

カイガラムシの性フェロモン

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- (E) ワタフキカイガラムシ科昆虫からの同定
- (F) 文献

化学構造からのグループ分け

1. Acyclic compounds
2. Cyclic compounds
3. Polyketides (propanogenins)



(A) カイガラムシとは？

半翅目、同翅亜目 (Hemiptera, Homoptera)

キジラミ上科
コナジラミ上科
アブラムシ上科
カイガラムシ上科 (15~20科から成る)

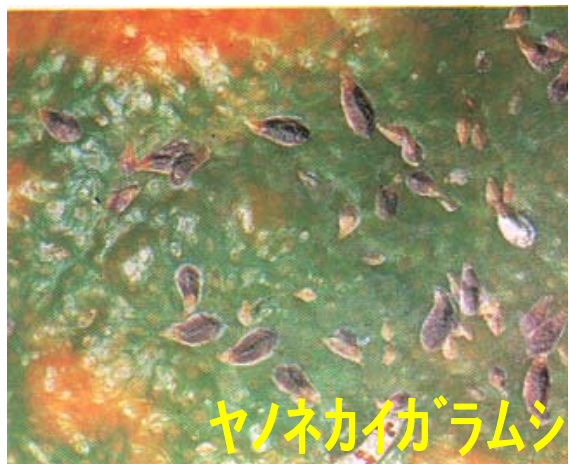
カイガラムシ

雌雄異形 ♀: 無翅(口ウ物質で覆われている)
♂: 有翅(前翅のみ、口器を欠く)



(B) 代表的なカイガラムシ

マルカイガラムシ科



コナカイガラムシ科



ワタフキカイガラムシ科



カタカイガラムシ科



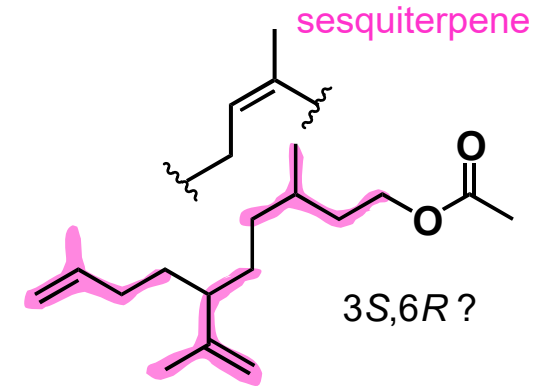
(C) マルカイガラムシ科 Diaspididae ①

i) California red scale (*Aonidiella aurantii*)

アカマルカイガラムシ

Roelofs *et al.*, 1977. *Nature*, **267**, 698

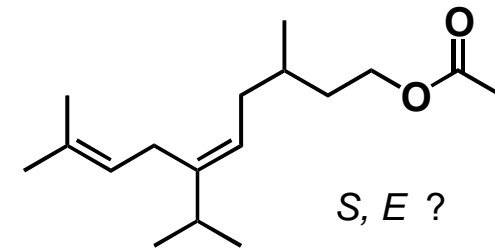
Roelofs *et al.*, 1978. *J. Chem. Ecol.*, **4**, 211



ii) Yellow scale (*Aonidiella citrina*)

キマルカイガラムシ

Gieselmann *et al.*, 1979. *J. Chem. Ecol.*, **5**, 27



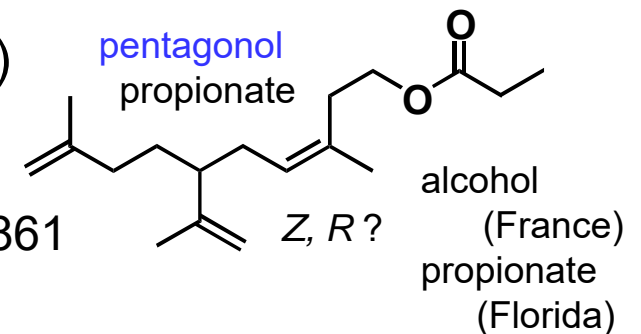
iii) White peach scale (*Psudaulascaspis pentagona*)

クワシロカイガラムシ

Heath *et al.*, 1979. *J. Chem. Ecol.*, **5**, 941

Einhorn *et al.*, 1983. *C. R. Acad. Sci., Ser. III*, **296**, 861

McLaughlin *et al.*, 1990. *J. Chem. Ecol.*, **16**, 749

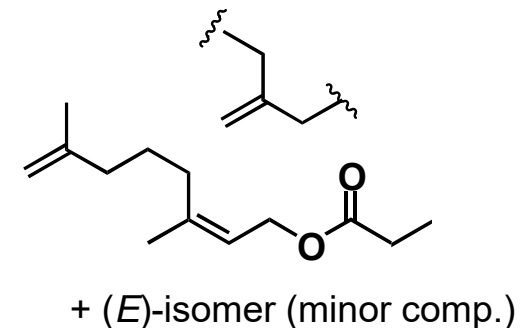


iv) San Jose scale (*Quadraspidiotus perniciosus*)

ナシマルカイガラムシ

Gieselmann *et al.*, 1979. *J. Chem. Ecol.*, **5**, 891

Anderson *et al.*, 1981. *J. Chem. Ecol.*, **7**, 695

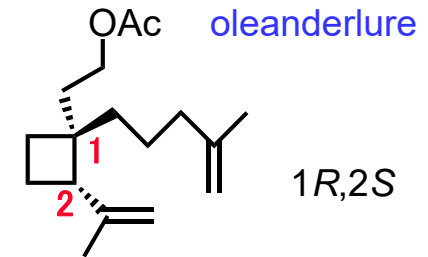


(C) マルカイガラムシ科 Diaspididae ②

v) Oleander scale (*Aspidiotus nerii* = *A. hederiae*)

