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LE VAN DUNG

SYNTHESIS OF SOME ALCOHOL INSECT PHEROMONES CONTAINING ADJACENT METHYL BRANCHES AND *(Z)*-ALKEN-1-OL

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Supervisors:
1. Assoc. Prof. Dr. Dang Chi Hien
2. Prof. Dr. Sc. Nguyen Cong Hao

Reviewer 1:

Reviewer 2:

Reviewer 3:

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INTRODUCTION

1. The urgency of this study

In Vietnam, people commonly use chemical ways to kill insects and plant pests, such as spraying, poisonous baits for termites, or manually trapping them, such as coconut beetles... However, the aforementioned alternatives lack long-term viability and stability. To overcome the aforementioned constraints, utilizing pheromones and insect attractants is a way that has numerous advantages while also limiting most of the detrimental effects and downsides of the aforementioned procedures without disrupting the ecological equilibrium. As a result, pest density may be efficiently controlled across a vast region. Many insect pheromones that are detrimental to crops exist in the racemic form of secondary alcohols with adjacent methyl branches and alkenol-based derivatives all over the world, including Vietnam. Therefore, we chose the topic: *"Synthesis of some alcohol insect pheromones containing adjacent methyl branches and (Z)-alken-1-ol"*

Racemic insect pheromones of secondary alcohols containing the methyl branch are preferred for use in insect traps due to lower production costs and simpler synthesis methods than photoactive compounds. However, there are many issues that need to be addressed before secondary racemic alcohols with adjacent methyl branches can be used effectively in insect trapping. Previously, when synthesizing (±)-4-methyl-5-nonanol, the pheromone of the coconut worm *Rhynchophorus ferrugineus* in Vietnam, it was discovered that the *threo* configuration: *erythro* isomerism appeared in the product. Similarly, (±)-4-methyl-5-nonanol, if there is exist the *threo : erythro* configuration in the compound, then the ratio of the two isomers will be how much should be used and which Grignard and aldehyde agents should be used to give the optimal ratio of *threo:erythro* configuration to effectively trap insects. Therefore, this new issue needs to be

researched and answered because no work has been published in domestic and foreign journals. Besides, for pheromones with geometrical isomers, especially (Z)-isomers, synthetic methods with high selectivity, simplicity, and convenience are always preferred. The pathway for synthesizing (Z)-alkenol derivatives from 1-alkyne with a suitable catalyst system without using molecular hydrogen for hydrogenation such as Pd(OAc)2/KOH/DMF, Pd(dba)2/KOH/DMF, PdNPsPEG/KOH/DMF, and PdNPs@pectin/KOH/DMF is used to play a decisive role in converting a compound containing a triple bond to a double bond with a well selective configuration, accompanied by more straightforward techniques, allowing the production a large amount of pheromone for the preparation of bait in insect traps and at the same time reducing costs.

2. The aims of this study

Structural synthesis of some alcohol-basis insect pheromones containing adjacent methyl substituents and the *(Z)*-alken-1-ol. Then, biologically test several structural pheromone compounds in the field.

3. The main contents of this study

1. Synthesis of racemic secondary alcohols containing adjacent methyl branches:

+ Synthesis of secondary alcohols containing adjacent methyl substituents from aldehydes containing methyl substituents of $CH_3(CH_2)_mCH(CH_3)CHO$ (m = 1, 2, 4) with the Grignard reagent without a methyl substituent of the form $CH_3(CH_2)_nCH_2MgBr$ (n = 1, 2, 3, 4, 5, 6) corresponds to alcohols **(1a-15a)** and aldehydes without methyl substituents of the form $(CH_3(CH_2)_nCH_2CHO$ (n = 1, 2, 3, 4, 5, 6) with Grignard reagent containing methyl substituent of $(CH_3(CH_2)_mCH(MgBr)CH_3$ with m = 1, 2, 4) corresponding to alcohols **(1b-15b)**.

2. Oxidize the alcohols **(1a-15a)** to the corresponding ketones **(1c-15c)** by oxidizing agents: IBX/CH$_3$CN. Thereby, demonstrating the disappearance of the configuration isomer *threo: erythro* in the structure of ketones **(1c-15c)**.

3. Reconstitute the ketones **(1c-15c)** with LiAlH$_4$/(C$_2$H$_5$)$_2$O to the alcohol form. Demonstrating and explaining the reappearance of the *threo:erythro* conformation in reconstituted alcohols.

4. Evaluating the structure and investigating the ratio of *erythro* and *threo* configuration isomers of secondary alcohols containing adjacent methyl branches in the product.

5. Define new composite structures on Scifinder.

6. Synthesis of insect pheromones based on *(Z)*-alken-1-ol:

+ Synthesis of some *n*-bromoalkan-1-ol using heptane to replace benzene.

+ Using catalyst systems: Pd(OAc)$_2$/KOH/DMF, Pd(dba)$_2$/KOH/DMF, PdNPsPEG/KOH/DMF and PdNPs@pectin/KOH/DMF successfully reduced alkyne to *(Z)*-alken-1-ol without using molecular hydrogen to synthesize some pheromones of *(Z)*-alken-1-ol such as mosquito bug sex pheromone (*Helopeltis theivora* Waterhouse), silkworm sex pheromone (*Plutella xylostella*), sweet potato beetle (*Cylas formicarius*) sex pheromone from the starting materials as 1-alkyne and alkanediol.

7. Biological activity test:

+ Identify new structures capable of attracting coconut weevil in Ben Tre.

+ Bioactivity testing against sweet potato weevils in Ben Tre.

CHAPTER 1: OVERVIEW

This section presents an overview of pheromones, methods for synthesizing alcohol pheromones containing the adjacent methyl branches and *(Z)*-alken-1-ol.

CHAPTER 2: EXPERIMENTAL

2.1. Chemicals and materials

This section introduces the solvents, and chemicals which were used in the experiences

2.2. Synthesis of secondary alcohols containing adjacent methyl branches, investigating and evaluating the ratio of *threo:erythro* isomers of alcohols

R_1: $CH_3(CH_2)_m$- R_2: $CH_3(CH_2)_nCH_2^-$

R_1: $CH_3(CH_2)_m$- R_2: $CH_3(CH_2)_nCH_2^-$
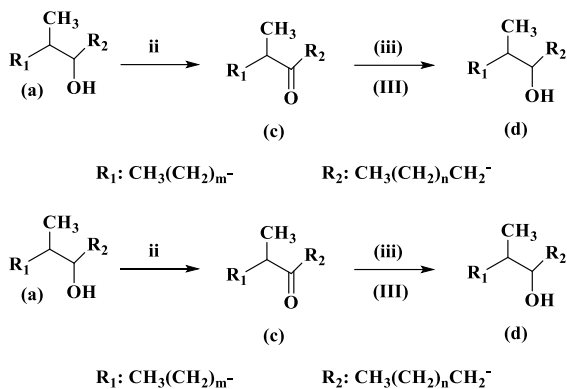
1 n = 1; m = 1	8 n = 2; m = 1	15 n = 4; m = 7
2 n = 1; m = 2	9 n = 2; m = 2	
3 n = 1; m = 3	10 n = 2; m = 3	
4 n = 1; m = 4	11 n = 2; m = 4	
5 n = 1; m = 5	12 n = 2; m = 5	
6 n = 1; m = 6	13 n = 2; m = 6	
7 n = 1; m = 7	14 n = 2; m = 7	

i. $Mg/(C_2H_5)_2O$; ii. IBX/CH_3CN; iii. $LiAlH_4/(C_2H_5)_2O$

Scheme 2.6. Synthesis of secondary alcohols containing adjacent methyl branches according to Cram's rule

