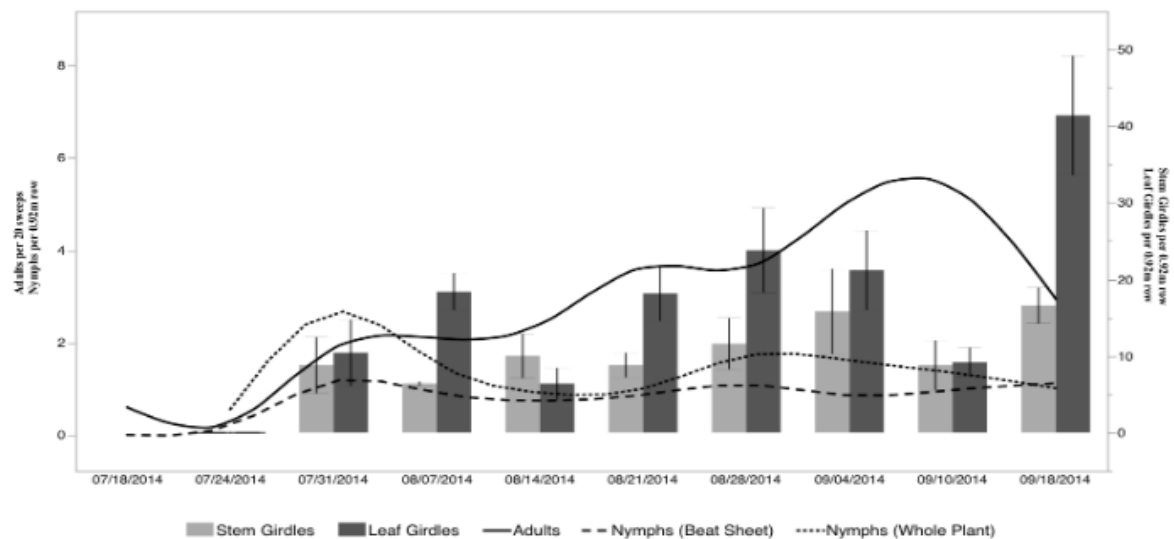


Figure 3.1B: Change over time of *S. festinus* adult and nymph means, in context of the means \pm SEM of stem and leaf girdles in the “Late” field at Lang-Rigdon farm 2014.

Estimated Gen. Time 2014-15

DD data Tifton GA station KTMA 2014 &2015

Adult Dds

	Estim Peaks	DDsF	Diff
OW spring OV	04/04/14	552	
F1	06/12/14	1952	
F2	07/28/14	3352	
F3	09/11/14	4641	1289
OW spring OV	04/25/15	972	
F1	06/22/15	2372	
F2	08/07/15	3772	
F3	09/26/15	5070	1298

Nymph Dds

from Fig 3.1B	07/27/14	3319	
	09/01/14	4359	1040
from Fig. 3.2	08/05/15	3712	
& 3.3	09/12/15	4783	1071

-data in Figs. 3.2 suggests the following:

- Two gens/yr in peanut: 2015 field adults recruiting field July-Aug, next gen peak around Sept 25-30
2015 Nymphs 2 possible peaks: Aug 15-21 and Sept 10-17
-so Nymphs in peanut in June were F1 generation indicating a first gen prior to peanut planting

Estimated Peak OW adult egg laying to produce later gen peaks in peanut (from figs. 3.1, 3.2, 3.3):

Avg OW Spring OV	762
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Generation Analysis:

Total Dds Jan 1 – Sept 20 (assumed enter reproductive diapause by this time):

KTMA 2014	4884
KTMA 2015	4953
KTMA 2016	4986
Avg	4941

3.53 no. gens/yr = 4941/1400; appears to be fully sufficient DDs for ca. 3 complete generations in GA vs. 3 implied in article

Avg Gen Time (adults only a 1294 DdsF

Avg Gen Time (both adult a 1175 DdsF

Avg Gen Time: 1400 (from analysis below)

-data in Figs. 3.4 & 3.5 suggests the following: (Location: Tift County, GA; peanut fields)

1) sweep net and trap data (not whole plant) 2014: field adults recruiting field July-Aug w/possible peak Aug 5-12, next gen peak around Aug 26-30 (or Sept 5-22 Sweep counts only)

Source #4a: Roberson, R. 2006. Timing critical factor in control of three-cornered alfalfa hopper. Southeast Farm Press

<http://www.southeastfarmpress.com/timing-critical-factor-control-three-cornered-alfalfa-hopper>

citing this abstract:

Rahman, K, J.W. Chapin, J.S. Thomas. 2006 (est). Seasonal occurrence of threecornered alfalfa hopper and girdling injury on peanut; effects of insecticide treatment timing.