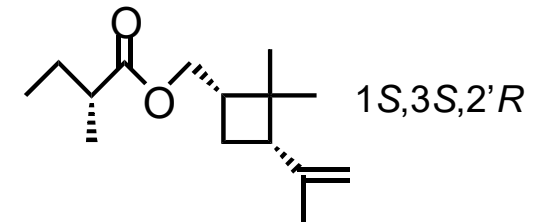
シロマルカイガラムシ

Einhorn *et al.*, 1998. PNAS, **95**, 9867



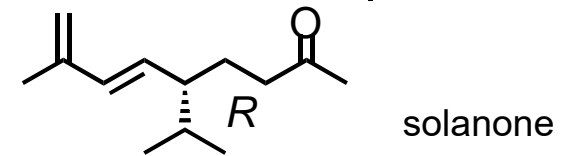
vi) *Acutaspis albopicta*

Millar *et al.*, 2012. *J. Econ. Entomol.*, **105**, 497



vii) *Aulacaspis murrayae*

Ho *et al.*, 2014. *J. Chem. Ecol.*, **40**, 379



(D) コナカイガラムシ科 Pseudococcidae ①

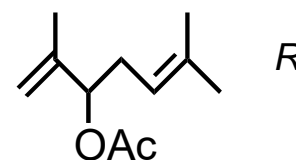
i) Comstock mealybug (*Pseudococcus comstocki*)

Negishi *et al.*, 1980. *Appl. Entomol. Zool.*, **15**, 328

Bierl-Leonhardt *et al.*, 1980. *Life Science*, **27**, 399

1982. *J. Chem. Ecol.*, **8**, 689

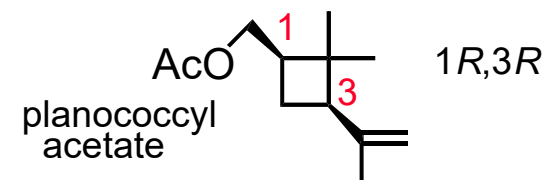
クワコナカイガラムシ



ii) Citrus mealybug (*Planococcus citri*)

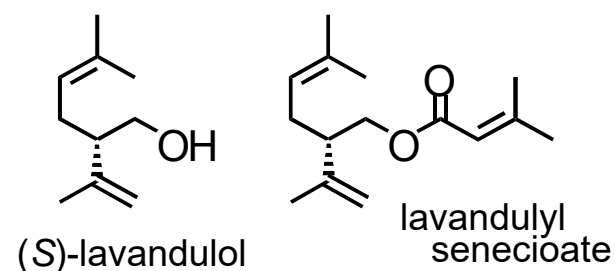
ミカンコナカイガラムシ

Bierl-Leonhardt *et al.*, 1981. *Tetrahedron Lett.*, **22**, 389



iii) Vine mealbug (*Planococcus ficus*)

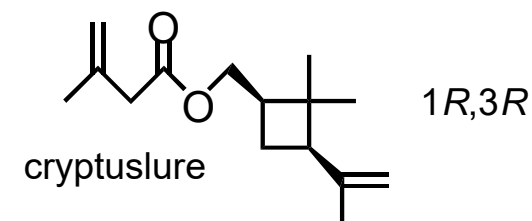
Hinkens *et al.*, 2001. *Tetrahedron Lett.*, **42**, 1619



iv) Citriculus mealybug (*Pseudococcus cryptus*)

ミカンヒメコナカイガラムシ = *P. citriculus*)

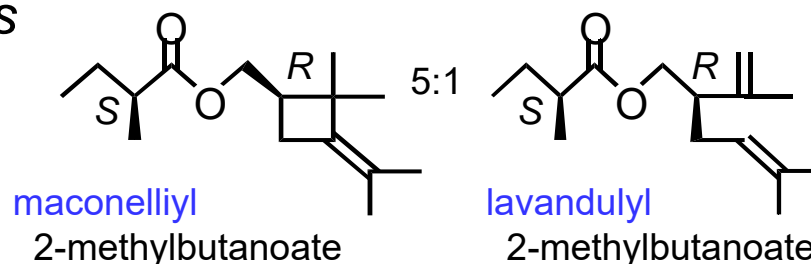
Arai *et al.*, 2003. *J. Chem. Ecol.*, **29**, 2213



v) Pink hibiscus mealybug (*Maconellicoccus*

ワタコナカイガラムシ (*hirsutus*)

Zhang *et al.*, 2004. *PNAS*, 101, 9601

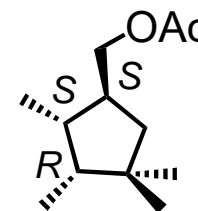


(D) コナカイガラムシ科 Pseudococcidae ②

vi) Obscure mealybug (*Pseudococcus viburni*)

Millar *et al.*, 2005. *J. Chem. Ecol.*, **31**, 2999

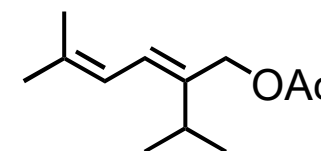
Figadéra *et al.*, 2008. *Chem. Comm.*, 1106 (stereo)



vii) Passionvine mealybug (*Planococcus minor*)