2.2.1. Synthesis of secondary alcohols (a), (b) containing adjacent methyl branches by Grignard reaction according to Cram's rule

In *scheme 2.6*, there are three methods for synthesizing secondary alcohols containing adjacent methyl branches. In which, methods **(I)**, **(II)** use Grignard reaction. To prepare compound **(a)** from branched aldehydes $(CH_3(CH_2)_mCH(CH_3)CHO$ with m = 1, 2, 4) and unbranched Grignard reagent $(CH_3(CH_2)_nCH_2MgBr$ with n = 1, 2, 3, 4, 5, 6) and alcohol **(b)** synthesized from an unbranched aldehyde $(CH_3(CH_2)_nCH_2CHO$ for n = 1, 2, 3, 4, 5, 6) with a branched

Grignard reagent (CH$_3$(CH$_2$)$_m$CH(MgBr)CH$_3$, m = 1, 2, 4). In the products of alcohols **(a)** and **(b)**, exist a mixture of racemic isomers with *threo:erythro* isomer ratios varying when the length of the carbon chain R$_1$, R$_2$ varies. The occurrence of *threo:erythro* isomers of alcohols **(a)** and **(b)** is explained by Cram's rule, but how does the ratio of these isomers change when the two radicals R$_1$, R$_2$ change.

The alcohols **(a)** and **(b)** are synthesized via Grignard reaction with two-stage

Generation of *n*-bromoalkanes: Place 66 mL of HBr solution (0,9 mol, d=1,38g/mL) into an ice-cooled bridge. Then, slowly add 20 mL of H$_2$SO$_4$ solution to the flask, and mix well. Then add 27,5 mL of *n*-alkanol solution (0,298 mol) drop by drop to the above mixture. Shake the mixture well and install a condenser and reflux for 3 hours. After cooling, the mixture was distilled to obtain the crude product, which was extracted with concentrated HCl, H$_2$O, saturated NaHCO$_3$, and H$_2$O, respectively. The product was then anhydrous with CaCl$_2$. The clean product was distilled to the correct boiling point, yield > 95% and used immediately for the next reaction.

Grignard reagent: The Grignard reagent produced between alkyl bromide (2) and (3) (0,1 mol) and magnesium (0,2 mL) in diethyl ether was carried out in an ultrasonic bath from 30 min up to 1 hour. The aldehydes (1) and (4) (0,1 mol) in diethyl ether (100-150 mL) dripped slowly into the Grignard reagent at 0°C. Ultrasonic (using ultrasonic processor) for 30 min at 0ºC and 30 min at room temperature, check the conversion of the reaction by thin plate chromatography (TLC monitoring).

2.2.2. Oxidation of alcohols (a) to ketones (c) by IBX

IBX (2-Iodoxibenzoic acid, [1-hydroxy-1,2-benzoiodoxol-3(1*H*)-one) was chosen because it is a particularly important oxidizing agent used to oxidize alcohols to aldehydes or ketones. The reaction occurs under mild conditions,

which can completely replace the traditional oxidizing agents ($K_2Cr_2O_7/H^+$, $KMnO_4/H^+$, PCC...), the traditional oxidizing agents have limitations when synthesizing compounds short-chain ketones will reduce efficiency

Add the 2-iodoxibenzoic acid (IBX) (30 mmol) dissolved in CH_3CN (30 mL) into the reaction flask (thick-walled Pyrex screw-cap), then the 20 mmol alcohols (**1a-15a**) dissolve in 30 mL of CH_3CN was slowly added. The reaction was carried out under microwave conditions. Monitor the reaction by TLC, after the reaction was finished, the reaction mixture was added to HCl solution (10%, 30 mL) and extracted with diethyl ether (3 x 30 mL). The organic layer was washed with saturated $NaHCO_3$, water, saturated brine and anhydrous $MgSO_4$. Solvent expelled under reduced pressure to obtain the crude product. The crude product was purified by column chromatography (*n*-hexane : EtOAc= 9 : 1) or by fractional distillation yielding ketones (**1c-15c**).

2.2.3. Reduce ketones (c) to alcohols (d) with LiAlH₄/ether

Reconstituted alcohols (**d**) from the ketones (**c**) LiAlH₄ in anhydrous diethyl ether (**method (III)**) performed on a magnetic stirrer. The product is tested for the ratio of *threo* and *erythro* isomers through NMR analysis results.

Ketone (**1c-15c**) (40 mmol) completely dissolved in anhydrous diethyl ether (100 mL) was slowly added to a three-necked flask containing LiAlH₄ (80 mmol) in anhydrous diethyl ether (100 mL) at 0°C. The reaction mixture was raised to room temperature and stirred for about 1 hour. Monitor response by TLC. After the reaction was completed, the reaction mixture was added to 10% HCl (30 mL) and the reaction mixture was extracted with diethyl ether (3 x 30 mL). The organic layer was washed with saturated $NaHCO_3$, water, saturated brine and anhydrous $MgSO_4$. After remove the solvent under reduced pressure to obtain the crude product. The crude product is purified by column chromatography with a solvent

system (*n*-hexane : ether = 4 : 1) or by fractional distillation to obtain alcohols (**1d-15d**).

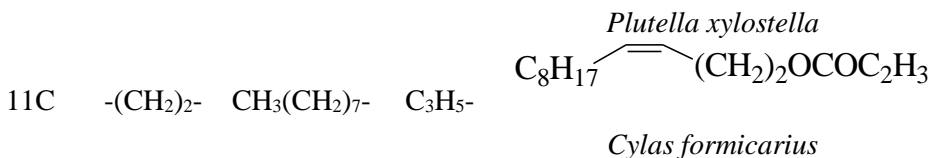**2.3. Synthesis of pheromones based on *(Z)*-alken-1-ol and ester of *(Z)*-alken-1-ol**
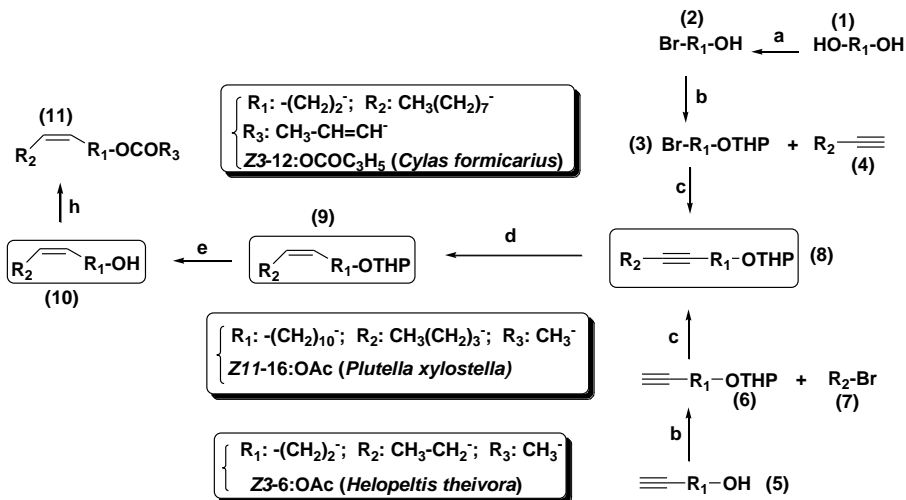
Scheme 2.11. Synthesis of pheromones based on *(Z)*-alken-1-ol and ester of *(Z)*-alken-1-ol

Reagents: a) HBr/heptane; b) DHP/*p*TSA/CH$_2$Cl$_2$; c) *n*-BuLi/KI/THF; d) xúc tác palladium/KOH/DMF; e) MeOH/*p*TSA; h) (CH$_3$CO)$_2$O hoặc Crotonyl chloride/Pyridine.