<http://caes2.caes.uga.edu/commodities/fieldcrops/peanuts/pins/documents/SeasonalOccurrenceofThreecornered.pdf>

-This report superceded by Source #4b; these mostly are just less accurate estimates as that one.

-Past studies indicate a higher level of hoppers in fields with cover crops.

In S. Carolina TCAH produces 2 generations per year in peanuts. Adults first colonized fields in June and produced a generation of nymphs from late June to early August in peanuts planted between May 11 and May 23. The 2nd gen. Of nymphs appeared in the peanut plots from late Aug through Sept. w/adults appearing late July -early Sept.

A second gen of nymphs from late Aug-Sept, and adults later in Sept. (studies from years 2004 and 2005 by Chapin)

Appears likely that later adults colonizing peanut (by late June/early July) are F1 that developed on wild legumes (not OW adults)

Or possibly from OW eggs (suggested by some sources but no data exist to support other than possibly this one)

Weather Station: BARNWELL04,05,06.txt

Est. Gen	Date	Dds F	Date	Dds F	PRISM BARNWELL	NCDC BLACKVILLESC
F3 adult	09/24/04	4554 (subtr. 1400=)	09/24/05	4442 (subtr. 1400=)	2004	4493 4367
F2 adult	07/29/04	3154 (subtr. 1400=)	08/04/05	3042 (subtr. 1400=)	2005	4331 4243
F1 Nymphs at	07/02/04	2288	07/09/05	2176	2006	4535 4145
OW oviposit:	06/10/04	1754 (subtr. 1400=)	06/15/05	1642		
		354		242		

Total Dds Jan 1 – Sept 20 (assumed enter reproductive diapause by this time):

BARNWELL04	4493
BARNWELL05	4331
BARNWELL06	4535
Avg	4453

Avg Gen Time: 1400 (from analysis below)

3.18 no. gens/yr = 4453/1400; appears to be fully sufficient DDs for ca. 2 complete generations in SC peanuts and most likely a complete gen. In Spring

Source #4b: Rahman, K., W.C. Bridges, J.W. Chapin, and J.S. Thomas. 2007. Threecornered alfalfa hopper (Hemiptera: Membracidae):

Seasonal occurrence, girdle distribution, and response to insecticide treatment on peanut in South Carolina. JEE 100:1229-1240

- Adult hoppers colonize peanut during June and produce 2 gens on peanut; thought to be gens 2 and 3 of 3 per year

Fig 6:

- 2004 S. Carolina fields - Adults grad increase July-Sep 4 (last sample), maybe peak Aug 5-10
- 2005 S. Carolina fields - Adults same as 2004 with peak extending to end of Aug then drop off early Sept last sample 16 Sept.
- 2005 Gravid adults peak Jun 30-July7 and Aug 3-Aug 11 (so apparent peak egg laying)
- 2005 Nymphs peak Jul 16-27 (ca 20 days after gravid adults peak), and again Aug 29-Sep 7 (same thing)
- generation spread is wide; F1 nymphs from June28 to Aug 12; F2 nymphs from Aug 12 to Sep 16.

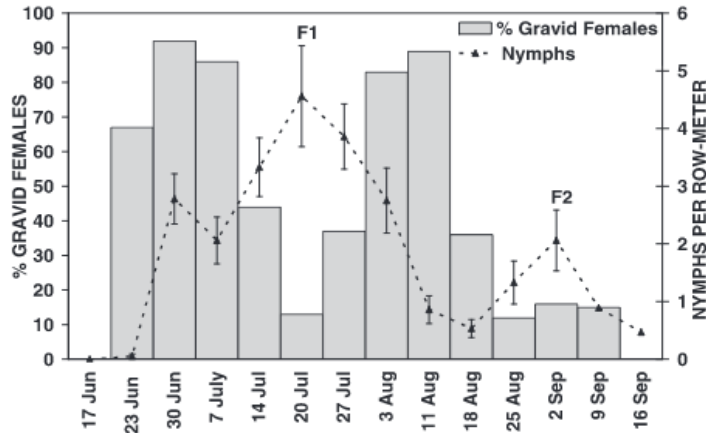


Fig. 6. Seasonal occurrence of gravid females and nymphs of threecornered alfalfa hopper South Carolina peanut fields in 2005. Vertical lines represent SEM. F1 and F2 indicate nymphs of the first and second filial generations on peanut.