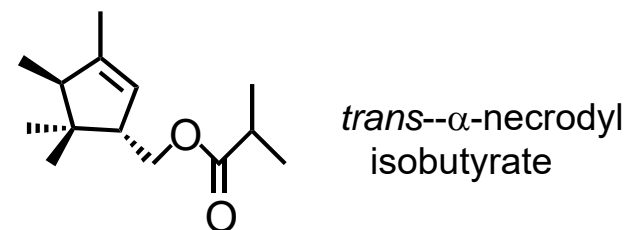
ニセミカンコナカイガラムシ

Ho *et al.*, 2007. *J. Chem. Ecol.*, **33**, 1986



viii) Grape mealybug (*Pseudococcus maritimus*)

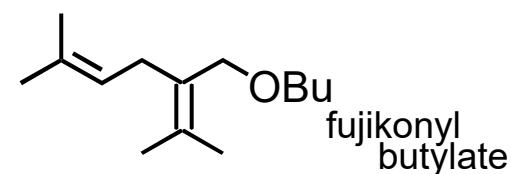
Figadère *et al.*, 2007. *Tetra. Lett.* **48**, 8434



ix) Japanese mealybug (*Planococcus kraunhiae*)

フジコナカイガラムシ

Sugie *et al.*, 2008. *Appl. Entmol. Zool.*, **43**, 369



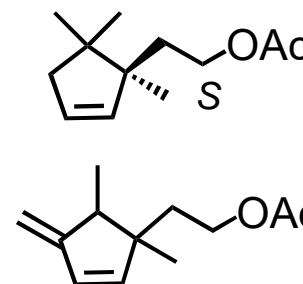
x) Longtailed mealybug (*Pseudococcus longispinus*)

ナガオコナカイガラムシ

Millar *et al.*, 2009. *Org. Lett.*, **11**, 2683

Ramesh *et al.*, 2013. *J. Org. Chem.*, **78**, 6281

Vacas, *et al.*, 2024. *J. Agric. Food Chem.*, **72**, 12478

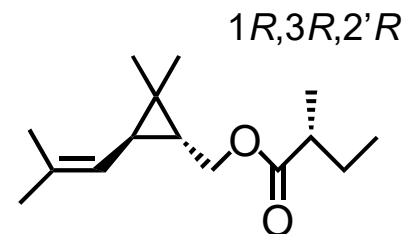


(D) コナカイガラムシ科 Pseudococcidae ③

xi) Madeira mealybug (*Phenacoccus madeirensis*)

マデイラコナカイガラムシ

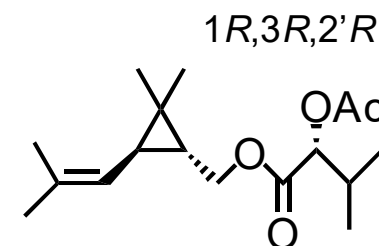
Ho *et al.*, 2009. *J. Chem. Ecol.*, **35**, 724



xii) Citrophilous mealybug (*Pseudococcus calceolariae*)

El-Sayed *et al.*, 2010. *Tetrahedron Lett.*, **51**, 1075

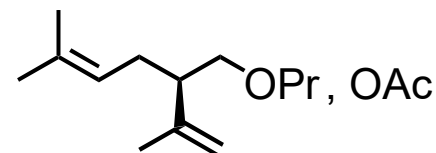
Unelius *et al.*, 2011. *J. Chem. Ecol.*, 37 166



xiii) Banana mealybug (*Dysmicoccus grassii*)

Alfonso *et al.*, 2012.

J. Agric. Food Chem., **60**, 11959

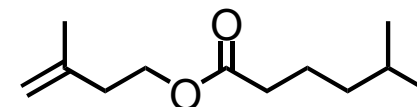


(R)-lavandulyl propionate

xiv) Matsumoto mealybug (*Crisicoccus matsumotoi*)

マツモトコナカイガラムシ

Tabata *et al.*, 2012. *Naturwissenschaften*, **99**, 567

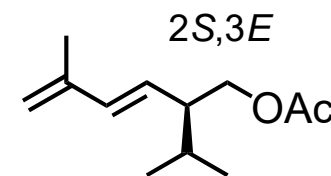


xv) Grey pineapple mealybug (*Dysmicoccus neobrevipes*)

バナナコナカイガラムシ

Tabata & Ichiki, 2015. *J. Chem. Ecol.*, **41**, 194

Tabata & Ohno, 2015. *Appl. Entomo. Zool.*, **50**, 341

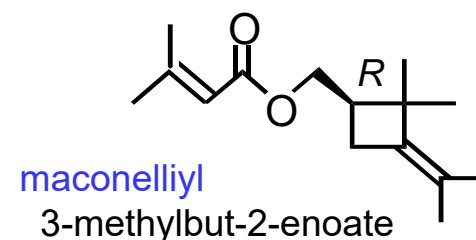


(D) コナカイガラムシ科 Pseudococcidae ④

xvi) Cotton mealybug (*Phenacoccus solenopsis*)

クロテンコナカイガラムシ

Tabata & Ichiki, 2016. *J. Chem. Ecol.*, **42**, 1193

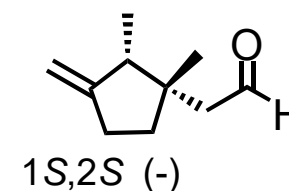


xvii) Pineapple mealybug (*Dysmicoccus brevipes*)

