

**REVIEW****Phytochemical and Biological Studies of *Abies* Species**by Xian-Wen Yang<sup>a)</sup>, Su-Mei Li<sup>b)</sup>, Yun-Heng Shen<sup>a)</sup>, and Wei-Dong Zhang<sup>\*a)</sup><sup>a)</sup> Department of Natural Product Chemistry, School of Pharmacy, Second Military Medical University, 325 Guohe Road, 200433 Shanghai, P. R. China<sup>b)</sup> Department of Ethnobotany, Kunming Institute of Botany, Chinese Academy of Sciences, 650204 Kunming, P. R. China (phone: +86 21 25070386; e-mail: wdzhangy@hotmail.com)

In the present review, the literature data on the phytochemical and biological investigations on the genus of *Abies* are summarized with 110 references. Up to now, 277 compounds were isolated from 19 plants of *Abies* species. The chemical constituents are mostly terpenoids, flavonoids, and lignans, together with minor constituents of phenols, steroids, and others. The crude extracts and metabolites have been found to possess various bioactivities including insect juvenile hormone, antitumor, antimicrobial, anti-ulcerogenic, anti-inflammatory, antihypertensive, antitussive, and CNS (central nervous system) activities.

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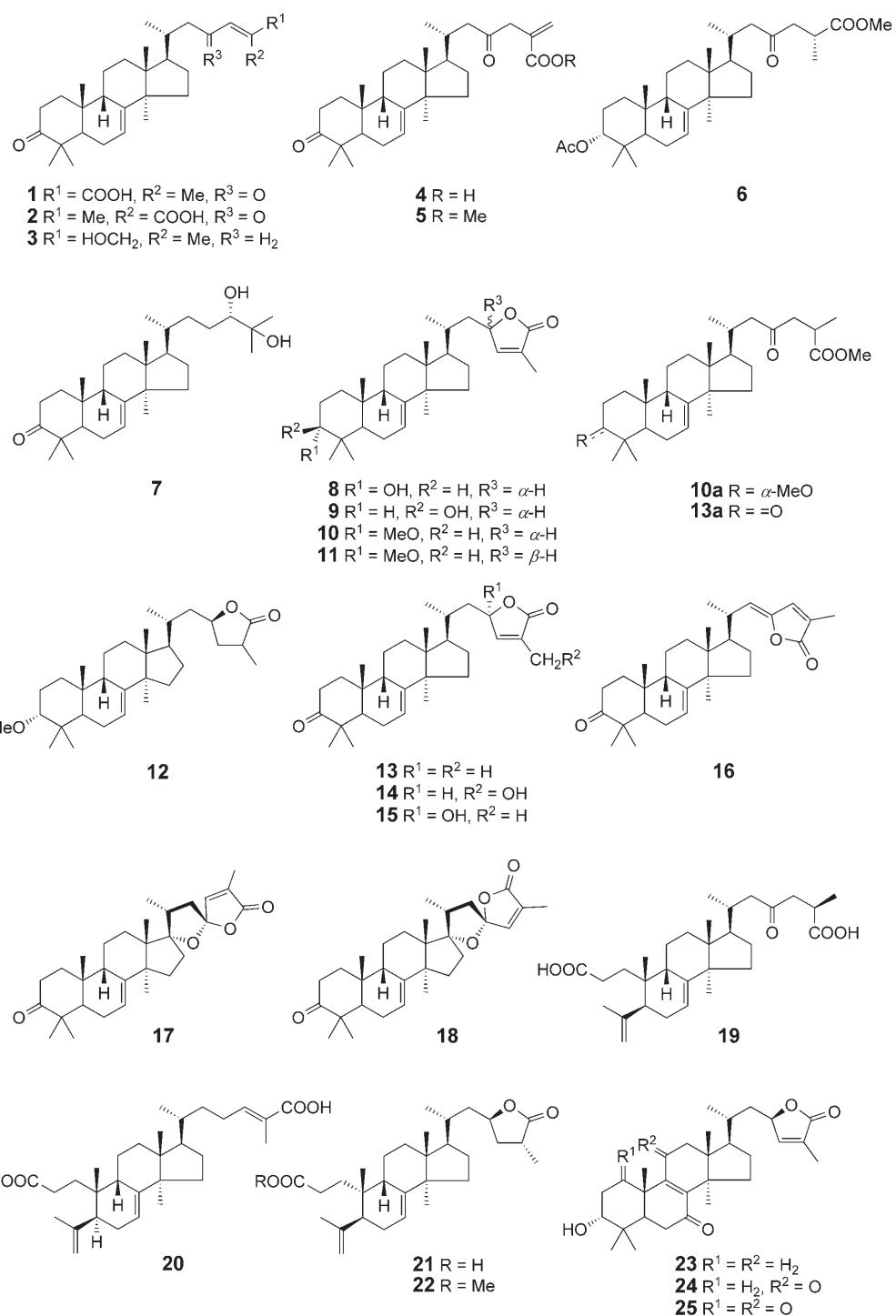
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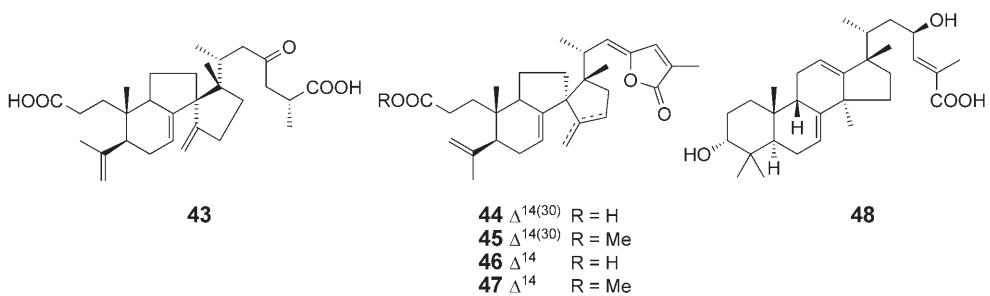
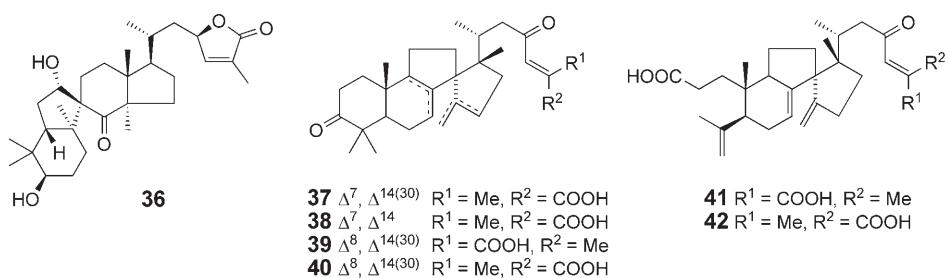
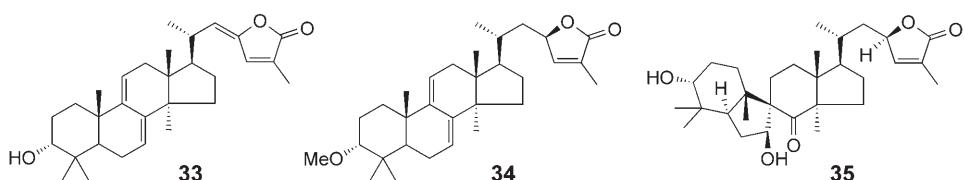
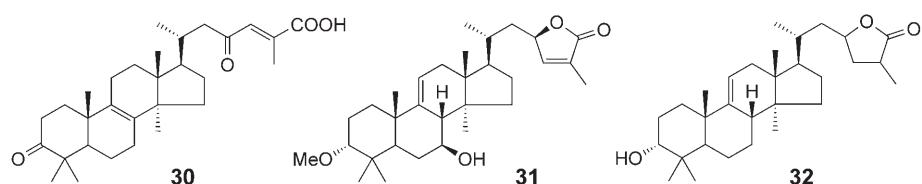
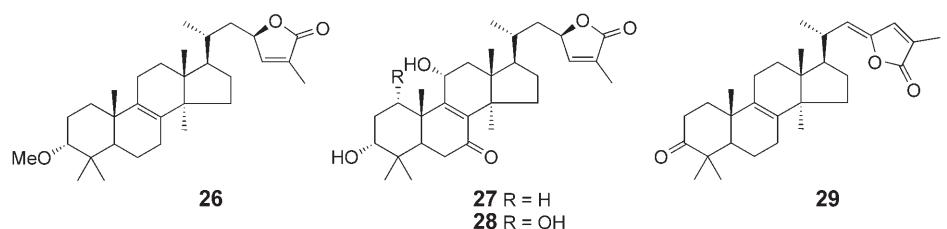
**1. Introduction.** – *Abies* is an important genus of the Pinaceae family. About 50 species occur in the highlands of Asia, European, North and Middle America, and North Africa [1]. Some species have been used as folk medicines against cold, stomachache, indigestion, vascular, pulmonary, and venereal diseases [2][3]. They have shown many kinds of activities, including insect juvenile hormone [4–6], antitumor [7–11], antibacterial [12–19], antifungal [20–22], anti-ulcerogenic [23][24], anti-inflammatory [23][25][26], antihypertensive [23][27], antitussive [24][28], and CNS (central nervous system) activities [23][29][30]. Due to the diverse biological activities, much attention has been paid to *Abies* species. In 1990, the results of the investigations on triterpenoids isolated from *Abies* species were summarized [31]. Since then, no correlative review has appeared. Herein, we review all the papers that have been published over the past few decades, concerning the chemical constituents and biological activities of this genus.