Estimation of Spring 1 st OV	KOGB		KCAE	
1 st F3 Nymphs:	08/23/05	3656	08/23/05	3650
1 st F2 Nymphs:	07/04/05	2109	07/04/05	2145 Subtr 1400=
1 st F1 Nymphs:	04/19/05	709	04/20/05	745 Subtr egg dev (325)=
1 st Eggs:	03/12/05	398	03/21/05	434
Avg 1 st Eggs:			416	

Total Dds Jan 1 – Sept 20 (assumed enter reproductive diapause by this time):

KCAE 2005	4408
KOGB 2005	4448
Avg 2005	4428

Avg Gen Time: **1423.5**

3.16 no. gens/yr = 4428/1400; appears to be fully sufficient DDs for ca. 3 complete generations in SC as cited in article

Estimated Gen. Time 2005 – ADULTS
DD data Orangeburg SC KCAE & KOGB

Adult Dds F	Estim Peaks	DD F	Diff
KOGB	07/28/05	2853	
est-->	09/18/05	4383	1530
KCAE	07/28/05	2872	
	09/18/05	4352	1480
Avg	07/28/05	2862.5	
	09/18/05	4367.5	1505 DD F

Estimated Gen. Time 2005 – NYMPHS
DD data Orangeburg SC KCAE & KOGB

Nymphal Dds F	Estim Peaks	DD F	Diff
KOGB	07/20/05	2591	
	09/02/05	3951	1360
KCAE	07/20/05	2614	
	09/02/05	3938	1324
Avg	07/20/05	2602.5	
	09/02/05	3944.5	1342 DD F

Source #5. Meisch, M.V., and N.M. Randolph: 1965. Life-history studies and rearing techniques for the three-cornered alfalfa hopper. J Econ. Entomol. 58:1057-1059.

- all data: fed alfalfa terminals held in small bottles w/nutrient solution; College Station TX
- alfalfa and soybean were equally suitable for rearing nymphs; soybean more convenient
- estimated fecundity avg 38 eggs/female (hatching), range 1-180
- adult pre-OV period ranged from 6-30 days in greenhouse in College Station, TX. Avg 14 days Temp. 80-95F RH 55-80%
- Egg devel range 6-27 days avg 16.5 days Temp 80-95F RH 55-80%
- Nymphal development times: total nymphal range: 18-33 days (greenhouse); 20-25 days (chamber)
- Note: recorded 6 nymphal instars; most all other studies cite only 5 instars; indicates sub-standard diet or other conditions? growth chamber RH 50-90%

Instar	days greenhouse	days at 79F	Temp F	Note
1	5.6	4.8		
2	3.2	2.8		
3	5	3.9		
4	6.8	4.1		
5	6.8	6.9		
6	6.8	7		
total nymphal	23.6	21.9	637.2	591.3
Pre-OV	14		378	
egg developm	16.5		445.5	
Total Egg to Egg (Egg+Nymph+Pre-OV):			1461	

Est Dds using 55F as Tlow; using greenhouse Tavgrnhouse = 79
 Note this was solved for and matches thermal chamber data but disagrees with reported temps of 80-95F

AVG: 614
 330
 310
 1254

← - Appears high vs. other work; constrain to 330 DD:
 ← - Appears high vs. other work; constrain to 310 DD:
 < - - Total still high

Source #6. Mitchell, P.L. and L.D. Newsom. 1984. Seasonal history of the threecornered alfalfa hopper (Homoptera: Membracidae) in Louisiana. J. Econ. Entomol. 77:906-914.

-adults overwinter on pine in Louisiana; begin colonization of vetch and clover in March
 -three gens/year; at point barre 3 initial peaks of "callow" females: April 25th, June 14th, and Aug 6th, 1982
 -eggs laid in clusters avg 6/site at ground level of stems, fewer at leaf nodes (soybean)

Analysis of callow female peaks using NCDC data for Paradis and Grand Coteau LA 1982 data: (Assume Tlow=52F, Thi=104F)

Filename:	PARADISLA82	GRANDCOT82.txt	(Data From NCDC)	
	Paradis LA	Grand Coteau	AVG	
	Dds	Dds	Dds	Gen. Diff
04/25/82	1311	1171	1241	
06/14/82	2540	2386	2463	1222
08/06/82	4082	3958	4020	1557
AVG			1389.5	DD F