パイナップルコナカイガラ

Tabata *et al.*, 2017. *J. R. Soc. Interface*, **14**, 20170027

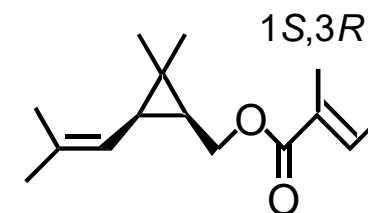
Mori & Tabata, 2017. *Tetrahedron*, **73**, 6530



xviii) Striped mealybug (*Ferrisia virgata*)

フタスジコナアイガラムシ

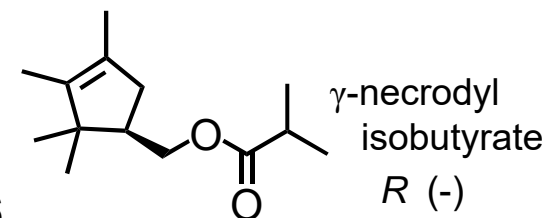
Tabata & Ichiki, 2017. *J. Chem. Ecol.*, **43**, 745



xix) Spherical mealybug (*Nipaecoccus viridis*)

Levi-Zada *et al.*, 2019. *J. Chem. Ecol.*, **45**, 455

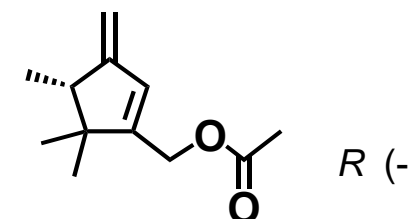
Levi-Zada *et al.*, 2021. *J. Agric. Food Chem.*, **69**, 3026



xx) *Delottococcus aberiae*

Vacas *et al.*, 2019. *J. Agric. Food Chem.*, **67**, 9441

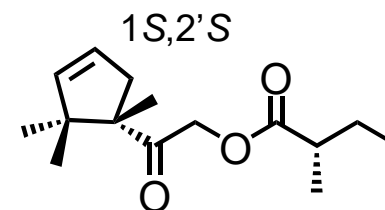
Bargues *et al.*, 2024. *J. Agric. Food Chem.*, **72**, 21488



(D) コナカイガラムシ科 Pseudococcidae ⑤

xxi) Aerial root mealybug (*Pseudococcus baliteus*)

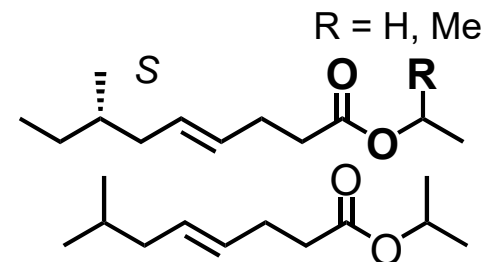
Tabata *et al.*, 2020. *Tetrahedron Lett.*, **61**, 151802



xxii) Azalea mealybug (*Crisicoccus azaleae*)

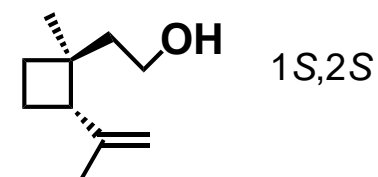
Tabata & Yasui, 2022. *J. Chem. Eco.*, **48**, 609

Sugawara *et al.*, 2024. *J. Chem. Eco.*, **50**, 858



xxiii) Papaya mealybug (*Paracoccus marginatus*)

Sugawara *et al.*, 2025. *J. Chem. Eco.*, **51**, 22

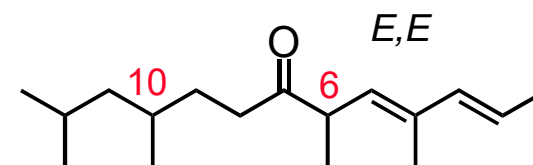


(E) ワタフキカイガラムシ科 Margarodidae ①

i) Japanese black pine bast scale マツモグリカイガラムシ
(*Matsucoccus matsumurae*)

Lanier *et al.*, 1989. *J. Chem. Ecol.*, **15**, 1645

Hibbard *et al.*, 1991. *J. Chem. Ecol.*, **17**, 89



6R,10R ? matsuone

(6R,10R)-matsuone

ii) Red pine scale (*M. resinosae*)

Lanier *et al.*, 1989. Hibbard *et al.*, 1991.

Shi *et al.*, 1995. *Tetrah. Lett.*, **36**, 7201

iii) Black pine bast scale (*M. thunbergiana*)

Lanier *et al.*, 1989. Hibbard *et al.*, 1991.

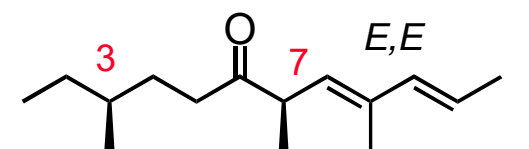
Park *et al.*, 1994. *J. Chem. Ecol.*, **20**, 2185

(6R,10R)-matsuone

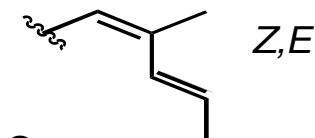
iv) Maritime pine scale (*M. feytaudi*)

Einhorn *et al.*, 1990. *Tetrah. Lett.*, **31**, 6633

Jactel *et al.*, 1994. *J. Chem. Ecol.*, **20**, 2159



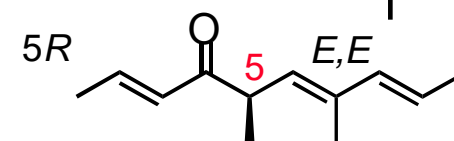
3S,7R



v) Israeli pine bast scale (*M. josephi*)