In *scheme 2.11*, it can be seen that the pheromones with the structure *(Z)*-alken-1-ol of ester are synthesized through 5 steps from the starting material are diols. The key reaction in this scheme is reduced of alkynes to *cis*-alkenes with the new catalytic systems of Pd in DMF/KOH without the use of molecular hydrogen.

Table 2.6. Synthesize the substances in the *Scheme 2.11*

TT	Compound	R_1	R_2	R_3	Structure
(1)	1A	$-(CH_2)_2-$			$HO(CH_2)_2OH$
	1B	$-(CH_2)_{10}-$			$HO(CH_2)_{10}OH$
(2)	2A	$-(CH_2)_2-$			$Br(CH_2)_2OH$
	2B	$-(CH_2)_3-$			$Br(CH_2)_3OH$
	2C	$-(CH_2)_5-$			$Br(CH_2)_5OH$
	2D	$-(CH_2)_6-$			$Br(CH_2)_6OH$
	2E	$-(CH_2)_7-$			$Br(CH_2)_7OH$
	2F	$-(CH_2)_8-$			$Br(CH_2)_8OH$
	2G	$-(CH_2)_{10}-$			$Br(CH_2)_{10}OH$
	3A	$-(CH_2)_{10}-$			$Br(CH_2)_{10}OTHP$
(6)	6C	$-(CH_2)_2-$			$\equiv\!\!-(CH_2)_2OTHP$
(8)	8A	$-(CH_2)_2-$	CH_3-CH_2-		$C_2H_5\!\!=\!\!\equiv\!\!-(CH_2)_2OTHP$
	8B	$-(CH_2)_{10}-$	$CH_3(CH_2)_3-$		$C_4H_9\!\!=\!\!\equiv\!\!-(CH_2)_{10}OTHP$
	8C	$-(CH_2)_2-$	$CH_3(CH_2)_7-$		$C_8H_{17}\!\!=\!\!\equiv\!\!-(CH_2)_2OTHP$
(9)	9A	$-(CH_2)_2-$	CH_3-CH_2-		$C_2H_5\overset{=}{\frown}(CH_2)_2OTHP$
	9B	$-(CH_2)_{10}-$	$CH_3(CH_2)_3-$		$C_4H_9\overset{=}{\frown}(CH_2)_{10}OTHP$
	9C	$-(CH_2)_2-$	$CH_3(CH_2)_7-$		$C_8H_{17}\overset{=}{\frown}(CH_2)_2OTHP$
(10)	10A	$-(CH_2)_2-$	CH_3-CH_2-		$C_2H_5\overset{=}{\frown}(CH_2)_2OH$
	10C	$-(CH_2)_2-$	$CH_3(CH_2)_7-$		$C_8H_{17}\overset{=}{\frown}(CH_2)_2OH$
(11)	11A	$-(CH_2)_2-$	CH_3-CH_2-	CH_3-	$C_2H_5\overset{=}{\frown}(CH_2)_2OCOCH_3$ *Helopeltis theivora*
	11B	$-(CH_2)_{10}-$	$CH_3(CH_2)_3-$	CH_3-	$C_4H_9\overset{=}{\frown}(CH_2)_{10}OCOCH_3$

| 11C | -(CH$_2$)$_2$- | CH$_3$(CH$_2$)$_7$- | C$_3$H$_5$- | *Plutella xylostella* C$_8$H$_{17}$ (CH$_2$)$_2$OCOC$_2$H$_3$ *Cylas formicarius* |

General procedure for the synthesis of a key reaction that reduces alkynes to *(Z)*-alkenes: Give (2.55 mmol) KOH, (0.04 mmol), (1.7 mmol) alkyn-1-yl tetrahydropyran-2 -yl ether **(8)** and catalyst Pd(dba)$_2$ in mL of DMF into the Pyrex reactor under nitrogene atmosphere connect a magnetic stirrer at 145°C in oil, reaction time is 6 hours. After finishing the reaction, cooled to room temperature, the reaction mixture was extracted with *n*-hexane (2 × 50 mL), washed with H$_2$O, and dried MgSO$_4$. Filter and evaporate the solvent under low pressure to obtain a crude product. The crude product was purified by column chromatography with solvent (*n*-hexane : diethyl ether = 9 : 1) to afford *(Z)*-alken-1-yl tetrahydropyran-2-yl ether **(9)**.

2.4. Isolation, physical properties, and structures of synthesized compounds

This section presents methods for isolating pure compounds: thin layer chromatography (TLC), multiple solvent washing, crystallization, and column chromatography. Methods for determining physical and structural properties: melting point, polar rotation. Nuclear magnetic resonance spectroscopy (^{1}H-NMR and ^{13}C-NMR). GC-MS spectra determine the conversion efficiency of the investigated reactions and fragmentation of the synthesized structure.

2.5. Test method for biological activity

This section presents the method of trap design, bait fabrication, testing location, testing time, testing methods and results processing for two insect species, coconut weevils and potato beetles. lang will be presented in this content.

CHAPTER 3: RESULTS AND DISCUSSION

3.1. Synthesis of secondary alcohols containing adjacent methyl branches, investigating and evaluating the ratio of *threo:erythro* isomer of alcohols

3.1.1. Synthesis of secondary alcohols (a), (b) containing adjacent methyl branches by Grignard reaction according to Cram's rule

On the ^{1}H NMR spectrum *(500 MHz, CDCl₃, δppm)* the alcohols **(1a-15a)** have a proton signal of -C**H**-OH at δ_H from 3.41 to 3.53 *ppm* (*m*, 1H)-*threo*. Beside, there is also a single-point signal appearing at δ_H from 3.35 to 3.45 *ppm* (*m*, 1H)-*erythro (Table 3.1)* suggesting the presence of another isomer beside the mainly substance. The main product and the *threo* isomer with a chemical shift on the ^{1}H NMR spectrum greater than that of *erythro* has been demonstrated by A. Zada and K. Mori. On the ^{13}C NMR spectrum *(125 MHz, CDCl₃, δppm)* appeared a signal of -**C**H-OH at δ_C from 75.5 to 77.6 *ppm-threo*. Product of alcohols **(1a-15a)** with *threo* configuration prevail over *erythro*. This is consistent with the actual results when these alcohols are analyzed on the ^{13}C NMR spectrum, which is found at the position of carbon-**C**HOH also has 2 signals where *threo* is dominant over *erythro* and the resonant nose integral value of the proton attached to -C**H**OH at H from 3.41 to 3.53 *ppm* and H from 3.35 to 3.45 *ppm* on ^{1}H NMR spectrum, with *threo: erythro* ratio = (1.6-2):1 *(Table 3.3 and Appendix 1.2 to 1.47)*
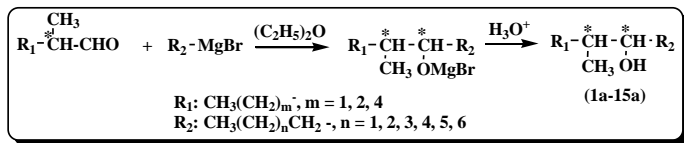
Scheme 3.1. Synthesis of alcohols **(1a-15a)**