Total Dds Jan 1 – Sept 20 (assumed enter reproductive diapause by this time):

PARADISLA8	5406	
GRANDCOT8	5276	
Avg 1982	5341	3.82 no. gens/yr = 5341/1400; appears to be sufficient DDs for ca. 3 ¾ complete generations in LA vs. 3 as cited in article

Nymphal development

Instar	Greenhouse (20-30C)		Est Dds F assuming Tlow= 52 F		
	days at 26.5 C 14:10 L:D	days at 21.1C 11:13 L:D	80F 14:10 L:D	70F 11:13 L:D	
1	3.7	8.3	102.5	149.2	
2	3.6	6.3	99.7	113.3	
3	3.4	6.3	94.2	113.3	
4	4.2	7.5	116.3	134.9	
5	6.9	14.6	191.1	262.5	
6 -					
total nymphal	21.5 (females; mal	42.8	595.6	769.5	AVG 682.5
egg develop	14.3		396.1	257.1	326.6
Female OV period days (collected from the field): assume at 26.5C; 80-90% humidity			Assume 25.5C	Assume 21.1C (70F)	
	38.6		1069.2 AVG	694.0 AVG	
Female OV period days (reared in lab): assume at 26.5C					
	27.5		761.8	494.5	915.5 594.2

Female OV rate (field collected) per day:

7.08

Female OV rate (lab reared) per day:

6.21

Total nymphal development:

(regression forced by adding approx. x-intercept point)

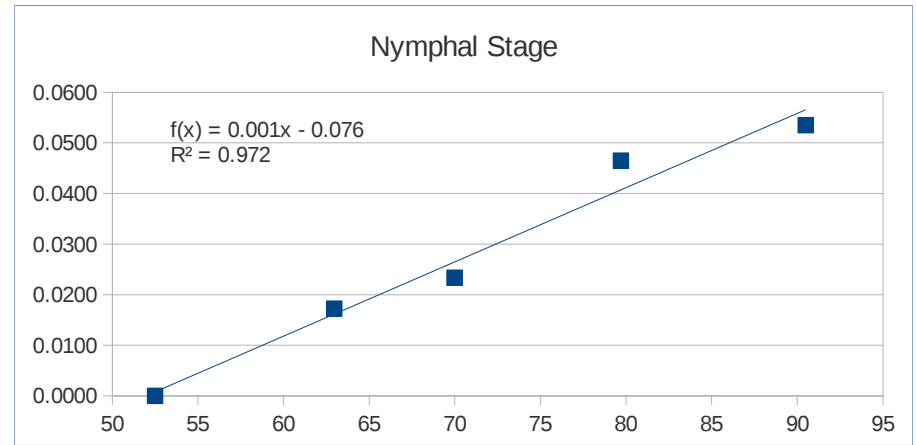
days	tempC	notes	Temp F	1/days
18.7	32.5	Range 30-35C on soybean (Moore and Muell	90.5	0.0535
58	17.2	Range 16.1-18.3C on alfalfa (Wildermuth 191	62.96	0.0172
21.5	26.5	Greenhouse 14:10	79.7	0.0465
42.8	21.1	Greenhouse 11:13	69.98	0.0234

Added: 52.5 0.000003

X-Intercept Est. Tlow, DD Nymphs:

slope 0.0015
intercept -0.0762

Tlow: -a/b 52.0
DDs: 1/slope 681.8



Egg development

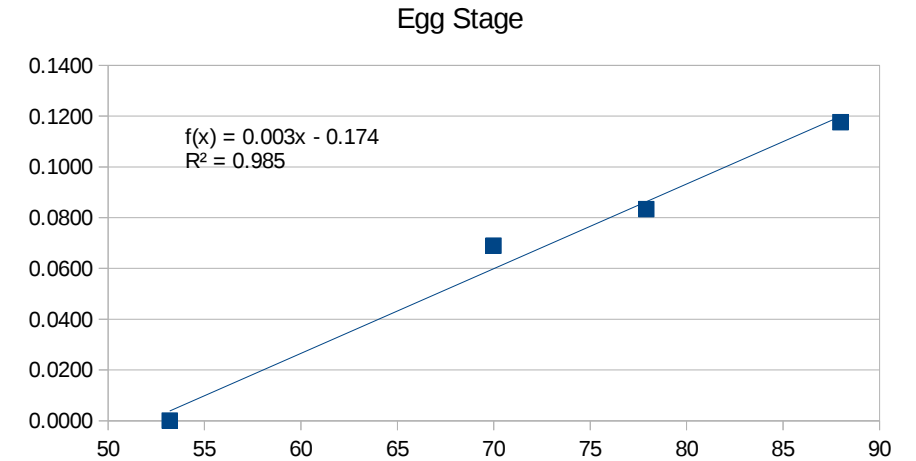
days	tempC	notes	Temp F	1/days
8.5	31.1	Range 7-10 days (Jordan 1952)	87.98	0.1176
12	25.5	Range 10-14 days "" ""	77.9	0.0833
14.5	21.1	Range 12-17 days "" ""	69.98	0.0690