Dunkelblum *et al.*, 1993. *Tetrah. Lett.*, **34**, 2805

Dunkelblum *et al.*, 1995. *J. Chem. Ecol.*, **21**, 849



5R



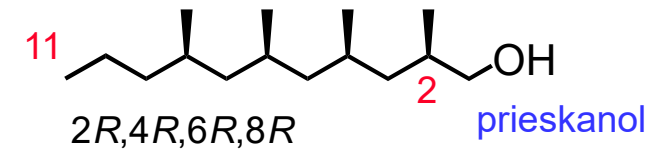
E:Z=3:1

(E) ワタフキカイガラムシ科 Margarodidae ②

vi) *Margarodes prieskaensis*

Burger *et al.*, 2017. *J. Chem. Ecol.*, **43**, 94

Me₂,Me₄,Me₆,Me₈₋₁₁:OH



(F) 文献リスト

マルカイガラムシ科 Diaspididae

- Acutaspis albopicta*
- Aonidiella aurantii* California red scale
アカマルカイガラムシ
- Aonidiella citrina* yellow scale
キマルカイガラムシ
- Aspidiotus nerii* = *A. hederae* oleander scale
シロマルカイガラムシ
- Aulacaspis murrayae*
- Psudaulascaspis pentagona* white peach scale
クワシロカイガラムシ
- Quadraspidotus perniciosus* San Jose scale
ナシマルカイガラムシ
- Millar *et al.*, 2012. *J. Econ. Entomol.*, **105**, 497
- Roelofs *et al.*, 1977. *Nature*, **267**, 698
- Roelofs *et al.*, 1978. *J. Chem. Ecol.*, **4**, 211
- Gieselmann *et al.*, 1979. *J. Chem. Ecol.*, **5**, 27
- Einhorn *et al.*, 1998. *PNAS*, **95**, 9867
- Ho *et al.*, 2014. *J. Chem. Ecol.*, **40**, 379
- Heath *et al.*, 1979. *J. Chem. Ecol.*, **5**, 941
- Einhorn *et al.*, 1983. *C. R. Acad. Sci., Ser. III*, 296, 861
- McLaughlin *et al.*, 1990. *J. Chem. Ecol.*, **16**, 749
- Gieselmann *et al.*, 1979. *J. Chem. Ecol.*, **5**, 891
- Anderson *et al.*, 1981. *J. Chem. Ecol.*, **7**, 695

コナカイガラムシ科 Pseudococcidae ①

- Crisicoccus azaleae* [azalea mealybug]
アザレアコナカイガラムシ
- Crisicoccus matsumotoi* [Matsumoto mealybug]
マツモトコナカイガラムシ
- Delottococcus aberiae*
- Dysmicoccus brevipes* [pineapple mealybug]
- Dysmicoccus grassii*
- Dysmicoccus neobrevipes* [grey pineapple mealybug]
バナナコナカイガラムシ
- Ferrisia virgate* [striped mealybug]
フタスジコナアイガラムシ
- Maconellicoccus hirsutus* [hibiscus mealybug]
ワタコナカイガラムシ
- Nipaecoccus viridis* [spherical mealybug]
- Paracoccus marginatus* [papaya mealybug]
- Phenacoccus madeirensis* [Madeira mealybug]
マデイラコナカイガラムシ
- Phenacoccus solenopsis* [cotton mealybug]
- Tabata & Yasui, 2022. *J. Chem. Ecol.*, **48**, 609
Sugawara *et al.*, 2024. *J. Chem. Ecol.*, **50**, 858
- Tabata *et al.*, 2012. *Naturwissenschaften*, **99**, 567
- Vacas *et al.*, 2019. *J. Agric. Food Chem.*, **67**, 9441
Bargues *et al.*, 2024. *J. Agric. Food Chem.*, **72**, 21488
- Tabata *et al.*, 2017. *J. R. Soc. Interface*, **14**, 20170027
Mori & Tabata, 2017. *Tetrahedron*, **73**, 6530
- Alfonso *et al.*, 2012. *J. Agric. Food Chem.*, **60**, 11959
- Tabata & Ichiki, 2015. *J. Chem. Ecol.*, **41**, 194
Tabata & Ohno, 2015. *Appl. Entomo. Zool.*, **50**, 341
- Tabata & Ichiki, 2017. *J. Chem. Ecol.*, **43**, 745-752
- Zhang *et al.*, 2004. *PNAS*, **101**: 9601
- Levi-Zada *et al.*, 2019. *J. Chem. Ecol.*, **45**, 455
Levi-Zada *et al.*, 2021. *J. Agric. Food Chem.*, **69**, 3026
- Sugawara *et al.*, 2025. *J. Chem. Ecol.*, **51**, 22
- Ho *et al.*, 2009. *J. Chem. Ecol.*, **35**, 724
- Tabata & Ichiki, 2016. *J. Chem. Ecol.*, **42**, 1193

コナカイガラムシ科 Pseudococcidae ②

Planococcus citri [citrus mealybug]
ミカンコナカイガラムシ

Planococcus ficus [vine mealbug]

Planococcus kraunhiae [Japanese mealybug]
フジコナカイガラムシ

Planococcus maritimus [grape mealybug]

Planococcus minoor [passionvine mealybug]
ニセミカンコナカイガラムシ

Pseudococcus baliteus [aerial root mealybug]