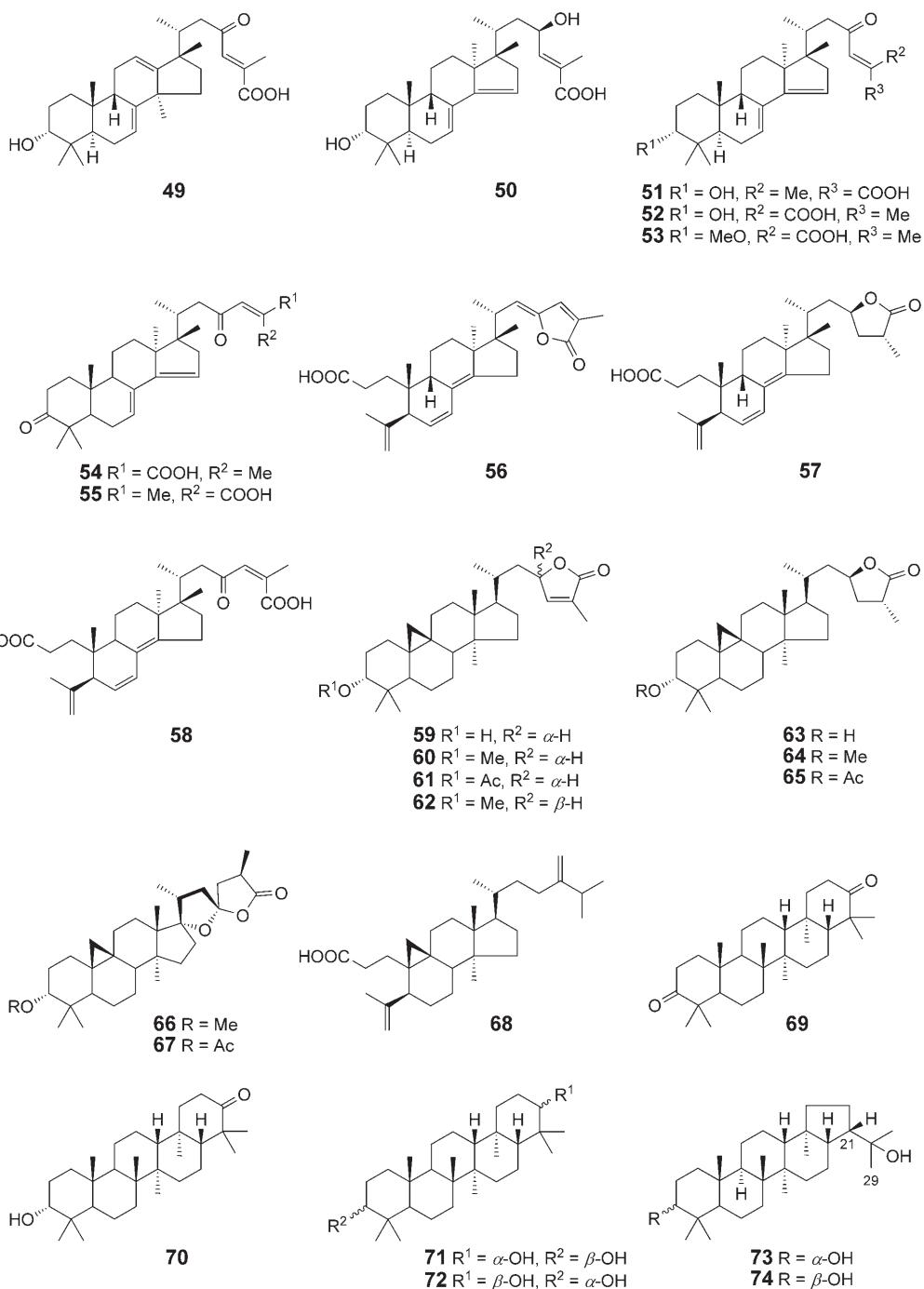
**2. Chemical Constituents.** – Compounds **1–277** are the known chemical constituents isolated from the *Abies* genus since 1938 (*Table*). They are mostly terpenoids, especially, triterpenoids. Many flavonoids, lignans, and a few of other constituents including phenols, steroids, fatty acids, and fatty alcohols are also found in this genus.

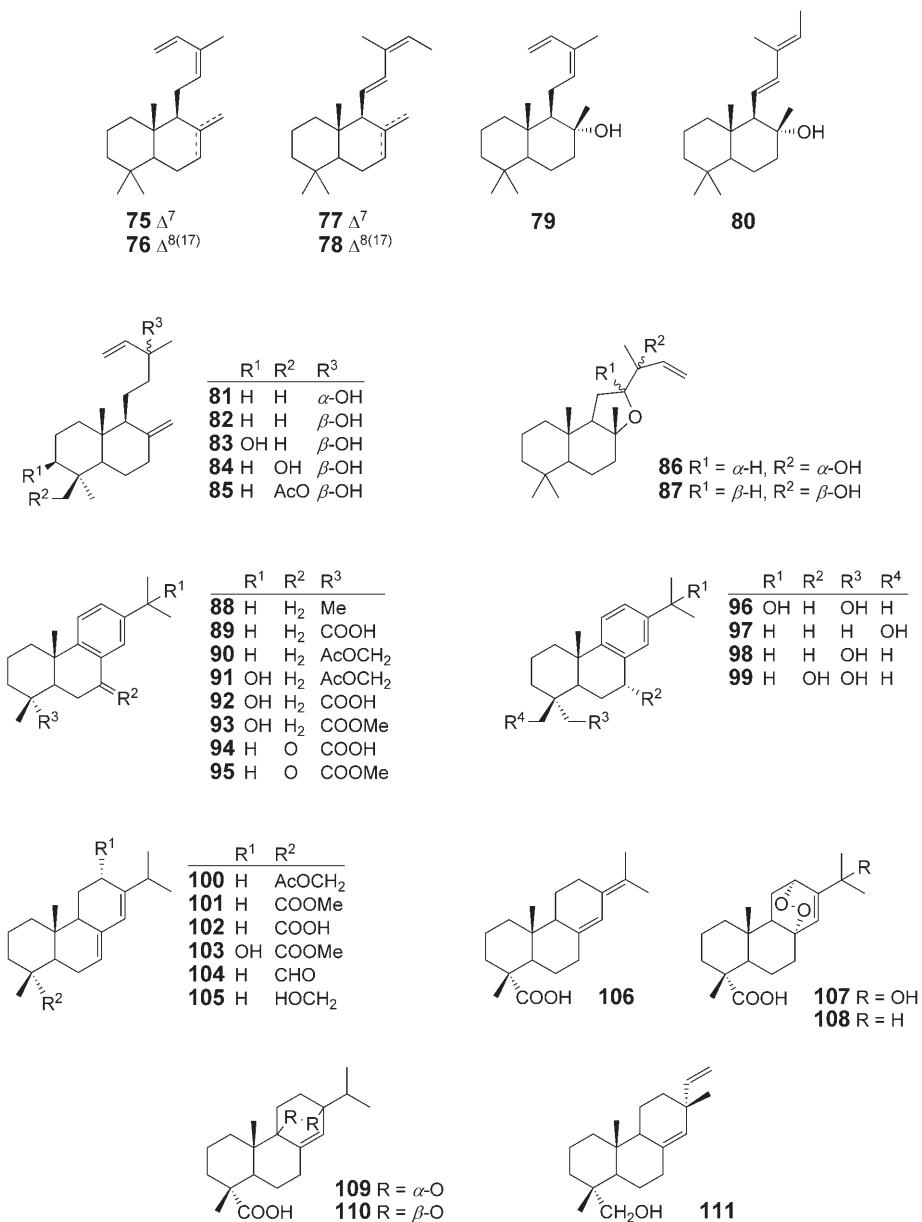
**2.1. Terpenoids.** 2.1.1. *Triterpenoids.* In 1990, *Raldugin* and *Shevtsov* reviewed literature information on *Abies* triterpenoids [31]. As a result, 35 compounds are divided into ten groups. However, according to the close biogenetic affinity of their C-skeletons [17][56][58], they are actually only two structures of lanstananes and cycloartananes. Although two other types of triterpenoids were also isolated from the plants of gammaceranes and hopanes, lanostane derivatives are still in majority. Compounds **1–58** are lanostane triterpenoids, among which **1–18** are  $9\beta$ -lanost-7-enoids isolated mainly from *A. firma* and *A. sibirica*; **19–22** are 3,4-seco- $9\beta$ -lanost-7-enoids; **23–30** are lanost-8-enoids isolated from *A. mariesii* and *A. sibirica*; **31** and **32** are two lanost-9(11)-enes isolated from *A. veitchii* and *A. alba*, repectively; **33** and **34** are two lanosta-7,9(11)-dienes isolated from *A. pindrow* and *A. veitchii*; **35** and **36** are 7(8→9)abeo-lanostananes, two unusually ‘migrated’ triterpene lactones, isolated from the stem barks of *A. mariesii*; **37–40** are 8(14→13R)abeo-17,13-friedo- $9\beta$ -lanostananes isolated from *A. mariesii* and *A. sibirica*; **41–47** are 3,4-seco-8(14→13R)abeo-17,13-friedo- $9\beta$ -lanostananes isolated from *A. alba*, *A. sibirica*, and *A. sachalinensis*; **48** and **49** are two 13,17-friedo- $9\beta$ -lanostananes from *A. mariesii*; **50–55** are mariesianes and **56–58** are 3,4-secomariesianoids, which were proposed for a new type of compounds that share the same C-skeleton with mariesic acid A (**50**). Compounds **59–67** are eight cycloartananes, and **68** is the only 3,4-secocycloartane. Four gammaceranes, **69–72**, and two hopanes, **73** and **74**, were isolated from *A. mariesii* and *A. veitchii*.