Added: 53.2 0.00003

X-Intercept Est. Tlow, DD Eggs:

slope 0.0033
intercept -0.1736

Tlow: -a/b 52.0
DDs: 1/slope 299.7



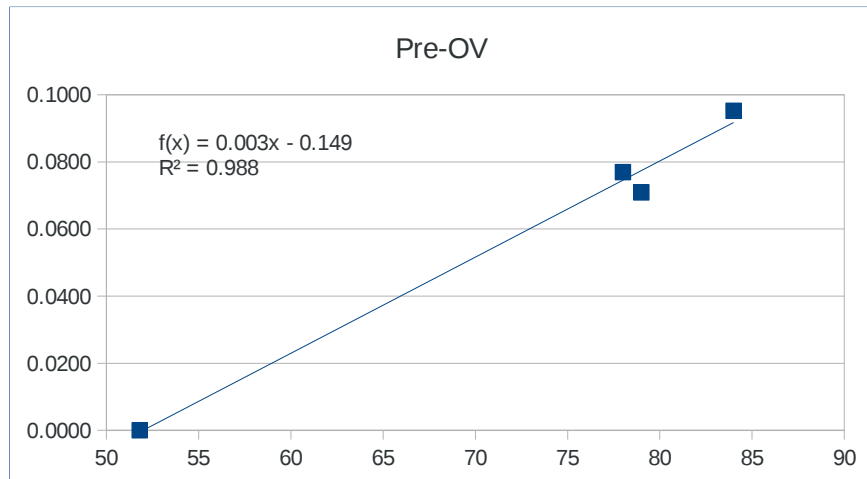
Pre-OV

days	tempC	Source and Notes	DDF(55)	Graph: Temp F	1/days
14.1	26.1	Meisch and Randolph 1965 (79F)	338.4	79	0.0709
17.2	13	Wildermuth 1915 unknown assume ambient lab	299	78	0.0769
10.5	28.9	Graham (1938) (summer ambient temp LA assume 84 F)	304.5	84	0.0952
Avg			314.0	Added: 51.8	0.00003

X-Intercept Est. Tlow, DD Pre-OV:

slope 0.0029
intercept -0.1489

Tlow: -a/b 52.0
DDs: 1/slope 349.1



Gen Time (OV to 1st OV)

days		w/o pre-OV	w/pre-OV	AVG	
35	w/o pre-OV (OV to adult only)	969.5	1318.6		
47	spring or summer		1301.9	1310.2	
supporting obs:	GRANDCOT PARADISLA			AVG	
-1st gravid females on clover 15 March 1982	537 619			578	
-Assume early significant OV 25 March 1982	737 829			783	
-1st callow adults of next gen: 23 April 1982	1143 1276			1209.5	-- OW as Eggs??
-1st grav females soybean: 10 May 1982	1458 1592			1525	-- Too early for a complete Spring gen. OW as Eggs??
-1st callow adults soybean: 15 Jun 1982	2415 2568			2491.5	-- Suffic. Time for complete gen So assume F2 gen.
-therefore 1 complete gen 23 April-15 Jun = 53 DAYS					
-Diff 23 April to 15 Jun (check Gen. Time)	1272 1292			1282	-- Within range of full population gen time

Source #7: Moore, G.C. and A. J. Mueller. 1976. Biological observations of the threecornered alfalfa hopper on soybean and three weed species. J. Ecol. Entomol. 69:14-16.

Research conducted in Arkansas

Nymphal development	Tlow=	52 F	notes
days	tempC	Estim Dds F	
18.7	32	703.12	on Soybean; Temp range 30-35C
26.8	32	1007.68	on cocklebur, Xanthium pensylvanicum L.