Pseudococcus calceolariae [citrophilous mealybug]

Pseudococcus comstocki [comstock mealybug]
クワコナカイガラムシ

Pseudococcus cryptus [citrus mealybug]
(= *P. citriculus*) ミカンヒメコナカイガラムシ

Pseudococcus longispinus [longtailed mealybug]
ナガオコナカイガラムシ

Pseudococcus viburni [obscure mealybug]

B.-Leonhardt *et al.*, 1981. *Tetrahedron Lett.*, **22**, 389

Hinkens *et al.*, 2001. *Tetrahedron Lett.*, **42**, 1619

Sugie *et al.*, 2008. *Appl. Entomol. Zool.*, **43**, 369

Figadère *et al.*, 2007. *Tetrahedron Lett.*, **48**, 8434

Ho *et al.*, 2007. *J. Chem. Ecol.*, **33**, 1986

Tabata *et al.*, 2020. *Tetrahedron Lett.*, **61**, 151802

El-Sayed *et al.*, 2010. *Tetrahedron Lett.*, **51**, 1075

Negishi *et al.*, 1980. *Appl. Entomol. Zool.*, **15**, 328

Bierl-Leonhardt *et al.*, 1980. *Life Sciences*, **27**, 399

Bierl-Leonhardt *et al.*, 1982. *J. Chem. Ecol.*, **8**, 689

Arai *et al.*, 2003. *J. Chem. Ecol.*, **29**, 2213

Millar *et al.*, 2009. *Org. Lett.*, **11**, 2683

Ramesh *et al.*, 2013. *J. Org. Chem.*, **78**, 6281

Vacas, *et al.*, 2024. *J. Agric. Food Chem.*, **72**, 12478

Millar *et al.*, 2005. *J. Chem. Ecol.*, **31**, 2999

Figadéra *et al.*, 2008. *Chem. Comm.*, 1106

ワタフキカイガラムシ科 Margarodidae

Margarodes prieskaensis

Burger *et al.*, 2017. *J. Chem. Ecol.*, **43**, 94

Matsucoccus feytaudi [martime pine scale]

Einhorn *et al.*, 1990. *Tetrah. Lett.*, **31**, 6633
Jactel *et al.*, 1994. *J. Chem. Ecol.*, **20**, 2159

Matsucoccus josephi [Israeli pine bast scale]

Dunkelblum *et al.*, 1993. *Tetrah. Lett.*, **34**, 2805
Dunkelblum *et al.*, 1995. *J. Chem. Ecol.*, **21**, 849

Matsucoccus matsumurae [Japanese pine bast scale]
マツモグリカイガラムシ

Lanier *et al.*, 1989. *J. Chem. Ecol.*, **15**, 1645
Hibbard *et al.*, 1991. *J. Chem. Ecol.*, **17**, 89
Mendel *et al.*, 2004. *Biolog. Control*, **30**, 134

Matsucoccus resinosae [red pine scale]

Lanier *et al.*, 1989. *J. Chem. Ecol.*, **15**, 1645
Hibbard *et al.*, 1991. *J. Chem. Ecol.*, **17**, 89
Shi *et al.*, 1995. *Tetrah. Lett.*, **36**, 7201

Matsucoccus thunbergiana [black pine red scale]

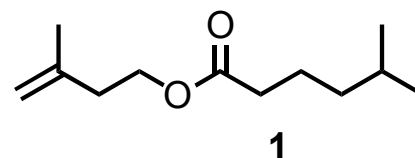
Lanier *et al.*, 1989. *J. Chem. Ecol.*, **15**, 1645
Hibbard *et al.*, 1991. *J. Chem. Ecol.*, **17**, 89
Park *et al.*, 1994. *J. Chem. Ecol.*, **20**, 2185

1. Acyclic terpene compounds

See compound numbers in Zou & Millar, 2015
(*Nat. Prod. Rep.*, **32**, 1067–1113)

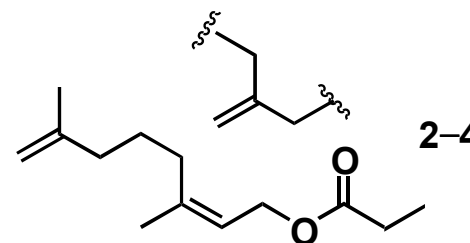
1-1. Hemiterpenol

Matsumoto mealybug



1-2. Esters of geraniol isomer

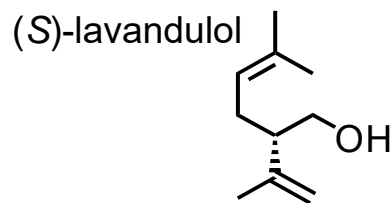
San Jose scale



+ (*E*)-isomer (minor comp.)