2.1.2. *Diterpenoids.* Compounds **75–111** are three types of diterpenoids. Among these 47 compounds, **75–87** are labdanes, **88–110** are abietanes, and **111** is the only pimarane. These diterpenoids were isolated mainly from *A. marocana*. Though **107–110** could be artifacts produced through oxidation of levopimamic and palustric acids during extraction and isolation procedure [37], the origin of these acids is apparently connected with the photooxidation of palustric or levopimamic acids in the growing needles with chlorophyll as sensitizer [105]. This process has been modeled *in vitro* on levopimamic acid by *Moore* and *Lawrence* in 1958 [106].

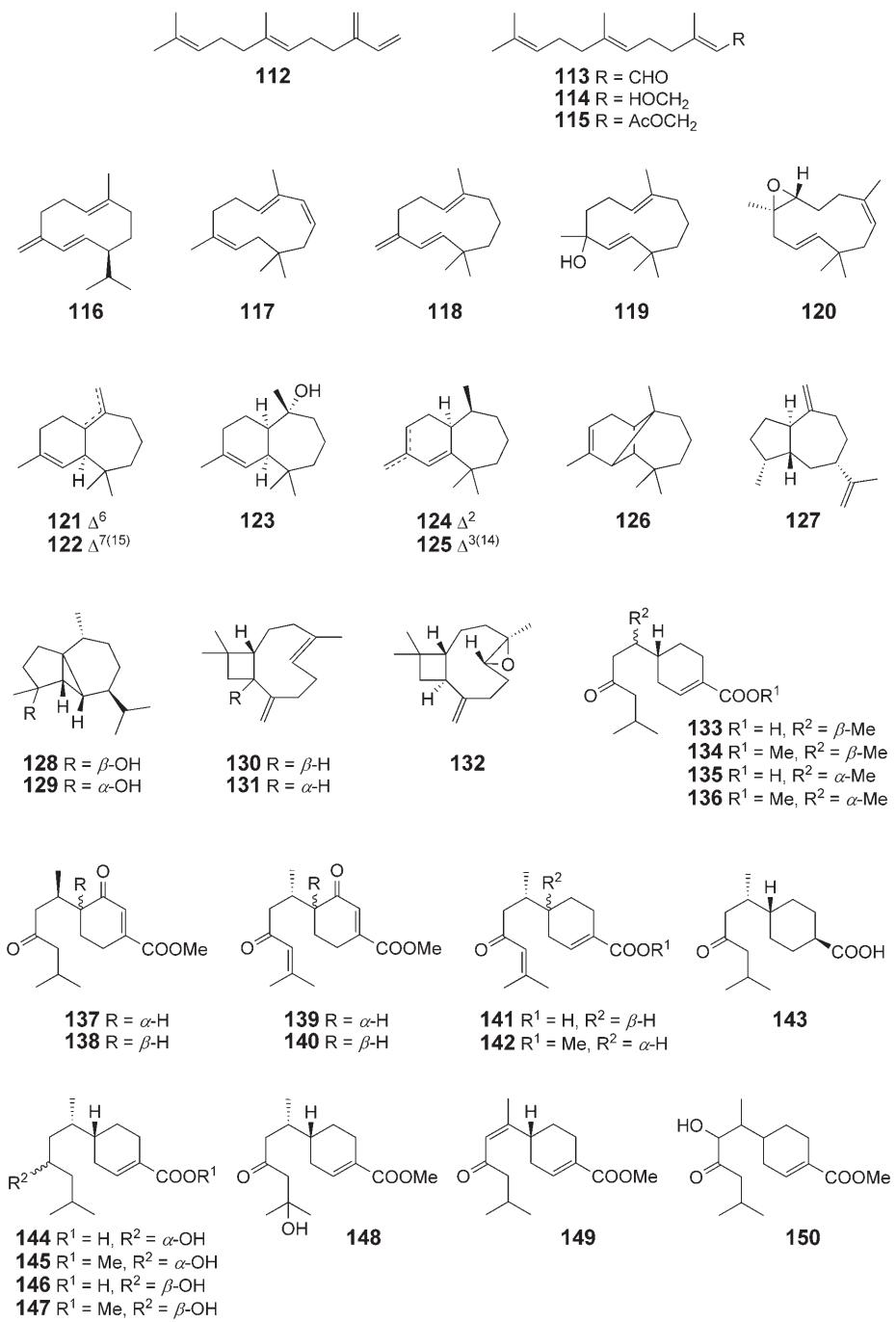


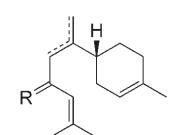




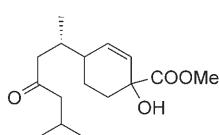
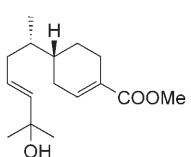
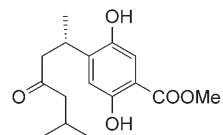
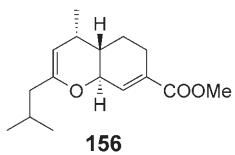
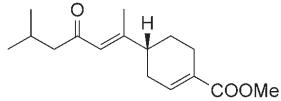
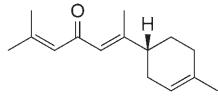
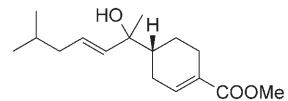
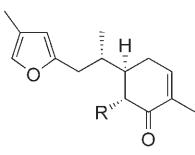


**2.1.3. Sesquiterpenoids and Monoterpeneoids.** These two types of compounds are mostly volatile constituents. Though hundreds of these components were identified from the essential oils [41][74][76][107–110], few were isolated, especially for monoterpeneoids. At present, only one monoterpeneoid, **180**, was isolated from this genus. Compounds

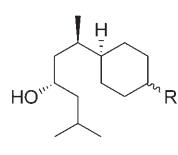




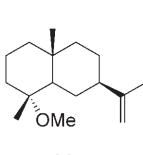
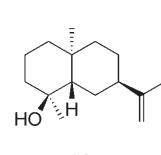
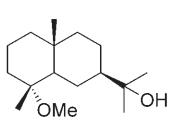
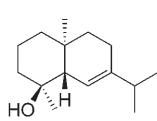
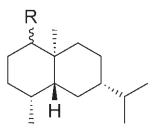
**151**  $\Delta^7$  R = O  
**152**  $\Delta^{7(14)}$  R = H<sub>2</sub>

**153****154****155****156****157****158****159**

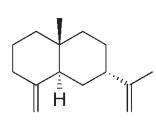
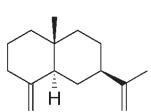
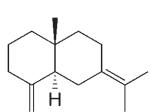
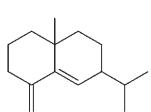
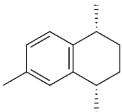
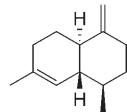
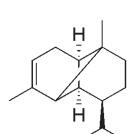
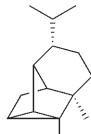
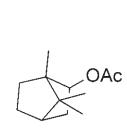
**160** R = H  
**161** R = OH