Similar to the above case: On the ^{1}H NMR spectrum (*500 MHz, CDCl₃, δ ppm*) the alcohols **(1b-15b)** have a proton signal of -C**H**-OH at δ_H from 3.41 to 3.53 *ppm* (*m*, 1H)-*threo*. There is also a single-point signal appearing at δ_H from 3.35 to 3.46 *ppm* (*m*, 1H)-*erythro* indicating the presence of another isomer

besides the main substance in the product. On the ^{13}C NMR spectrum (*125 MHz, CDCl₃, δppm*), there is a signal of -**C**H-OH at δ_C from 74.9 to 76.8 *ppm-threo*. There is also a signal adjacent to the appearance of -**C**H-OH at δ_C from 75.8 to 77.1 *ppm-erythro*, further demonstrating the presence of a mixture of 2 isomers of *threo* and *erythro* in the molecule. However, if comparing the height of the peak adjacent carbon to the -**C**HOH position on the ^{13}C NMR spectrum as well as the value of the resonance nose integral of the attached proton -C**H**OH on the ^{1}H NMR spectrum, the ratio is 1:1. *(Table 3.3 and appendix 2.1 to 2.30)*

To clarify the problem of the ratio of *threo:erythro* isomers in a mixture of alcohols (**1a-15a**) and (**1b-15b**), the compound (±)-6-methyl-7-pentadecanol (**15a**) is a novel structure (see on Scifinder 09/2022) was selected as an example for analysis *(Figure 3.1)* shows that alcohol (**15a**) synthesized from 2-methylheptanal and 1-bromooctane has a resonance nose integral value of protons at -C**H**OH with a ratio of two configuration isomers *threo : erythro* respectively 1.79 : 1.00. Meanwhile, alcohol (**15b**) is synthesized from 2-bromoheptane and nonanal, the ratio of these two configuration isomers is 1.07 : 1.00.
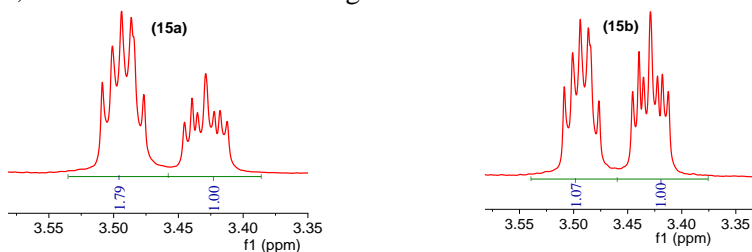

Figure 3.1. Ratio of *threo:erythro* isomer mixtures in alcohol (**15a**), (**15b**)

3.1.2. Oxidation of alcohols (a) to ketones (c) by IBX

The actual analysis of the ^{13}C NMR spectrum of the ketone product (**1c-15c**) performed exactly as predicted in theory. The clean product obtained by fractional distillation under reduce pressure. Examining the structural compounds of ketones on the ^{13}C NMR spectrum (*125 MHz, CDCl₃, δppm*) appeared enough

signal of the number of C equal to the number of C present in the structure of the ketones, including the signal of the -C =O at $\delta_C > 210$ *ppm. (Appendix 3.1 to 3.34)*

Thus, the result of oxidation of alcohols **(1a-15a)** to ketones **(1c-15c)** further confirmed that alcohol compounds **(1a-15a)** and **(1c-15c)** synthesized from the Grignard reaction as described above is a compound with *threo* and *erythro* configuration isomers. Ketone compounds **(1c-15c)** do not exist in this configuration isomer. However, when reducing the ketone **(1c-15c)** back to the alcohols show that still present configuration isomers and if so, what will be their ratio?

3.1.3. Reduce ketones (c) to alcohols (d) with LiAlH₄/ether

On the ^{1}H NMR spectrum (*500 MHz, CDCl₃, δppm*) there is a proton signal of –C**H**-OH at δ_H from 3.44 to 3.53 *ppm* (*m*, 1H). In addition, a single-point signal appeared at δ_H from 3.36 to 3.46 *ppm*, indicating the possible presence of another isomer besides the main substance in the product. However, if we compare the heights of the resonance nose integral value of the proton attached to –C**H**OH at 3.44 to 3.53 *ppm* and from 3.36 to 3.46 *ppm* on the ^{1}H NMR spectrum, there is a ratio is 1:1. *(Table 3.5 and annex 4.1 to 4.15)*. This means that when synthesizing alcohols from the respective ketones by reducing the ketones with LiAlH₄, the ratio of *threo* and *erythro* isomers in the mixture is approximately equal.

In conclusion

1) In order to synthesize adjacent methyl-branched alcohols with a greater ratio of *threo* isomers than *erythro*, the initial aldehyde must contain a methyl branch at carbon 2 position, and Grignard reagent does not carry a methyl substituent according to Cram's rule *(Table 3.3)*.

2) When synthesizing alcohols with adjacent methyl substituent with equal ratios of *threo* and *erythro* isomers, the raw material is an aldehyde without a methyl substituent and the Grignard reagent has a methyl substituent at carbon 2.

3) Ketone compounds are synthesized from alcohols **(1a-15a)** do not exist *threo* and *erythro* isomers, but the alcohol product converted from ketones still has a ratio of *threo : erythro* = 1:1.

4) The practical significance of the research problem has made new scholarly contributions in supplementing the completed Cram rule, previously according to Cram's rule that the steric effect of the substituents affects the ratio of *threo* and *erythro* isomers when adding a nucleophile to a carbonyl compound. However, this study shows that Cram's rule is not completely correct when changing the length of the carbon chain of an aldehyde compound containing a methyl branch at carbon 2 and changing the length of the carbon chain of Grignard reagent as a nucleophile. The ratio of the two isomers *threo* and *erythro* is not much different. *(Table 3.3).*

5) Another implication when using mixtures of *threo* and *erythro* isomers to make decoy traps in field trials which ratio is most effective at attracting insects.

3.2. Synthesis of pheromones based on *(Z)*-alkenol and ester

The Pd(dba)$_2$/KOH/DMF catalyst system as a source of hydrogene converts triple bond to double bond with efficiency 86-99%, selectivity over 95%. The mechanism of the semi-reduction reaction (semihydrogeneation) of alkynes to *cis*-alkenes was proposed by Martynov et al., (2003) (*Figure 3.3*). First, DMF in KOH hydrolyzes to produce HCOOH as a source of hydrogen with suitable concentration, and at the same time, oxidation to Pd(0) gives complex **(B)**, which selectively combines alkyne and Pd-H to create intermediates **(C)**. Then, decarboxylation and decleavage of C-C bonds to form *(Z)*-alkene derivatives and regenerate Pd(0).
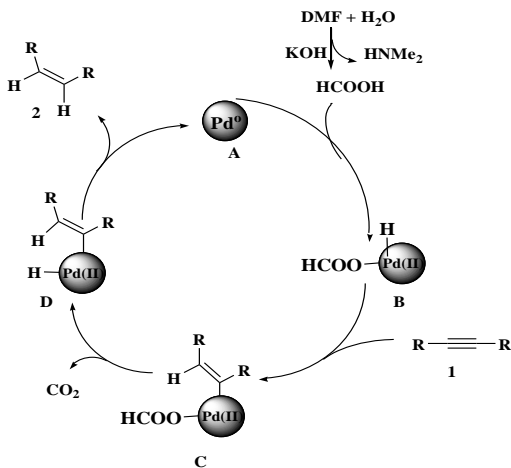
Figure 3.3. Mechanism of alkyne reduction to cis-alkene with
Pd(dba)$_2$/KOH/DMF catalyst system