Source #8: Johnson, D. 2013. Threecornered alfalfa hopper in Kentucky. UK Cooperative Extension Service ENTFACT-153

<https://entomology.ca.uky.edu/files/efpdf1/ef153.pdf>

Devel at 88F:

	Days Avg	Range days	Estim Dds F	
Eggs	8.5	7-10	306	
Nymphs	10.5	8-13	378	-- This Extension bulletin finding not in accord with other work

- 2 gens/yr in soybean in KY
- OW adults enter field, 1st gen in field, 2nd gen adults leave for OW
- eggs reported to OW within plant tissue
- spring adults feed in legume crops, cotton, clovers, dock, wild geranium, sunflowers, tomatoes
- OW adults move into soybean in May and June < - - This would be tail end of OW adults since this is a planted annual cropping system

Analysis: Lexington KY KLEX in 2011 &2012

05/25/12	904
06/10/12	1173
05/25/11	662
06/10/11	1027

Estimated spring Dds before OW adults move into field to reproduce: ca. 650-1000 Dds < - - Again, this would be after 1st OV in weeds/perrenial crops; should be near PEAK OV

AVG (est peak C) 783

Total Dds Jan 1 – Sept 20 (assumed enter reproductive diapause by this time):

KLEX11	3309	SINGLE SINE
KLEX12	3571	
AVG	3440	

2.48 no. gens/yr = 3440/1400; appears to be sufficient DDs for ca. 2 ½ complete generations in KY vs. 2 as cited in article

Source #9: Battany, M. 2016. Red Blotch and the Threecornered Alfalfa Hopper. Grape Notes: Information for grape growers in San Luis Obispo and Santa Barbara Counties. Univ. Calif. Website: <http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=20473>

Estimated Springtime phenology:

-girdling appeared in vineyards by May 2015 (Santa Maria CA); treat this with suspicion as TCAH not confirmed cause

Dds by: (KSMX Santa Maria CA)		Tlow=		52 F				
05/01/14	1042	05/01/15	1081	05/01/16	979	Avg	1034.0	
05/15/14	1235	05/15/15	1171	05/15/16	1092		1166.0	

-Girdling caused by late instar nymphs or through oviposition activity; so assume this result is near END of spring OV

-From this peak OV would be somewhat earlier, such as 800 DD

Avg	1100.0
Peak OV ca.	800

Summary Analysis #1: Determination of Tlow: (Lower Developmental Temperature)

Evidence 1) Source 6 above, temperature development x-intercept with forcing: Egg, Nymphs, and Pre-OV all look good (high R2) using Tlow = 52 F

Evidence 2) Other reported leaf hopper Tlows (no Membracidae found; these are mostly Cicadellidae):

Blackberry leafhopper	46.6	Williams 1984
Potato leafhopper	52.5	Kouskolekas and Decker 1966
Western grape leafhopper	50.5	Jensen and Flaherty 1982
Beet leafhopper	58	Harries and Douglas 1948
AVG	51.9 F	← --- Homoptera in general have Tlow in range 48-54 F; 52 is probably close to correct for TCLH

Evidence 3) Lowest C.V. analysis of rearing data by Wildermuth 1915 (Table 4: Lengths of nymphal stages):

Source #10: Wildermuth, V.L. 1915. Three-cornered alfalfa hopper. J. Agric. Res. 3(4):343-62
Location: Tempe, AZ

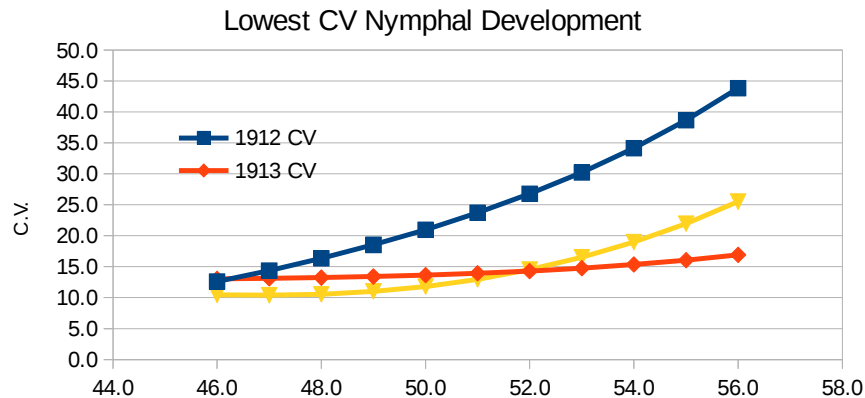
Colr Key: questionable result
 removed from final results