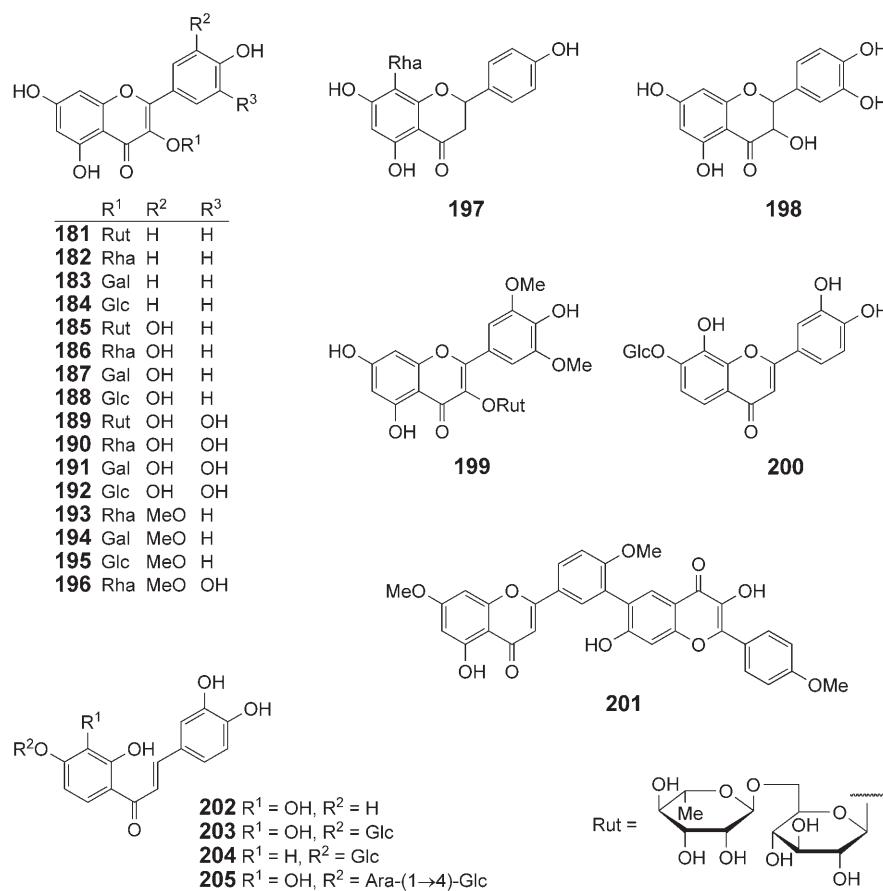


**162** R =  $\alpha$ -COOH  
**163** R =  $\beta$ -COOH

**164****165****166****167**

**168** R =  $\alpha$ -OH  
**169** R =  $\beta$ -OH

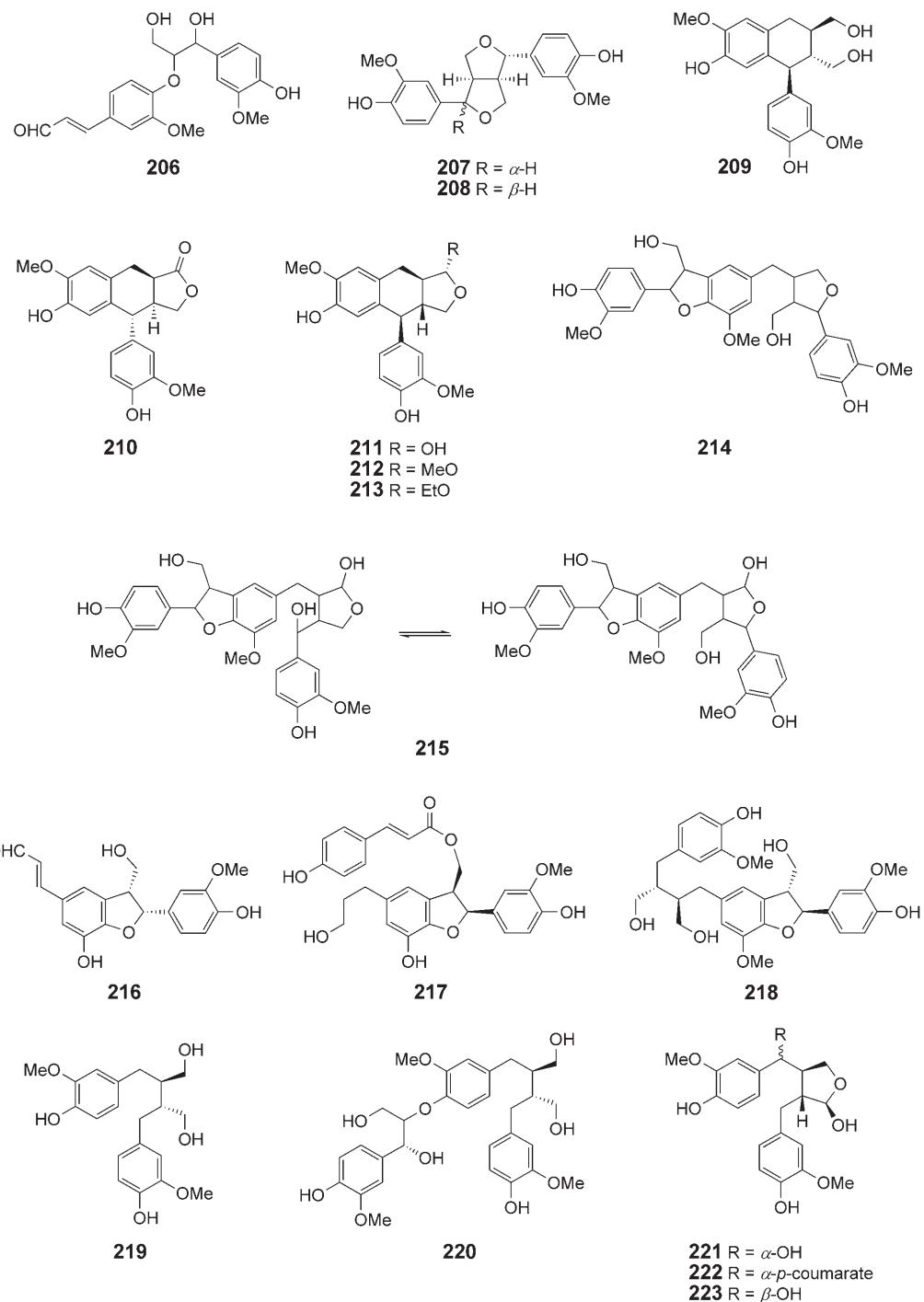
**170****171****172****173****174****175****176****177****178****179****180**