The oxidation of HCOOH to Pd(0) and the formation of vinyl-Pd by alkyne insertion into the Pd-H bond were suggested by Zargarian and Brunel. Among them, HCOOH/NEt$_3$ can be used as a hydrogen source for the hydrogenation reaction in the presence of Pd(II). The decomposition of HCOOH into H$_2$ and CO$_2$ in the reaction is the limiting point of semihydrogeneation. Therefore, the formation of HCOOH of appropriate concentration in the reaction is a determinant of the half-reduction process with alkynes.

This research result opens a new direction for *(Z)*-alkene synthesis, especially in the synthesis of pheromones with *(Z)* configuration such as *(Z)*-alken-1-ol, in which, the bug pheromone mosquitoes *(Helopeltis theivora)*, silkworm sex pheromone *(Plutella xylostella)*, and sweet potato beetle *(Cylas formicarius)* sex pheromones are examples.

3.2.1. Synthesis of mosquito bug pheromone (Helopeltis theivora)

Compound *(Z)*-3-hexenyl acetate **(11A)** is an important component of the sex pheromone complex of the mosquito bug *Helopeltis theivora* Waterhouse

identified by Sachin J.P. et al., 2008. A process for the synthesis of *(Z)*-3-hexenyl acetate, with propane-1,3-diol and but-3-yn-1-ol as starting materials was selected *(Scheme 2.9)*. The structure of compound **(10A)**, which plays a key role, was examined by spectroscopic methods (^{1}H, ^{13}C NMR). On the ^{1}H-NMR spectrum, the proton signal positions are at δ 3.85 *ppm* (*t*, *J* = 7.3 Hz, 2H, -C**H$_2$**O-tetrahydropyranyl), 4.60 *ppm* (*t, J* = 4.3 Hz, 1H, -OC**H**O) of the tetrahydropyranyl compound disappeared, and proton signals with chemical shift δ 2.25 *ppm* (*s*, 1H) appeared, 3.62 *ppm* (*t, J* = 6.5 Hz, 2H) was assigned to the proton of the -OH and -CH$_2$OH group, contributing to confirm the compound structure as *(Z)*-3-hexen-1-ol. The proton signals of the double bond (-C**H**= and =C**H**-) are also evident around the δ 5.33 *ppm* (*dtt*, J_{cis} = 11.0 Hz, J_4 = 7.0 Hz, J_5 = 1.5 Hz, 1 H, H$_B$) and 5.54 *ppm* (*dtt*, J_{cis} = 11.0 Hz, J_4 = 7.5 Hz, J_5 = 1.5 Hz, 1H, H$_A$) when using CDCl$_3$ solvent, coupling constant *J* from 4 to 12 Hz suitable the *(Z)* configuration of **(10A)** *(Figure 3.5)*. The formation of alkenol structure is also demonstrated by the appearance of signals on the ^{13}C-NMR spectrum at 14.2; 62.2; 124.5; 134.7 *ppm* (assigned to -**C**H$_3$, -**CH$_2$**OH and -**C**H=**C**H- respectively). *(Appendix 10.1 and 10.2)*

3.2.2. Synthesis of sex pheromones of silkworm (Plutella xylostella)

(Z)-11-Hexadecen-1-yl acetate **(11B)** is the main component in the sex pheromone complex of silkworms synthesized according to S*cheme 2.9* from the starting materials 1,10-decandiol and 1-hexyne through 6 steps, overall efficiency 70%. The key reaction in *Scheme 2.11* is the reduction of 2-(hexadec-11-yn-1-yloxy)tetrahydro-2*H*-pyran **(8B)** to 2-(hexadec-11-en-1-yloxy)tetrahydro-2*H*-pyran **(3)** using the Pd(dba)$_2$/KOH/DMF catalyst system similar to the diagram 2.9, 91% yield. The structure **(9B)** playing a decisive role was examined by spectroscopic methods (^{1}H, ^{13}C NMR and DEPT). On the ^{1}H NMR spectrum of **(9B)**, the proton signals are characteristic at δ_H = 3.36-3.52 *ppm* (*m*, 2H, -CH$_2$C**H$_2$**O-); δ_H = 3.79-3.89 *ppm* (*m*, 2H, -CH$_2$C**H$_2$**O-tetrahydropyranyl); δ_H = 4.57-4.58 *ppm* (*m*, 1H, -OC**H**O-); The proton signals of the double bond (-C**H**=

and =C*H*-) are also evident around the δ_H = 5.34-5.36 *ppm* (*m*, 2H) positions *(Appendix 9.4)*. The formation of **(9B)** is also demonstrated by the appearance of signals on the ^{13}C-NMR spectrum at positions 13.9; 62.2; 67.7; 98.8; 129.8; 129.9 *ppm* (assigned to *C*H₃-, -CH₂*C*H₂O-; -*C*H₂CH₂O-tetrahydropyranyl; -O*C*O- and -*C*H=*C*H- respectively). The DEPT spectrum combined with the ^{13}C NMR spectrum shows that on the DEPT spectrum, there are 2 carbons of the -*C*H- group at the -*C*H=*C*H- double bond, one carbon of the -O*C*HO-tetrahydropyranyl group and one carbon of the *C*H₃- group *(Appendix 9.5 and 9.6)*. From the results of NMR spectroscopy and comparison with previously published documents, it can be concluded that the synthetic compound is 2-(hexadec-11-en-1-yloxy)tetrahydro-2*H*-pyran **(9B)**.

Then, compound **(9B)** was removed from the protective group to obtain alcohol **(10B)** and esterified **(10B)** obtained *(Z)*-11-hexadecen-1-yl acetate **(11B)**. The structure of compound **(11B)** was determined on the spectrum (^{1}H, ^{13}C NMR). On the ^{1}H NMR spectrum the proton signals are characteristic at δ_H = 0.90 (*t, J* = 7.5 Hz, 3H, C*H*₃CH₂-); δ_H = 2.04 (*s*, 3H, C*H*₃CO-); δ_H = 4.05 (*t, J*= 7.5 Hz, 2H, -CH₂*CH*₂O-); two proton signals at the double bond have δ_H = 5.34-5.39 (*m*, 2H, -C*H*=C*H*-). On the ^{13}C NMR spectrum, there are typical signals at positions 13.9; 21.0; 64.7; 129.9 (2C); 171.2 in turn assigned to *C*H₃CH₂-; CH₃*C*O-; -CH₂*C*H₂O-; -*C*H=*C*H- and -*C*O-.