1-3. Esters of lavandulol and analogus

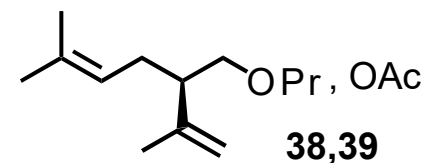
vine mealbug



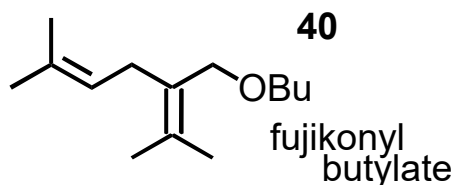
pink hibiscus mealybug



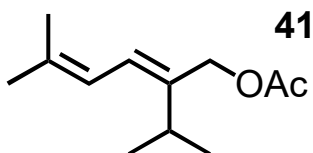
banana mealybug



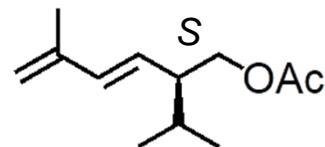
Japanese mealybug



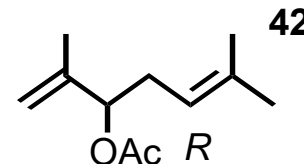
passionvine mealybug



grey pineapple mealybug

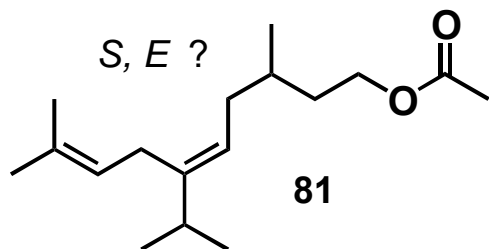


comstock mealybug

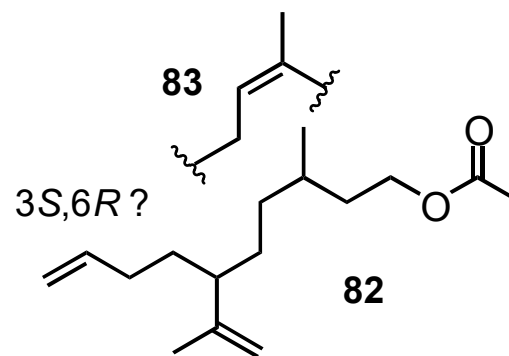


1-4. Esters of sesquiterpenols and analogus

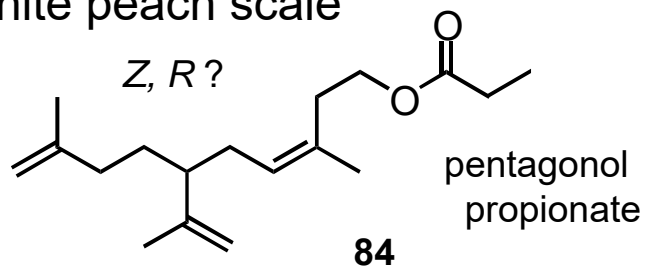
yellow scale



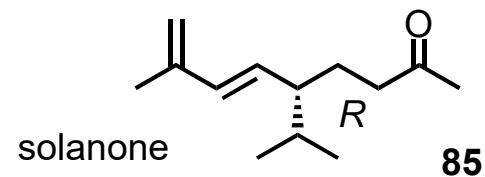
California red scale



white peach scale



Aulacaspis murrayae

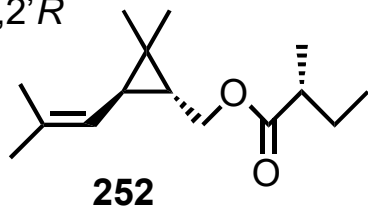


2. Cyclic terpene compounds

2-1. Cyclopropane-containing pheromones

Madeira mealybug

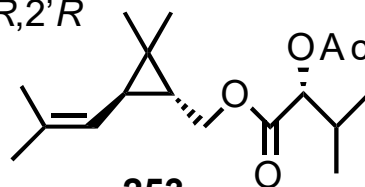
1*R*,3*R*,2'*R*



252

citrophilous mealybug

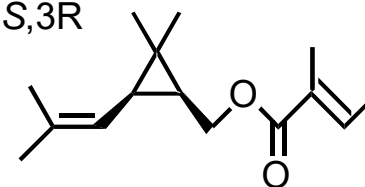
1*R*,3*R*,2'*R*



253

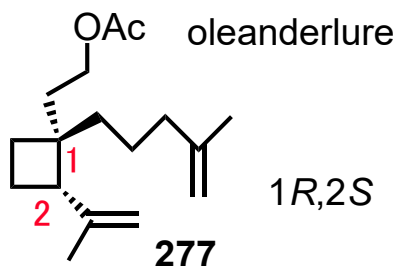
striped mealybug

1*S*,3*R*



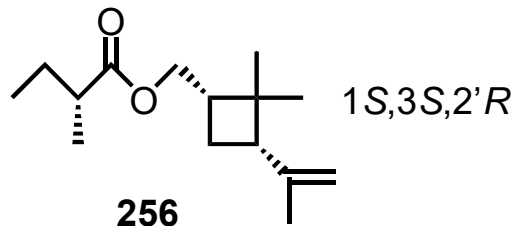
2-2. Cyclobutane-containing pheromones

oleander scale



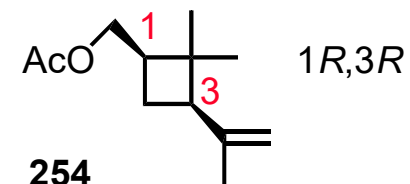
277

Acutaspis albopicta



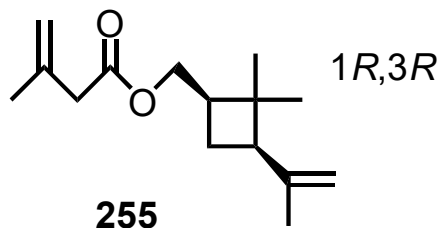
256

citrus mealybug



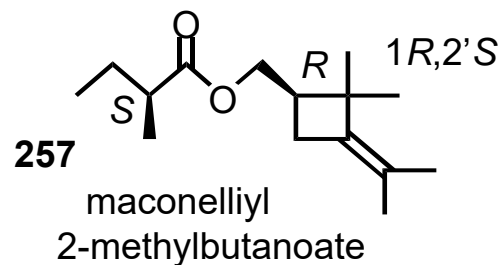
254