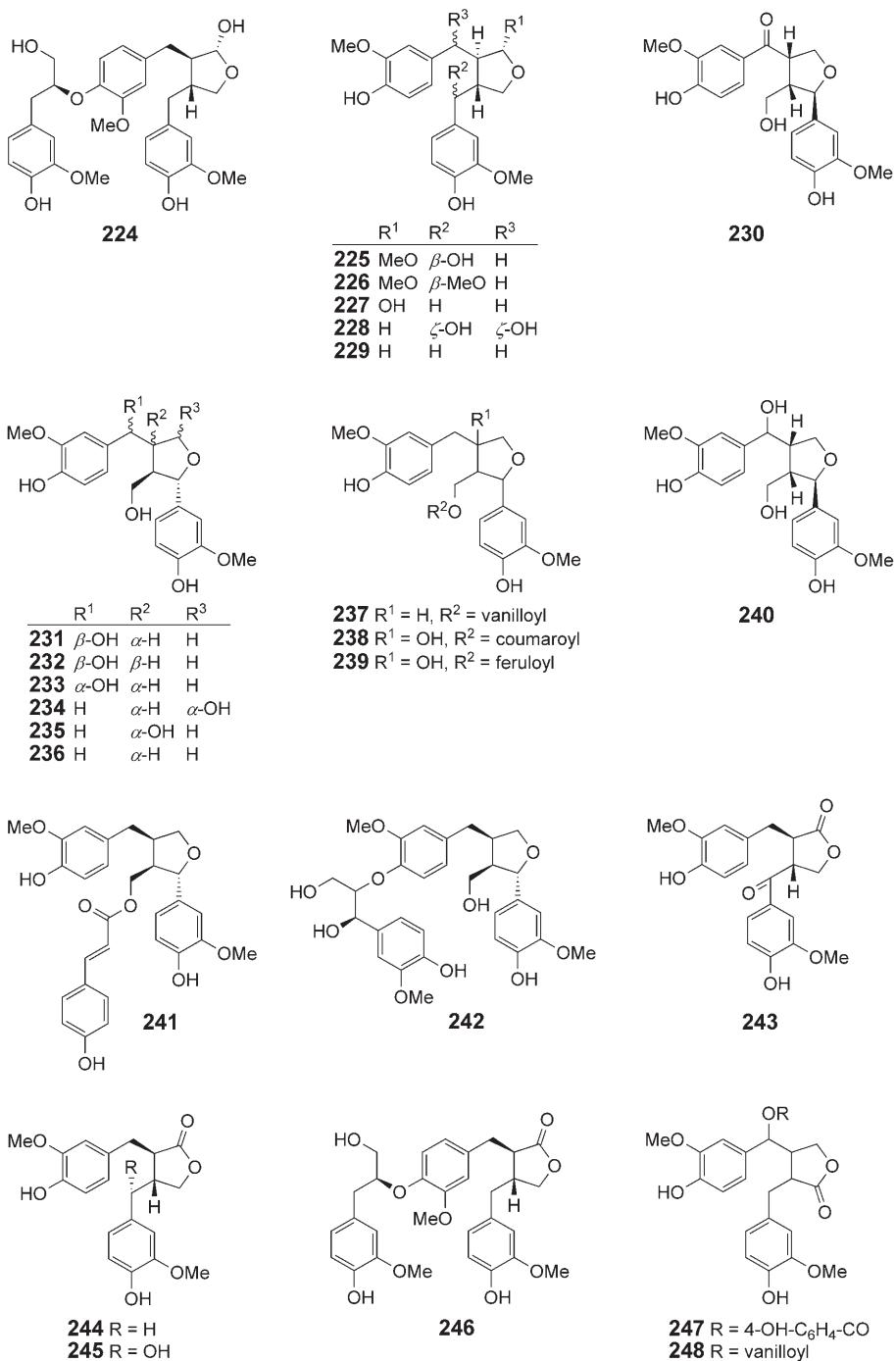


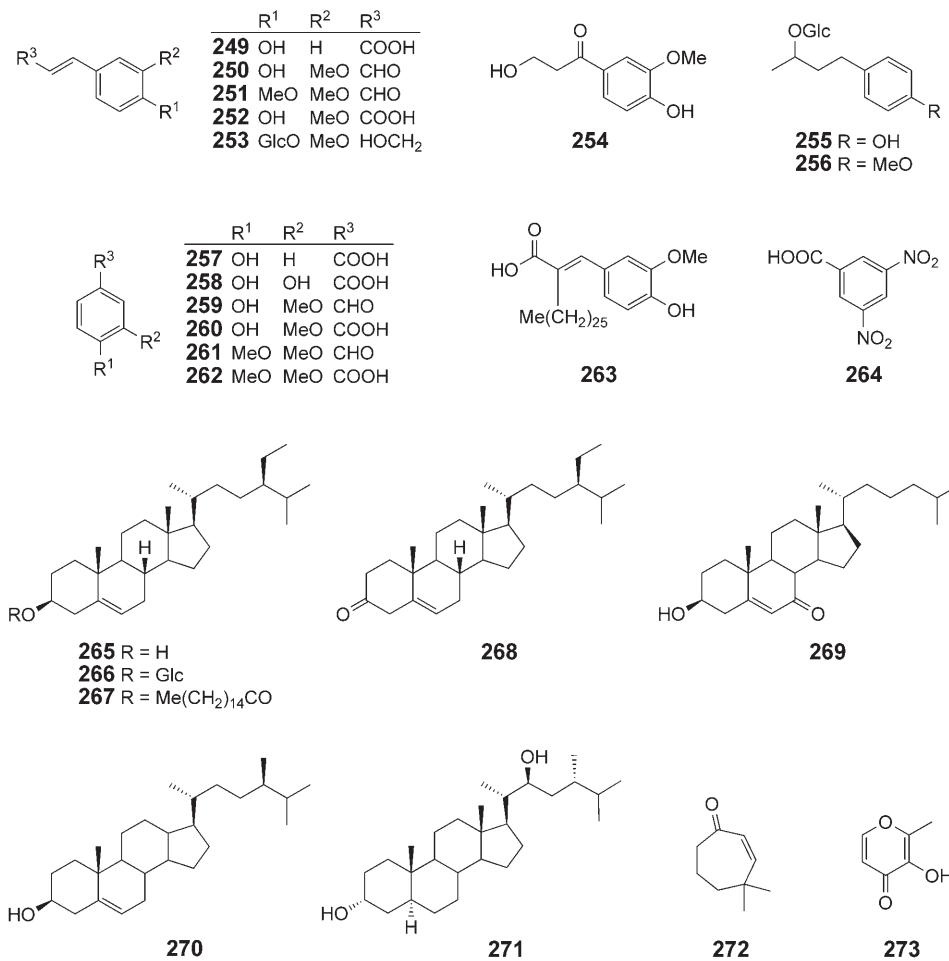
**112–179** are sesquiterpenoids from *Abies* species. Specifically, **112–115** are four acyclic sesquiterpenoids isolated from *A. alba* and *A. firma*; **116** is the only germacranes isolated from *A. pinsapo*; **117–120** are humulanes, most of them isolated from *A. alba*; **121–126** are himachalanes isolated from *A. alba*; **127–129** are guaiaines isolated from *A. alba* and *A. koreans*; **130–132** are dodecanes isolated mainly from *A. alba*; **133–163** are bisabolanes isolated mainly from *A. sachalinensis*; **164–173** are eudesmanes isolated mainly from *A. firma*; **174–176** are cadinanes from *A. marocana*, *A. pinsapo*, and *A. alba*; **177, 178**, and **179** are three other types of diterpenoids from *A. magnifica*, *A. alba*, and *A. pinsapo*.

**2.2. Flavonoids.** Compounds **181–205** were 24 flavonoids isolated from the *Abies* species. Among these compounds, **181–200** are flavones isolated mainly from *A. amabilis*, **201** is one biflavone isolated from *A. webbiana*, and **202–205** are four chalcones isolated from *A. pindrow*.

**2.3. Lignans.** One 8-O-4'-neolignan, **206**, two ditetrahydrofuran, **207** and **208**, five 4-phenyltetrahydronaphthalene derivatives, **209–213**, five benzofurans, **214–218**, twenty-four dibenzylbutanes, **219–242**, and six dibenzylbutyrolactones, **243–248**, were







isolated from several species of *Abies*. Interestingly, **215** turned out to be a hemiacetal in equilibration *via* the open-chain form [95].

2.4. *Phenols*. Sixteen phenols, **249–264**, were isolated from this genus.

2.5. *Steroids*. Sitosterol (**265**) was isolated from various *Abies* species. While the other four cholestanes, **266–269**, were only isolated from three species of *A. koreana*, *A. sachalinensis*, and *A. marocana*. Two ergostanes, **270** and **271**, were isolated from *A. alba*, *A. firma*, and *A. pinsapo*.

2.6. *Others*. One cycloheptenone, **272**, one pyrone, **273**, two fatty acids, **274** and **275**, and two fatty alcohols, **276** and **277**, were isolated from several species.

**3. Biological Activities.** – 3.1. *Insect Juvenile Hormone Activity*. In 1965, Slama and Williams found that the extract of *A. balsamea* showed high juvenile hormone activity to the European bug *Pyrrhocoris apterus* [5]. Larvae exposed to the extracts ultimately

Table. *Chemical Constituents from Abies Species*

| No.                  | Compound class and name   | Sources                 | Ref.     |
|----------------------|---|-------------------------|----------|
| <i>Triterpenoids</i> |   |                         |          |
| <b>1</b>             | Firmanoic acid  | <i>A. sibirica</i>      | [32][33] |
| <b>2</b>             | (24Z)-3,23-Dioxo-9 $\beta$ -lanosta-7,24-dien-26-oic acid                                     | <i>A. sibirica</i>      | [32][34] |
| <b>3</b>             | (24E)-3-Oxo-9 $\beta$ -lanosta-7,24-dien-26-ol  | <i>A. koreana</i>       | [9]      |
| <b>4</b>             | Isofirmanoic acid   | <i>A. firma</i>         | [35]     |
|                      |   | <i>A. sibirica</i>      | [36]     |
| <b>5</b>             | Methyl isofirmanoate  | <i>A. firma</i>         | [35]     |
|                      |   | <i>A. sibirica</i>      | [36]     |
| <b>6</b>             | Methyl (25 <i>R</i> )-3 $\alpha$ -acetoxy-23-oxo-9 $\beta$ -lanost-7-en-26-oate               | <i>A. marocana</i>      | [37]     |
| <b>7</b>             | (24 <i>S</i> )-3-Oxo-9 $\beta$ -lanost-7-ene-24,25-diol                                       | <i>A. sachalinensis</i> | [10]     |
| <b>8</b>             | (23 <i>R</i> )-3 $\alpha$ -Hydroxy-9 $\beta$ -lanosta-7,24-dien-26,23-olide                   | <i>A. sibirica</i>      | [38]     |
|                      |   | <i>A. veitchii</i>      | [39]     |
| <b>9</b>             | (23 <i>R</i> )-3 $\beta$ -Hydroxy-9 $\beta$ -lanosta-7,24-dien-26,23-olide                    | <i>A. firma</i>         | [40]     |
|                      |   | <i>A. mariesii</i>      | [41]     |
|                      |   | <i>A. veitchii</i>      | [39]     |
| <b>10</b>            | Abieslactone  | <i>A. amabilis</i>      | [42]     |
|                      |   | <i>A. grandis</i>       | [43]     |
|                      |   | <i>A. mariesii</i>      | [41][42] |
|                      |   |                         | [44][45] |
|                      |   | <i>A. procera</i>       | [46]     |
|                      |   | <i>A. sibirica</i>      | [38]     |
|                      |   | <i>A. veitchii</i>      | [47]     |
| <b>11</b>            | Grandisolide  | <i>A. grandis</i>       | [43]     |
| <b>12</b>            | (25 <i>R</i> )-24,25-Dihydroabieslactone  | <i>A. sibirica</i>      | [38]     |
| <b>13</b>            | (23 <i>R</i> )-3-Oxo-9 $\beta$ -lanosta-7,24-dien-26,23-olide                                 | <i>A. firma</i>         | [40][48] |
|                      |   | <i>A. veitchii</i>      | [39][44] |
|                      |   | <i>A. mariesii</i>      | [49]     |
|                      |   | <i>A. sibirica</i>      | [38]     |
| <b>14</b>            | (23 <i>R</i> )-27-Hydroxy-3-oxo-9 $\beta$ -lanosta-7,24-dien-26,23-olide                      | <i>A. firma</i>         | [40]     |
| <b>15</b>            | (23 <i>R</i> )-23-Hydroxy-3-oxo-9 $\beta$ -lanosta-7,24-dien-26,23-olide                      | <i>A. sibirica</i>      | [34]     |
| <b>16</b>            | (22 <i>Z</i> )-3-Oxo-9 $\beta$ -lanosta-7,22,24-trien-26,23-olide                             | <i>A. sibirica</i>      | [34]     |
|                      |   | <i>A. koreana</i>       | [8]      |
| <b>17</b>            | Firmanolide   | <i>A. firma</i>         | [35]     |
| <b>18</b>            | 23-Epifirmanolide   | <i>A. firma</i>         | [35]     |
| <b>19</b>            | (25 <i>R</i> )-23-Oxo-3,4-seco-9 $\beta$ -lanosta-4(28),7-diene-3,26-dioic acid               | <i>A. alba</i>          | [50]     |
| <b>20</b>            | (24 <i>E</i> )-3,4-Seco-9 $\beta$ -lanosta-4(28),7,24-triene-3,26-dioic acid                  | <i>A. koreana</i>       | [9]      |
| <b>21</b>            | Abiesolidic acid  | <i>A. sibirica</i>      | [51]     |
|                      |   | <i>A. sachalinensis</i> | [10]     |
| <b>22</b>            | Methyl (23 <i>R</i> ,25 <i>R</i> )-3,4-Seco-9 $\beta$ -lanosta-4(28),7-dien-26,23-olid-3-oate | <i>A. sachalinensis</i> | [10]     |
| <b>23</b>            | (23 <i>R</i> )-3 $\alpha$ -Hydroxy-7-oxolanosta-8,24-dien-26,23-olide                         | <i>A. mariesii</i>      | [52]     |
| <b>24</b>            | (23 <i>R</i> )-3 $\alpha$ -Hydroxy-7,11-dioxolanosta-8,24-dien-26,23-olide                    | <i>A. mariesii</i>      | [52]     |
| <b>25</b>            | (23 <i>R</i> )-3 $\alpha$ -Hydroxy-1,7,11-trioxolanosta-8,24-dien-26,23-olide                 | <i>A. mariesii</i>      | [52]     |
| <b>26</b>            | Neoabieslactone   | <i>A. mariesii</i>      | [41]     |
| <b>27</b>            | (23 <i>R</i> )-3 $\alpha$ ,11 $\alpha$ -Dihydroxy-7-oxolanosta-8,24-dien-26,23-olide          | <i>A. mariesii</i>      | [49]     |