3.2.3. Synthesis of sex pheromones of the sweet potato beetle (Cylas formicarius)

(Z)-3-Dodecen-1-ol *(E)*-2-butenoate **(11C)** is the main sex pheromone component of sweet potato beetle synthesized according to *Scheme 2.10* from the starting material 3-butyn-1-ol and *n*-bromooctane consists of 5 reaction stages with a total yield of 68%. The reaction is mediated by 2-(dodec-3-yn-1-yloxi)tetrahydro-2H-pyran **(8C)** which is a compound containing a triple bond, which is then reduced to the form *(Z)*-2-(dodec-3)-en-1-yloxy)tetrahydro-2*H*-pyran (3) with 90% efficiency this is also the key reaction of the reaction scheme. The result of compound structure **(9C)** was determined on the spectrum (^{1}H, ^{13}C

NMR). Then, compound **(9C)** was removed from the protective group to obtain *(Z)*-3-dodedcen-1ol **(10C)**. On the proton spectrum of **(10C)**, the signals are characteristic at δ 0.88 *ppm* (*t, J* = 7.0 Hz, 3H, C***H**$_3$-); 3.63 (*t, J* = 6.5 Hz, 2H, -C***H***$_2$O-); the two proton signals at the double bond have δ_H 5.60 (*dtt, J$_{cis}$* = 10.5 Hz, *J$_4$* = 7.5 Hz, *J$_5$* = 1.5 Hz, 1H, H$_B$); 5.39 (*dtt, J$_{cis}$* = 11.0 Hz, *J$_4$* = 7.5 Hz, *J$_5$* = 1.5 Hz, H$_C$) *(Figure 3.6)*. On the ^{13}C NMR spectrum, there are typical signals at 14.1; 62.4; 124.9; 133.6 is in turn assigned to C***H**$_3$-; -C***H**$_2$O-; -***C***H=***C***H-. The DEPT spectrum combined with the ^{13}C NMR spectrum shows that on the DEPT spectrum, there are two carbons at δ_C 124.9; 133.6 and 1 carbon of the CH$_3$- group at δ_C 14.2 *ppm (Appendix 10.7)*. From ^{1}H, ^{13}C NMR, DEPT spectral data and comparison with the spectral data according to the literature, it can be concluded that the synthetic compound is *(Z)*-3-dodecen-1-ol **(10C)**.

Compound **(10C)** esterified with crotonyl chloride in pyridine yielded *(Z)*-3-dodecen-1-ol *(E)*-2-butenoate **(11C)** which is the sex pheromone component of the sweet potato beetle.

3.3. Biological test results

3.3.1. Test results for coconut weevils

Pheromone composition of coconut worms is known to be a combination of two components: (±)-4-methylnonan-5-ol **(10a)** and (±)-4-methylnonan-5-one **(10c)**. The results of these two-component trials on coconut weevils in Ben Tre have been presented in this section. However, the research results show that in addition to the above two ingredients, some new alcohols have also been found that can attract coconut weevils such as: (±)-3-methyl-4-nonanol **(4b)**, (±)-4-methyl-5-decanol **(11b)**, (±)-3-methyl-4-nonanol **(4c)**, (±)-3-methyl-4-decanone **(5c)** and (±)-4-methyl-5-decanone **(11c)** and (±)-4-methyl-5-decanol **(11a)**. The results after statistical processing are as follows:

Two compounds **(5c)** and **(11a)** are two new compounds that have the best ability to attract coconut weevils with the number of children entering the trap, respectively: 3.6 ± 0.55 insects/3 traps/week and 3.8 ± 0.45 insects / 3 traps/week.

In which, compound (±)-4-methyl-5-decanol (**11a**) is an alcohol with a predominant ratio of *threo* isomers over *erythro* capable of attracting insects into the trap more effectively than compound (±)-4-methyl-5-decanol (**11b**) has the same ratio of these two isomers with the number of insects entering the trap 1,6 ± 0,55 insects/3 traps/week. *(Appendix 13.1, 13.2. 13.3)*

Comparing compounds (**11a**), (**11b**) with the two main components of pheromones in the combination (**10a**) and (**10b**) found that there is a similar relationship that alcohols have a similar ratio. The *threo* isomer is dominant over *erythro* attracting more insects into the trap. This suggests that compound (**11a**) containing the component *(4S, 5S)*-4-methyl-5-decanol which is the optical isomer in the predominant *threo* isomer is responsible for the strong bioactivity. similar to *(4S, 5S)*-4-methyl-5-nonanol is known to be the major constituent pheromone of coconut worms. Experimental results on a racemic mixture of (±)-4-methyl-5-nonanol (**10a**) with a predominant ratio of *threo* isomers also showed the same strong trapping efficiency as compound (**11a**). However, this is only a comparative result based on similar compounds, so we want to accurately assess whether compound (**11a**) is *(4S, 5S)*-4-methyl-5-decanol is the cause major bioactivity in the racemic mixture or not require further experiments in the future.

Besides, (±)-4-methyl-5-decanone (**11c**) is a ketone oxidized from (**11a**) also has the ability to attract coconut weevils but the insect trapping efficiency is lower and equal to (**4b**), (**4c**) with the number of insects entering the trap 1 ± 0,71 insects/3 traps/week. However, if the combination (**11a**) with (**11c**) or (**11b**) with (**11c**), the efficiency of attracting insects is reduced with the number of insects entering the trap, respectively 2 ± 0,71 insects/3 traps/ week and 1,4 ± 0,55 insects / 3 traps/week *(Appendix 13.1, 13.2. 13.3)*. This suggests that compound (**11c**) is an inhibitory component for insects when combining the components while the combination (±)-4-methyl-5-nonanol (**10a**) and (±)-4-methyl-5-nonanone (**10c**) ketone components increased the ability to attract insects.
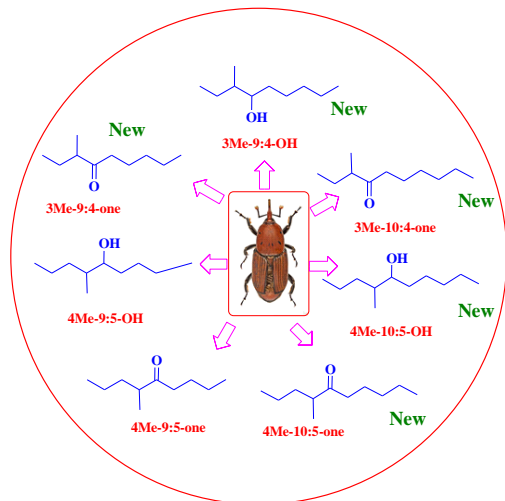
Figure 3.13. New structures attract coconut weevil

Statistical results are at the significance level of $P < 0,05$, df = 9 and F = 14,691 *(Appendix 13.2)*. The above results show that compound **(5c)**, **(11a)** are two new attractants. It was found that the inducing efficiency equivalent to the pheromone synthesis of coconut worms was (±)-4-methyl-5-nonanol **(10a)** and (±)-4-methyl-5-nonanone **(10c)**. Therefore, these two compounds have a lot of potential and can replace coconut weevil pheromones with low cost of making bait traps that effectively trap insects equivalent to its pheromones.

From the above results it can be concluded:

Statistical results using SPSS software, with statistical difference at 5% significance level, df = 9 and F = 14,691 *(Appendix 13.2)*. The results show that compounds **(5c)**, **(11a)** are two new discovered attractants that have the ability to attract coconut worms more effectively than the main pheromone components of coconut worms **(10a)**, **(10b)** and even equivalent to the pheromone combination of coconut weevils (±)-4-methyl-5-nonanol **(10a)** and (±)-4-methyl-5-nonanone **(10c)**. Therefore, these two compounds have a lot of potential and can replace the

combination of coconut weevils pheromone **(10a + 10c)** with low cost and simple decoy traps to trap in practice.