A) Analyze years separately:

reported avg Temp F	1912 avg TempF	Tlow C:	Tlow F:	13.3	12.8	12.2	11.7	11.1	10.6	10.0	9.4	8.9	8.3	7.8
		days	days	56	55	54	53	52	51	50	49	48	47	46
61	67	335	402	469	536	603	670	737	804	871	938	1005		
61	67	335	402	469	536	603	670	737	804	871	938	1005		
61	69	345	414	483	552	621	690	759	828	897	966	1035		
61	68	340	408	476	544	612	680	748	816	884	952	1020		
65	50	450	500	550	600	650	700	750	800	850	900	950		
65	57	513	570	627	684	741	798	855	912	969	1026	1083		
76	42	840	882	924	966	1008	1050	1092	1134	1176	1218	1260		
76	44	880	924	968	1012	1056	1100	1144	1188	1232	1276	1320		
84	32	896	928	960	992	1024	1056	1088	1120	1152	1184	1216		
84	33	924	957	990	1023	1056	1089	1122	1155	1188	1221	1254		
86	37													
86	33	990	1023	1056	1089	1122	1155	1188	1221	1254	1287	1320		
86	33	990	1023	1056	1089	1122	1155	1188	1221	1254	1287	1320		
	Avg	653	703	752	802	852	901	951	1000	1050	1099	1149		
	Stdev	286	272	257	242	228	213	199	185	171	158	145		
	CV	43.8	38.6	34.2	30.2	26.8	23.7	21.0	18.5	16.3	14.4	12.6		
1913	69	43	559	602	645	688	731	774	817	860	903	946	989	
	69	45	585	630	675	720	765	810	855	900	945	990	1035	
	73	39	663	702	741	780	819	858	897	936	975	1014	1053	
	73	39	663	702	741	780	819	858	897	936	975	1014	1053	
	71	31	465	496	527	558	589	620	651	682	713	744	775	
	73	38	646	684	722	760	798	836	874	912	950	988	1026	
	73	38	646	684	722	760	798	836	874	912	950	988	1026	
	71	26	390	416	442	468	494	520	546	572	598	624	650	
	73	35	595	630	665	700	735	770	805	840	875	910	945	
	74	44	792	836	880	924	968	1012	1056	1100	1144	1188	1232	
	72	34	544	578	612	646	680	714	748	782	816	850	884	
	73	40	680	720	760	800	840	880	920	960	1000	1040	1080	
	75	32	608	640	672	704	736	768	800	832	864	896	928	
	75	32	608	640	672	704	736	768	800	832	864	896	928	
	87	25	775	800	825	850	875	900	925	950	975	1000	1025	
	86	23	690	713	736	759	782	805	828	851	874	897	920	
	87	23	713	736	759	782	805	828	851	874	897	920	943	
	86	27	810	837	864	891	918	945	972	999	1026	1053	1080	
	Avg		635	669	703	737	772	806	840	874	908	942	976	
	Stdev		107	107	108	109	110	112	114	117	120	123	127	
	CV		16.9	16.1	15.3	14.8	14.3	13.9	13.6	13.4	13.2	13.1	13.0	

B) Analyze years combined, leaving out some tough-to-accept 1912 Data:

	Temp C		13.3	12.8	12.2	11.7	11.1	10.6	10.0	9.4	8.9	8.3	7.8
	avg TempF	days	56	55	54	53	52	51	50	49	48	47	46
1912	76		42										
	61	67	335	402	469	536	603	670	737	804	871	938	1005
	61	67	335	402	469	536	603	670	737	804	871	938	1005
	61	69	345	414	483	552	621	690	759	828	897	966	1035
	61	68	340	408	476	544	612	680	748	816	884	952	1020
	65	50	450	500	550	600	650	700	750	800	850	900	950
	65	57	513	570	627	684	741	798	855	912	969	1026	1083
1913	69	43	559	602	645	688	731	774	817	860	903	946	989
	69	45	585	630	675	720	765	810	855	900	945	990	1035
	73	39	663	702	741	780	819	858	897	936	975	1014	1053
	73	39	663	702	741	780	819	858	897	936	975	1014	1053
	71	31	465	496	527	558	589	620	651	682	713	744	775
	73	38	646	684	722	760	798	836	874	912	950	988	1026
	73	38	646	684	722	760	798	836	874	912	950	988	1026
	71	26	390	416	442	468	494	520	546	572	598	624	650
	73	35	595	630	665	700	735	770	805	840	875	910	945
	72	34	544	578	612	646	680	714	748	782	816	850	884
	73	40	680	720	760	800	840	880	920	960	1000	1040	1080
	75	32	608	640	672	704	736	768	800	832	864	896	928
	75	32	608	640	672	704	736	768	800	832	864	896	928
	87	25	775	800	825	850	875	900	925	950	975	1000	1025
	86	23	690	713	736	759	782	805	828	851	874	897	920
	87	23	713	736	759	782	805	828	851	874	897	920	943
	86	27	810	837	864	891	918	945	972	999	1026	1053	1080
	Avg		563	605	646	687	728	769	811	852	893	934	976
	Stdev		144	133	123	113	106	100	96	94	94	97	102
	CV		25.5	21.9	19.0	16.5	14.5	12.9	11.8	11.0	10.5	10.4	10.5
Graph:	Tlow F:		56.0	55.0	54.0	53.0	52.0	51.0	50.0	49.0	48.0	47.0	46.0
	1912 CV		43.8	38.6	34.2	30.2	26.8	23.7	21.0	18.5	16.3	14.4	12.6
	1913 CV		16.9	16.1	15.3	14.8	14.3	13.9	13.6	13.4	13.2	13.1	13.0
	Combined CV		25.5	21.9	19.0	16.5	14.5	12.9	11.8	11.0	10.5	10.4	10.5