Table (cont.)

| No. | Compound class and name  | Sources                 | Ref.     |
|-----|--|-------------------------|----------|
| 28  | (23R)-1 $\alpha$ ,3 $\alpha$ ,11 $\alpha$ -Trihydroxy-7-oxolanosta-8,24-dien-26,23-olide                   | <i>A. mariesii</i>      | [49]     |
| 29  | (22Z)-3-Oxolanosta-8,22,24-trien-26,23-olide   | <i>A. sibirica</i>      | [34]     |
| 30  | (24E)-3,23-Dioxolanosta-8,24-dien-26-oic acid  | <i>A. sibirica</i>      | [36]     |
| 31  | Veitchiolide   | <i>A. veitchii</i>      | [47]     |
| 32  | 3 $\alpha$ -Hydroxylanost-9(11)-en-26,23-olide   | <i>A. alba</i>          | [53]     |
| 33  | Pindrolactone  | <i>A. pindrow</i>       | [54]     |
| 34  | (23R)-3 $\alpha$ -Methoxylanosta-7,9(11),24-trien-26,23-olide  | <i>A. veitchii</i>      | [39]     |
| 35  | Spiromarienol A  | <i>A. mariesii</i>      | [55]     |
| 36  | Spiromarienol B  | <i>A. mariesii</i>      | [55]     |
| 37  | Mariesiic acid C   | <i>A. mariesii</i>      | [56]     |
| 38  | Isomariesiic acid C  | <i>A. mariesii</i>      | [56]     |
| 39  | (24Z)-8(14 $\rightarrow$ 13)-abeo-17,13-friedo-3,23-Dioxo-9 $\beta$ -lanosta-8,14(30),24-trien-26-oic acid | <i>A. sibirica</i>      | [57]     |
| 40  | (24E)-8(14 $\rightarrow$ 13)-abeo-17,13-friedo-3,23-Dioxo-9 $\beta$ -lanosta-8,14(30),24-trien-26-oic acid | <i>A. sibirica</i>      | [57]     |
| 41  | Abiesonic acid   | <i>A. sibirica</i>      | [58]     |
|     |  | <i>A. alba</i>          | [50]     |
| 42  | 24-cis-Abiesonic acid  | <i>A. sibirica</i>      | [33]     |
| 43  | (25R)-23-Oxo-3,4-secoabiesa-4(28),7,14(30)-triene-3,26-dioic acid  | <i>A. alba</i>          | [50]     |
| 44  | Abiesanolide A   | <i>A. sachalinensis</i> | [19]     |
| 45  | Abiesanolide B   | <i>A. sachalinensis</i> | [19]     |
| 46  | Abiesanolide C   | <i>A. sachalinensis</i> | [19]     |
| 47  | Abiesanolide D   | <i>A. sachalinensis</i> | [19]     |
| 48  | Mariesiic acid B   | <i>A. mariesii</i>      | [56]     |
| 49  | 23-Oxomariesiic acid B   | <i>A. mariesii</i>      | [56]     |
| 50  | Mariesiic acid A   | <i>A. mariesii</i>      | [17][56] |
| 51  | 23-Oxomariesiic acid A   | <i>A. sibirica</i>      | [33]     |
|     |  | <i>A. mariesii</i>      | [56]     |
|     |  | <i>A. firma</i>         | [56]     |
| 52  | (3R,20R,24Z)-3-Hydroxy-23-oxomariesia-7,14,24-trien-26-oic acid  | <i>A. sibirica</i>      | [33]     |
| 53  | (3R,20R,24Z)-3-Methoxy-23-oxomariesia-7,14,24-trien-26-oic acid  | <i>A. sibirica</i>      | [59]     |
| 54  | (24E)-3,23-Dioxomariesia-7,14,24-trien-26-oic acid   | <i>A. sibirica</i>      | [33]     |
| 55  | (24Z)-3,23-Dioxomariesia-7,14,24-trien-26-oic acid   | <i>A. sibirica</i>      | [33]     |
| 56  | Anhydrosibiric acid  | <i>A. sibirica</i>      | [59]     |
|     |  | <i>A. sachalinensis</i> | [19]     |
| 57  | (23R,25R)-3,4-Seco-17,14-friedo-9 $\beta$ -lanosta-4(28),6,8(14)-trien-26,23-olid-3-oic acid               | <i>A. sachalinensis</i> | [10]     |
| 58  | cis-Sibric acid  | <i>A. sibirica</i>      | [59]     |
| 59  | (23R)-3 $\alpha$ -Hydroxy-9,19-cyclo-9 $\beta$ -lanost-24-en-26,23-olide                                   | <i>A. marocana</i>      | [60][61] |
| 60  | Cyclorgrandisolide   | <i>A. grandis</i>       | [43][62] |
|     |  | <i>A. alba</i>          | [53]     |
| 61  | (23R)-3 $\alpha$ -Acetoxy-9,19-cyclo-9 $\beta$ -lanost-24-en-26,23-olide                                   | <i>A. marocana</i>      | [61]     |
|     |  | <i>A. pinsapo</i>       | [63]     |
| 62  | Epicyclorgrandisolide  | <i>A. grandis</i>       | [43][62] |
|     |  | <i>A. alba</i>          | [53]     |
| 63  | (23R,25R)-3 $\alpha$ -Hydroxy-9,19-cyclo-9 $\beta$ -lanostan-26,23-olide                                   | <i>A. marocana</i>      | [60][61] |
|     |  | <i>A. pinsapo</i>       | [63]     |
| 64  | (23R,25R)-3 $\alpha$ -Methoxy-9,19-cyclo-9 $\beta$ -lanostan-26,23-olide                                   | <i>A. pinsapo</i>       | [63]     |
| 65  | (23R,25R)-3 $\alpha$ -Acetoxy-9,19-cyclo-9 $\beta$ -lanostan-26,23-olide                                   | <i>A. marocana</i>      | [61]     |

Table (cont.)