3.3.2. Test results with sweet potato beetle

In this content, the results of biological tests on sweet potato beetles are presented in detail by dose, time, trap door height, and trap material type. The following results:

3.3.2.1. The results of the survey on the effectiveness of attracting sweet potato beetles according to the dose

Initially tested on sweet potato beetle at concentrations: 0.1 mg; 0.2 mg; 0.4 mg, 0.8 mg and the control samples in a continuous period from November 26, 2020 to December 17, 2021 achieved some results as follows:

The amount of insects entering the trap corresponds to the doses: 0.1 mg, 0.2 mg, 0.4 mg and 0.8 mg, respectively: 91,3 ± 3,22; 98,3 ± 1,53; 108,3 ± 1,53; 132 ± 3,61 fish/trap/week at the significance level of P < 0,05. From the practical results in the field, it is found that the number of beetles entering the trap with different doses is different. Experimental results show that the appropriate dose for a bait is 0.4 mg (with an average of 108,3 ± 1,53 insects/trap/week).

From practical results in the field, it is found that the suitable concentration for a bait trap is 0.4 mg. To test what factors affect the number of insects entering the trap, another experiment continues to be investigated, which is to survey the number of insects entering the trap over time with the selected concentration of 0.4 mg. *(Figure 3.14, Appendix 14.1, 14.2, 14.3)*

3.3.2.2. Investigate the effectiveness of decoy traps over time

Statistical processing of treatments T1, T2. T3, T4 by SPSS software, with statistical difference at 5% significance level, df = 5, F = 265.85 *(Appendix 15.1, 15.2, 15.3)*, combined with *Figure 3.15* shows: from week 1 to week 2, the number of beetles entering the trap decreased (average 115 insects/trap/week) compared to the first week (141 insects/trap/week), then the number of beetles entering the trap continued to. The third week (92 insects/trap/week) and by the

fourth week the number of beetles entering the trap continued to decrease more than 2 times (65 insects/trap/week) compared to the first week. However, two consecutive weeks after that, the bait still lured the beetles into the trap with no difference compared to week 4. *(Figure 3.15)*

3.3.2.3. Effect of the height of the insect trap door

When changing the height of the insect traps, it was found that the number of sweet potato families entering the trap was not different in D2, D3 but there was a difference compared to the rest of the NT. The height of the traps of D2 (0 cm) and D3 (40 cm) above the surface of the potato leaves with the number of sweet potato beetles entering the trap was not different but the different control sample *(Figure 3.7)*. The average number of beetles entering the trap is 116 ± 18; 102 ± 15; 78 ± 10; 42 ± 6; 25 ± 4 corresponding to the species of D1 (-20 cm), D2 (0 cm), D3 (20 cm), D4 (40 cm) and D5 (60 cm) *(Appendix 16.1, 16.2, 16.3)*.

3.3.2.4. Effect of trap material type

The number of beetles entering the traps for the two material types containing pheromone lure (V1, V3) was higher and different from that of the control treatment without pheromone lures (V2, V4): containing only *n*-Hexane), while the number of beetles entering the trap for NT V1, V3 did not differ *(Table 3.9)*, with the number of respectively: V1-trap of opaque plastic bottles (105 insects/ traps/week) is 1,26 times higher than that of NT V2-clear plastic bottles (83 insects/trap/week) *(Figure 3.9)*.

IN CONLUSION

Synthesis and testing of secondary alcohols containing adjacent methyl branche according to Cram's rule

1) Successfully synthesized 45 secondary alcohol structures containing adjacent methyl substituents according to Cram's rule. In there:

a) Alcohols **(1a-15a)** are synthesized from aldehydes containing adjacent methyl substituents of $CH_3(CH_2)_mCH(CH_3)CHO$, m = 1, 2, 4 with the Grignard reagent without a methyl substituent of $(CH_3(CH_2)_nCH_2MgBr$, n = 1, 2, 3, 4, 5, 6) are

conformational isomers with a *threo* ratio 1.5-2 higher than that of *erythro*, sequestration efficiency 86-96%.

b) Alcohols **(1b-15b)** are synthesized from aldehydes that do not carry adjacent methyl substituents $(CH_3(CH_2)_nCH_2CHO$, n = 1, 2, 3, 4, 5, 6) with Grignard reagent containing methyl substituents $(CH_3(CH_2)_mCH(MgBr)CH_3$, m = 1, 2, 4, with ratio of *threo : erythro* isomers = 1 : 1, sequestration efficiency 86-95%.

2) Successfully used oxidizing agent IBX/CH_3CN under microwave condition (450W, 20 minutes) to oxidize 15 alcohols **(1a-15a)** to 15 ketones **(1c-15c)**, isolation yield 54-85 %.

3) Synthesis of secondary alcohols containing adjacent methyl branches found out two new compounds, (±)-6-methyl-7-pentadecanol **(15b)** and (±)-6-methyl-7-pentadecanone **(15c)** *(Checked on Scifinder 09/2022)*.

4) Results of ¹H NMR analysis of secondary alcohols containing adjacent methyl substituents showed that the carbon chain lengths of aldehydes containing and not containing adjacent methyl substituents did not change the ratio of *threo* and *erythro* formed in the product.

5) Experimental results in the field showed that alcohols with a greater proportion of *threo* isomers than *erythro* attracted coconut weevils better. Therefore, to synthesize these alcohols, it is recommended to choose raw materials from aldehydes bearing methyl substituents adjacent to Grignard reagents without methyl substituents to create better coconut weevils.

6) Through experimental results in the field, 5 new compounds have been discovered that have the ability to attract coconut weevil: (±)-3-methyl-4-nonanol **(4b)**, (±)-3-methyl- 4-nonanone **(4c)**, 3-methyl-4-decanone **(5c)**, (±)-4-methyl-5-decanol **(11a)**, (±)-4-methyl-5-decanol **(11b)**, (±))-4-methyl-5-decanone **(11c).** In which, two compounds with good attractant effect equivalent to pheromone combination of coconut worm known are (±)-4-methyl-5-nonanol **(10a)** and (±)-4-methyl-5- nonanone **(10c)**.

Synthesis and selective testing of insect pheromones *(Z)*-**alken-1-ol and ester of** *(Z)*-**alken-1-ol**

1) Using *n*-heptane to replace benzene efficiently synthesizes *n*-bromoalkan-1-ols from diols with 6 carbons or more. This is a fundamental but very important contribution to pheromone synthesis.

2) Successfully applied new catalyst systems as Pd(dba)$_2$/KOH/DMF, PdNPsPEG/KOH/DMF and PdNPs@pectin/KOH/DMF to reduce alkyne to *(Z)*-alkene without using molecular hydrogen in the synthesis of insect pheromones *(Z)*-alken-1-ol or precursors of the form *(Z)*-alken-1-ol such as sex pheromone mosquito bugs (*Helopeltis theivora* Waterhouse), silkworms (*Plutella xylostella*), sweet potato beetles (*Cylas formicarius*) with total efficiency over 80%, 60%, and 64% respectively. In which, Pd(dba)$_2$/KOH/DMF should be selected because of its convenient fabrication and high efficiency.

3) Successfully tested the sweet potato beetle with the sex pheromone composition of *(Z)*-3-dodecen-1-yl *(E)*-2-butenoate.