Interpretation: Parts of 1912 data is suspect; probably due to the variable temperature conditions. Outliers ID'd and removed in combined analysis.

While the C.V. continues to drop down to 46F (esp. 1912 data); 50-52F is probably closer value. Note lowest C.V. method tends to have this artifact (of continually lower C.V. Values with lower thresholds). Combined analysis removed outliers with mean Nymphal devel = 728 DD; close to range and mean of combined results Table 1. Examining the 1913 and Combined results; substantial leveling off occurs by 52F

Conclusion: Use 52F as Tlow until further studies indicate otherwise.

Table 1. Summary analysis #2: Combining sources above

	Estimated DDs (Tlow=52F)										Average (or sum)	St. Dev.	Rounded/ Final Estimates	
	Source 1	Source 3	Source 4	Source 5	Source 6a	Source 6b	Source 7	Source 8	Source 9					
Author, Year	Wistrom 2010	Bayer 2015	Rahman 2007	Meisch 1965	Mitchell 1984	Mitchell 1984	Moore 1976	Johnson 2013	Battany 2016					
Location of research	CA	GA	SC	TX	LA	LA	ARK	KY	CA					
Egg development				310	300	327		306		311	12	310		
Nymphal development				614	682	683	703	378		670	135	670		
Adult Pre-OV				330	349					340	13	340		
Oviposition Period					594					594		590		
Oviposition Period divided by 5 to use for Pop. Gen. Time					119					119		120		
Egg to 1 st Egg (sum of egg+nymph+pre-OV)				1254	1331	1310				1321	40	1320		
Full population Gen time (Egg-1st Egg+1/4 fecun. period)					1449					1439		1400		
Full Gen from field sampling peaks		1294	1424		1390	1282				1347	70	1400		
OW adult to first OV in sprin	377		416		578					457	114	450		
OW adult to peak OV in spring		762			783			783	800	782	16	780		

Table 2. Phenology Model Version 1.0 from above:

Phenology (Degree-Day) Model:	Built for USPEST.ORG	
Common Name:	Threecornered Alfalfa Hopper	
Species:	<i>Spissistilus festinus</i> (Say)	
Order and Family:	Homoptera: Membracidae	
Pest of:	Alfalfa, Soybean, Peanut, Winegrapes, other legumes	
Model Sourced from studies in:	TX, AR, LA, SC, KY, GA, CA	
	(F)	(C)
Tlow:	52	11.1
Thi: (nominal)	100	37.8
Calc Method:	Single Sine or S1 (default method)	
Main Stage Development:	DD (F)	DD (C)
Egg development:	310	172
Nymphal development:	670	372
Adult Pre-OV:	340	189
OV period to peak (1/5 of total OV period):	120	67
Egg+Nymph+Pre-OV:	1320	733
Full Generation time in the field:	1400	778
Field Events:		
OW adult to first OV:	450	250
OW adult to peak OV:	780	433
F1 late instar nymphs	1179	655
First F1 adults	1430	794
F1 peak adults, also F2 young nymphs	2180	1211
F2 late instar nymphs	2579	1433
First F2 adults	2830	1572
F2 peak adults, also F3 young nymphs (wa	3580	1989
First F3 adults (warmer climates)	4230	2350