| No.                 | Compound class and name  | Sources   | Ref.                                 |
|---------------------|--|---|--------------------------------------|
| <b>66</b>           | Abietospiran   | <i>A. alba</i>  | [64]                                 |
| <b>67</b>           | (23S,25R)-3 $\alpha$ -Acetoxy-17,23-epoxy-9,19-cyclo-9 $\beta$ -lanostan-26,23-olide | <i>A. marocana</i>  | [11][61]                             |
| <b>68</b>           | 24-Methylidene-3,4-secocycloart-4(28)-en-3-oic acid                                  | <i>A. sibirica</i><br><i>A. koreana</i>   | [65]<br>[8]                          |
| <b>69</b>           | Gammacerane-3,21-dione   | <i>A. mariesii</i>  | [66]                                 |
| <b>70</b>           | 3 $\alpha$ -Hydroxygammaceran-21-one   | <i>A. mariesii</i>  | [66]                                 |
| <b>71</b>           | Gammacerane-3 $\beta$ ,21 $\alpha$ -diol   | <i>A. veitchii</i><br><i>A. mariesii</i>  | [67]<br>[66]                         |
| <b>72</b>           | Gammacerane-3 $\alpha$ ,21 $\beta$ -diol   | <i>A. mariesii</i>  | [66]                                 |
| <b>73</b>           | Hopane-3 $\alpha$ ,22-diol   | <i>A. veitchii</i><br><i>A. mariesii</i>  | [67]<br>[66]                         |
| <b>74</b>           | Hopane-3 $\beta$ ,22-diol  | <i>A. mariesii</i>  | [66]                                 |
| <i>Diterpenoids</i> |  |   |                                      |
| <b>75</b>           | (12Z)-Labda-7,12,14-triene   | <i>A. marocana</i>  | [60]                                 |
| <b>76</b>           | (12Z)-Labda-8(17),12,14-triene   | <i>A. marocana</i>  | [60]                                 |
| <b>77</b>           | (11E,13Z)-Labda-7,11,13-triene   | <i>A. marocana</i>  | [60]                                 |
| <b>78</b>           | (11E,13Z)-Labda-8(17),11,13-triene   | <i>A. marocana</i>  | [60]                                 |
| <b>79</b>           | cis-Abienol  | <i>A. marocana</i><br><i>A. sachalinensis</i>   | [60][61]<br>[68]                     |
| <b>80</b>           | Neoabienol   | <i>A. marocana</i>  | [60]                                 |
| <b>81</b>           | Manool   | <i>A. lasiocarpa</i><br><i>A. sachalinensis</i>   | [6]<br>[69]                          |
| <b>82</b>           | 13-Epimanool   | <i>A. alba</i><br><i>A. pinsapo</i><br><i>A. marocana</i><br><i>A. firma</i><br><i>A. sachalinensis</i> | [70]<br>[63]<br>[61]<br>[71]<br>[68] |
| <b>83</b>           | 3 $\beta$ -Hydroxy-13-epimanool  | <i>A. pinsapo</i>   | [63]                                 |
| <b>84</b>           | 13-Epitorulosol  | <i>A. firma</i>   | [71]                                 |
| <b>85</b>           | 19-Acetoxy-13-epimanool  | <i>A. firma</i>   | [71]                                 |
| <b>86</b>           | (8R,12S,13S)-13-Hydroxy-8,12-epoxylabd-14-ene  | <i>A. marocana</i>  | [61]                                 |
| <b>87</b>           | (8R,12R,13R)-13-Hydroxy-8,12-epoxylabd-14-ene  | <i>A. marocana</i>  | [11][61]                             |
| <b>88</b>           | Dehydroabietane  | <i>A. alba</i>  | [70]                                 |
| <b>89</b>           | Dehydroabietic acid  | <i>A. marocana</i><br><i>A. firma</i><br><i>A. sibirica</i><br><i>A. sachalinensis</i>                  | [61]<br>[71]<br>[33]<br>[68][72]     |
| <b>90</b>           | 18-Acetoxyabiet-8,11,13-triene   | <i>A. pinsapo</i>   | [63]                                 |
| <b>91</b>           | 18-Acetoxy-15-hydroxyabiet-8,11,13-triene  | <i>A. pinsapo</i>   | [63]                                 |
| <b>92</b>           | 15-Hydroxyabiet-8,11,13-trien-18-oic acid  | <i>A. marocana</i>  | [61]                                 |
| <b>93</b>           | Methyl 15-hydroxydehydroabietate   | <i>A. marocana</i>  | [37]                                 |
| <b>94</b>           | 7-Oxoabiet-8,11,13-trien-18-oic acid   | <i>A. marocana</i>  | [61]                                 |
| <b>95</b>           | Methyl 7-oxodehydroabietate  | <i>A. marocana</i>  | [37]                                 |
| <b>96</b>           | Daturabietatriene  | <i>A. marocana</i>  | [61]                                 |
| <b>97</b>           | Dehydroabietinol   | <i>A. firma</i>   | [71]                                 |
| <b>98</b>           | Pomiferin A  | <i>A. marocana</i>  | [61]                                 |
| <b>99</b>           | 7 $\alpha$ ,18-Dihydroxyabiet-8,11,13-triene   | <i>A. marocana</i>  | [60]                                 |
| <b>100</b>          | 18-Acetoxyabiet-7,13-diene   | <i>A. pinsapo</i>   | [63]                                 |
| <b>101</b>          | Methyl abietate  | <i>A. marocana</i>  | [37]                                 |

Table (cont.)

| No.                     | Compound class and name   | Sources  | Ref.                       |
|-------------------------|---|--|----------------------------|
| <b>102</b>              | Abietic acid  | <i>A. firma</i><br><i>A. nordmanniana</i><br><i>A. sibirica</i>                            | [71]<br>[73]<br>[33]       |
| <b>103</b>              | Methyl 12 $\alpha$ -hydroxyabietate   | <i>A. marocana</i>   | [37]                       |
| <b>104</b>              | Abietinal   | <i>A. nordmanniana</i><br><i>A. firma</i>  | [73]<br>[71]               |
| <b>105</b>              | Abietinol   | <i>A. firma</i>  | [71]                       |
| <b>106</b>              | Neoabietic acid   | <i>A. sibirica</i><br><i>A. sachatinensis</i>  | [33]<br>[72]               |
| <b>107</b>              | 15-Hydroxy-8,12 $\alpha$ -epidioxyabiet-13-en-18-oic acid                   | <i>A. marocana</i>   | [11][61]                   |
| <b>108</b>              | 8,12 $\alpha$ -Epidioxyabiet-13-en-18-oic acid                              | <i>A. marocana</i><br><i>A. sibirica</i>   | [37][61]<br>[50]           |
| <b>109</b>              | 9,13 $\alpha$ -Epidioxyabiet-8(14)-en-18-oic acid                           | <i>A. marocana</i><br><i>A. sibirica</i>   | [37][61]<br>[50]           |
| <b>110</b>              | 9,13 $\beta$ -Epidioxyabiet-8(14)-en-18-oic acid                            | <i>A. marocana</i>   | [37][61]                   |
| <b>111</b>              | Isopimarinal  | <i>A. firma</i>  | [71]                       |
| <i>Sesquiterpenoids</i> |   |  |                            |
| <b>112</b>              | $\beta$ -Farnesene  | <i>A. alba</i>   | [74][75]                   |
| <b>113</b>              | Farnesal  | <i>A. firma</i>  | [71]                       |
| <b>114</b>              | Farnesol  | <i>A. firma</i>  | [71]                       |
| <b>115</b>              | Farnesyl acetate  | <i>A. firma</i>  | [71]                       |
| <b>116</b>              | Germacrene D  | <i>A. pinsapo</i>  | [63]                       |
| <b>117</b>              | $\alpha$ -Humulene  | <i>A. firma</i><br><i>A. pinsapo</i><br><i>A. alba</i>                                     | [71]<br>[63]<br>[74]       |
| <b>118</b>              | $\gamma$ -Humulene  | <i>A. alba</i>   | [74]                       |
| <b>119</b>              | Humula-4,9-dien-8-ol  | <i>A. alba</i>   | [74][75]                   |
| <b>120</b>              | Humulene epoxide II   | <i>A. nordmanniana</i>   | [73]                       |
| <b>121</b>              | $\beta$ -Himachalene  | <i>A. alba</i>   | [74]                       |
| <b>122</b>              | $\alpha$ -Himachalene   | <i>A. alba</i>   | [74]                       |
| <b>123</b>              | Himachalol  | <i>A. alba</i>   | [74]                       |
| <b>124</b>              | Himachala-2,4-diene   | <i>A. alba</i>   | [74][75]                   |
| <b>125</b>              | Himachala-3(12),4-diene   | <i>A. alba</i>   | [74][75]                   |
| <b>126</b>              | $\alpha$ -Longipinene   | <i>A. alba</i>   | [74]                       |
| <b>127</b>              | (+)-(1 <i>R</i> ,4 <i>R</i> ,5 <i>R</i> ,7 <i>S</i> )-Guaia-10(14),11-diene | <i>A. koreans</i>  | [76]                       |
| <b>128</b>              | Cubebol   | <i>A. alba</i>   | [74]                       |
| <b>129</b>              | 4-Epicubebol  | <i>A. alba</i>   | [74]                       |
| <b>130</b>              | Epicaryophyllene  | <i>A. alba</i>   | [74]                       |
| <b>131</b>              | Caryophyllene   | <i>A. alba</i><br><i>A. firma</i><br><i>A. marocana</i>                                    | [74]<br>[71]<br>[60]       |
| <b>132</b>              | Caryophyllene oxide   | <i>A. alba</i><br><i>A. nordmanniana</i>   | [74]<br>[73]               |
| <b>133</b>              | Todomatuic acid   | <i>A. sachalinensis</i>  | [77]                       |
| <b>134</b>              | Juvabione   | <i>A. balsamea</i><br><i>A. lasiocarpa</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i> | [4]<br>[6]<br>[63]<br>[78] |