RECOMMENDATIONS

1. Continue to study the synthesis optical isomers to new compounds **(4a), (4c), (5c), (11a), (11c)** and biological test of compound for coconut weevils.

2. Biological testing of two new constructs **(15a), (15b)** on other subjects.

3. Extensive testing of the new compound in different growing areas to target the known pheromone substitution of coconut weevils (±)-4-methyl-5-nonanol **(10a, 10b)** and (±)-4-methyl-5-nonanone **(10c)**.

4. Research on synthesis of carrying pheromone materials for the purpose of prolonging the efficiency traction and reducing usage costs for the people.

5. Research on synthesizing other *(Z)*-alken-1-ol insect pheromones in Vietnam using Pd(dba)$_2$/KOH/DMF catalyst system, and industrial scale deployment.

CONTRIBUTION OF THIS STUDY

1. Synthesis of 15 contiguous methyl branched secondary alcohol structures from branched aldehydes and unbranched Grignard reagents with a *threo*-isomer ratio (from 1.6 to 2.0) greater than that of *erythro*, with yield 86-96% (**1a-15a).**

2. Synthesis of 15 methyl-branched secondary alcohol structures from branched aldehyde and unbranched Grignard reagent with *threo* isomer ratio (from 1.6 to 2.0) greater than *erythro's* 1, with yield 86-95% (**1a-15a**).

3. Using IBX/CH$_3$CN under microwave conditions for the first time synthesized 15 ketones (**1c-15c**) containing adjacent methyl branches, with an efficiency of yield 54-60%.

4. The reduction of ketones with LiAlH$_4$ yields 15 alcohols (**1d-15d**) with a 1:1 ratio of *threo* and *erythro* isomers, with an yield of 95-98%.

5. Synthesis of two new structures: (±)-6-methyl-7-pentanol (**15a)** and (±)-6-methyl-7-pentanone (**15c**) looked up on Scifinder 09/2022.

6. Discovered 5 new structures that attract coconut weevils: (±)-3-methyl-4-nonanol (**4b**), (±)-3-methyl-4-nonanone (**4c**), (±)-3-methyl-4-decanone (**5c**), (±)-4-methyl-5-decanol (**11a**), (±)-4-methyl-5-decanone (**11c**). Trong đó, (±)-3-methyl-4-decanone (**5c**), (±)-4-methyl-5-decanol (**11a**) gave very impressive attractive effect.

7. The study proved that the length of the carbon chain of branched and unbranched aldehydes did not change the ratio of *threo* and *erythro* isomers. This adds a more complete Cram rule in the *threo* and *erythro* configuration selectivity problem.

8. Using efficient Pd(dba)$_2$/DMF/KOH catalyst systems to synthesize *cis*-alken-1-ol from alkynes without using molecular hydrogen in the synthesis of sex pheromone components of the mosquito bug (*Helopeltis theivora*), Silkworm (*Plutella xylostella*), Sweet potato beetle (*Cylas formicarius*) with total efficiency over 80%, 60%, and 64% respectively.

PUBLICATIONS RELATED TO THIS STUDY
National Journal

1. **Van-Dung Le**, Cong-Hao Nguyen, Thanh-Danh Nguyen, Chi-Hien Dang, *The synthesis of 4-Methyl-3-hexanol and 3-methyloctan- 4-ol*, Vietnam Journal of Chemistry, 55 (3e), 183-186 (**2017**).

2. **Van-Dung Le**, Cong-Hao Nguyen, Thanh-Danh Nguyen and Chi-Hien Dang, *Sự ảnh hưởng của nhóm alkyl trong tổng hợp các pheromone dạng ancol có nhóm thế metyl liền kề*, Tạp chí hóa học, 55(5E34), 132-136 (**2017**).

3. **Van-Dung Le**, Cong-Hao Nguyen, Thanh-Danh Nguyen and Chi-Hien Dang, *Một số phương pháp tổng hợp (Z)-3-hexenyl acetate thành phần pheromon giới tính của bọ xít muỗi gây hại điều (Helopeltis theivora* Waterhouse), Tạp chí hóa học, 55(5E34), 294-298 (**2017**).

4. **Lê Văn Dũng**, Nguyễn Thành Danh, Trương Thị Thanh Lam, Nguyễn Thị Hằng, Lê Nhựt Thi, Nguyễn Công Hào, Đặng Chí Hiền, *Nghiên cứu sự bay hơi và một số kết quả thử nghiệm pheromone tập hợp của đuông dừa Rhynchophorus palm weevil (Rhynchophorus ferrugineus* Oliv.) tại Bến Tre, Tạp chí Hóa học, 57(4E3,4), 86-89 (**2019**).

5. **Le Van Dung**, Nguyen Cong Hao, Nguyen Thanh Danh, Nguyen Thi Hang, Dang Chi Hien, *A facile synthesis for the sex Pheromone of Mosquito Bug* (*Helopeltistheivora Waterhouse) from Propargyl alcohol*, Vietnam Journal of Chemistry, 57(6E1,2), 524-528 (**2019**).

6. Accept to publish an article in Vietnam Journal of Science and Technology *(Scopus)*.
   Le Van Dung, Nguyen Cong Hao, Nguyen Thanh Danh, Ngo Le Ngoc Luong, Nguyen Thuy Duong, Nguyen Thi My Thao, Dang Chi Hien, *Synthesis and field experiments of the female sex pheromone of sweet potato weevil, Cylas Formicarius,* Vietnam Journal of Science and Technology.

International Journals (SCI-E)

1. Chi-Hien Dang, **Van-Dung Le**, Cong-Hao Nguyen, and Thanh-Danh Nguyen, *A facile synthesis of racemic aggregation pheromones of palm pests, Rhinoceros beetle and Rhynchophorus* weevil, Arkivoc, V**,** 187-195 (**2017**). (**IF = 1.14, 2020, Q.4)**

2. **Van-Dung Le**, T. Cam-Huong Le, Van-Trung Chau, T. Ngoc-Duyen Le, Chi-Hien Dang, T. To-Nguyen Vo, Trinh Duy Nguyen and Thanh-Danh Nguyen, *Palladium nanoparticles in situ synthesized on Cyclea barbata pectin as a heterogeneous catalyst for Heck coupling in water, reduction of nitrophenols and alkynes*, New Journal of Chemistry, 45, 4746-4755 (**2021**). (**IF = 3.591, 2020, Q.1)**

3. **Van-Dung Le**, Chi-Hien Dang, Cong-Hao Nguyen, Hong-Ung Nguyen, and Thanh-Danh Nguyen, *Synthesis of β-Methyl Alcohols: Influence of Alkyl Chain Length on Diastereoselectivity and New Attractants of Rhynchophorus ferrugineus*. Journal of Agricultural and Food Chemistry, 69(21), 5882-5886 **(2021). (IF = 5.279, 2020, Q.1)**

National Conference Report (oral): 3 reports

1. Conference report: "*Application of biotechnology in sustainable agricultural - aquaculture production*", Tra Vinh University, December 20, **2019**.

2. Report of the IX National Chemistry Conference: "*Some new results in synthesizing and testing insect pheromones in Vietnam*", Hanoi, December 22, **2019.**

3. Conference report: "*Presented in the international conference on chemistry and application*", Industrial University of Ho Chi Minh City, 14th-15th, July **2022**.