citriculus mealybug



255

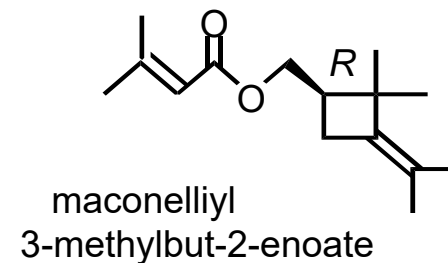
pink hibiscus mealybug



257

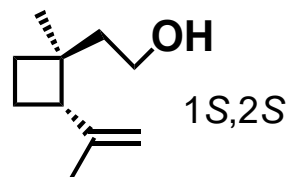
maconelliyl
2-methylbutanoate

cotton mealybug



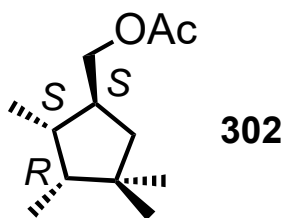
maconelliyl
3-methylbut-2-enoate

papaya mealybug

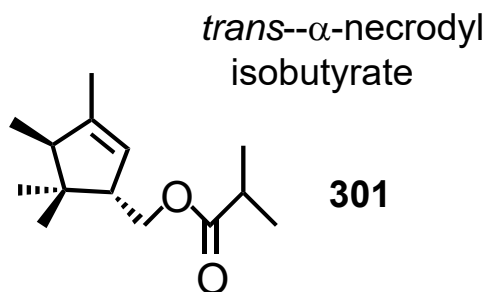


2-3. Cyclopenta(e)ne-containing pheromones

obscure mealybug



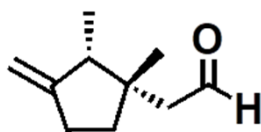
grape mealybug



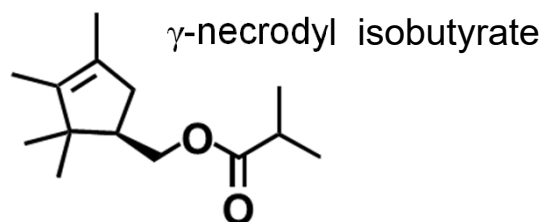
longtailed mealybug



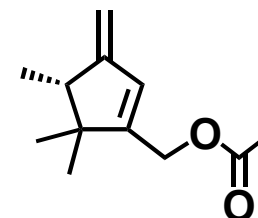
pineapple mealybug



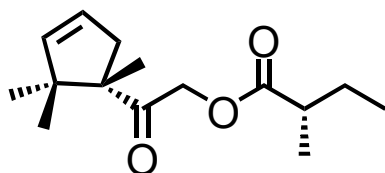
spherical mealybug



Delottococcus aberiae



aerial root mealybug

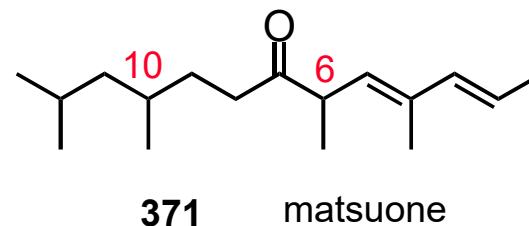


3. Non-terpene methyl-branched compounds (propanogenins)

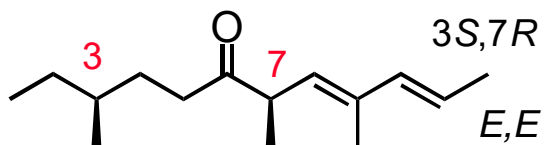
Japanese black pine bast scale 6R,10R ?

red pine scale (6R,10R)-matsuone

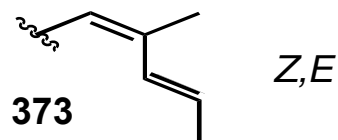
black pine bast scale (6R,10R)-matsuone



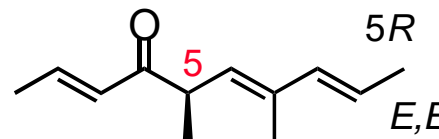
maritime pine scale



372

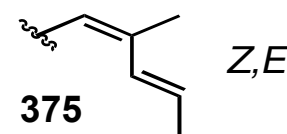


Israeli pine bast scale



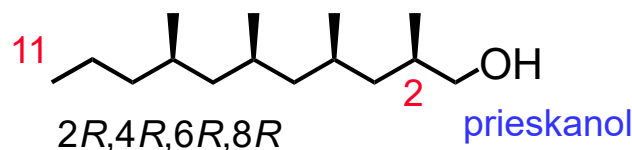
374

E:Z=3:1



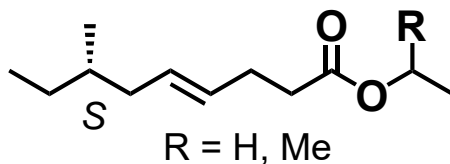
Margarodes prieskaensis

Me₂,Me₄,Me₆,Me₈₋₁₁:OH



Azalea mealybug

E₄,Me₇₋₉:acid ester



E₄,Me₇₋₈:acid ester