Table (cont.)

| No. | Compound class and name  | Sources  | Ref.                 |
|-----|--|--|----------------------|
| 135 | Epitodomatuic acid   | <i>A. marocana</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i>   | [61]<br>[79]<br>[69] |
| 136 | Epijuvabione   | <i>A. marocana</i><br><i>A. sachalinensis</i>                        | [61]<br>[80]         |
| 137 | (+)-Oxojuvabione   | <i>A. sachalinensis</i>  | [80][81]             |
| 138 | (-)-Oxoepijuuvabione   | <i>A. sachalinensis</i>  | [80][81]             |
| 139 | 4'-Dehydrooxoepijuuvabione   | <i>A. sachalinensis</i>  | [69]                 |
| 140 | 4'-Dehydrooxojuvabione   | <i>A. sachalinensis</i>  | [69]                 |
| 141 | 4'-Dehydroepitodomatuic acid   | <i>A. marocana</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i>   | [61]<br>[79]<br>[69] |
| 142 | 4'-Dehydroepijuuvabione  | <i>A. marocana</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i>   | [61]<br>[63]<br>[80] |
| 143 | cis-Dihydroepitodomatuic acid  | <i>A. pinsapo</i>  | [79]                 |
| 144 | 3'-Dihydroepitodomatuic acid   | <i>A. pinsapo</i>  | [79]                 |
| 145 | Epijuvabiol  | <i>A. lasiocarpa</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i> | [6]<br>[63]<br>[69]  |
| 146 | 3'-Isodihydroepitodomatuic acid  | <i>A. sachalinensis</i>  | [69]                 |
| 147 | Isoepijuuvabiol  | <i>A. sachalinensis</i>  | [69]                 |
| 148 | 5'-Hydroxyepijuuvabione  | <i>A. sachalinensis</i>  | [69]                 |
| 149 | (1'Z)-Dehydrojuvabione   | <i>A. lasiocarpa</i>   | [6]                  |
| 150 | Methyl 4-(2-hydroxy-1,5-dimethyl-3-oxohexyl)cyclohex-1-ene-1-carboxylate               | <i>A. sachalinensis</i>  | [81]                 |
| 151 | (Z)- $\alpha$ -Atlantone   | <i>A. lasiocarpa</i>   | [82]                 |
| 152 | $\beta$ -Bisabolene  | <i>A. alba</i>   | [74]                 |
| 153 | Methyl 1-hydroxy-4-[ <i>(S</i> )-1,5-dimethyl-3-oxohexyl]-cyclohex-2-ene-1-carboxylate | <i>A. sachalinensis</i>  | [81]                 |
| 154 | 3'-Dehydroepijuuvabi-5'-ol   | <i>A. sachalinensis</i>  | [69]                 |
| 155 | ar-Dihydroxyepijuuvabione  | <i>A. sachalinensis</i>  | [69]                 |
| 156 | Epijuvabenol ether   | <i>A. sachalinensis</i>  | [69]                 |
| 157 | (1'E)-Dehydrojuvabione   | <i>A. lasiocarpa</i>   | [6]                  |
| 158 | (E)- $\alpha$ -Atlantone   | <i>A. lasiocarpa</i>   | [6][82]              |
| 159 | Epimeric 2'-dehydrojuvabi-1'-ol  | <i>A. lasiocarpa</i>   | [6]                  |
| 160 | Lasiocarpenone   | <i>A. lasiocarpa</i>   | [6][82]              |
| 161 | Lasiocarpenonol  | <i>A. lasiocarpa</i>   | [82]                 |
| 162 | Tetrahydrotodomatuic acid  | <i>A. sachalinensis</i>  | [78]                 |
| 163 | cis-Tetrahydrotodomatuic acid  | <i>A. sachalinensis</i>  | [78]                 |
| 164 | 4 $\alpha$ -Methoxyselina-11-ene   | <i>A. firma</i>  | [71]                 |
| 165 | Intermedeol  | <i>A. nordmanniana</i>   | [73]                 |
| 166 | 11-Hydroxy-4 $\alpha$ -methoxyselinane   | <i>A. firma</i>  | [71]                 |
| 167 | (4 <i>S</i> ,5 <i>S</i> ,10 <i>S</i> )-Selin-6-en-4-ol                                 | <i>A. alba</i>   | [74][75]             |
| 168 | $\alpha$ -Eudesmol   | <i>A. firma</i>  | [71]                 |
| 169 | $\beta$ -Eudesmol  | <i>A. firma</i>  | [71]                 |
| 170 | $\alpha$ -Selinene   | <i>A. firma</i>  | [71]                 |
| 171 | $\beta$ -Selinene  | <i>A. firma</i>  | [71]                 |
| 172 | $\gamma$ -Selinene   | <i>A. firma</i>  | [71]                 |
| 173 | Sibirene   | <i>A. alba</i>   | [74]                 |

Table (cont.)

| No.                    | Compound class and name  | Sources   | Ref.                                 |
|------------------------|--|---|--------------------------------------|
| <b>174</b>             | <i>cis</i> -Calamenene   | <i>A. marocana</i><br><i>A. pinsapo</i>   | [60]<br>[63]                         |
| <b>175</b>             | $\gamma$ -Cadinene   | <i>A. marocana</i><br><i>A. pinsapo</i>   | [60]<br>[63]                         |
| <b>176</b>             | $\alpha$ -Copaene  | <i>A. alba</i>  | [74]                                 |
| <b>177</b>             | Cyclosativene  | <i>A. magnifica</i>   | [83]                                 |
| <b>178</b>             | Longicyclene   | <i>A. alba</i><br><i>A. magnifica</i>   | [74]<br>[83]                         |
| <b>179</b>             | Longifolene  | <i>A. alba</i><br><i>A. pinsapo</i>   | [74]<br>[63]                         |
| <i>Monoterpeneoids</i> |  |   |                                      |
| <b>180</b>             | Bornyl acetate   | <i>A. firma</i>   | [71]                                 |
| <i>Flavonoids</i>      |  |   |                                      |
| <b>181</b>             | Kaempferol 3- <i>O</i> -rutinoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>182</b>             | Kaempferol 3- <i>O</i> -rhamnoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>183</b>             | Kaempferol 3- <i>O</i> -galactoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>184</b>             | Kaempferol 3- <i>O</i> -glucoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>185</b>             | Quercetin 3- <i>O</i> -rutinoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>186</b>             | Quercetin 3- <i>O</i> -rhamnoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>187</b>             | Quercetin 3- <i>O</i> -galactoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>188</b>             | Quercetin 3- <i>O</i> -glucoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>189</b>             | Laricytrin 3- <i>O</i> -rutinoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>190</b>             | Laricytrin 3- <i>O</i> -rhamnoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>191</b>             | Laricytrin 3- <i>O</i> -galactoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>192</b>             | Laricytrin 3- <i>O</i> -glucoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>193</b>             | Isorhamnetin 3- <i>O</i> -rhamnoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>194</b>             | Isorhamnetin 3- <i>O</i> -galactoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>195</b>             | Isorhamnetin 3- <i>O</i> -glucoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>196</b>             | Myricetin 3- <i>O</i> -rhamnoside  | <i>A. amabilis</i>  | [84]                                 |
| <b>197</b>             | Rhamnosylvitexin   | <i>A. amabilis</i>  | [84]                                 |
| <b>198</b>             | Dihydroquercetin   | <i>A. amabilis</i>  | [84]                                 |
| <b>199</b>             | Syringetin 3- <i>O</i> -rutinoside   | <i>A. amabilis</i>  | [84]                                 |
| <b>200</b>             | 8,3',4'-Trihydroxyflavanone-7- <i>O</i> - $\beta$ -D-glucopyranoside                                   | <i>A. pindrow</i>   | [85]                                 |
| <b>201</b>             | Abiesin  | <i>A. webbiana</i>  | [86]                                 |
| <b>202</b>             | Okanin   | <i>A. pindrow</i>   | [85]                                 |
| <b>203</b>             | Okanin-4'- <i>O</i> - $\beta$ -D-glucopyranoside   | <i>A. pindrow</i>   | [85]                                 |
| <b>204</b>             | Butein-4'- <i>O</i> - $\beta$ -D-glucopyranoside   | <i>A. pindrow</i>   | [85]                                 |
| <b>205</b>             | 2',3',4',3,4-Pentahydroxychalcone-4'-(L-arabinofuranosyl- $\alpha$ -1 → 4- $\beta$ -D-glucopyranoside) | <i>A. pindrow</i>   | [85]                                 |
| <i>Lignans</i>         |  |   |                                      |
| <b>206</b>             | Guaiacylglycerol-coniferyl aldehyde ether  | <i>A. sachalinensis</i>   | [87]                                 |
| <b>207</b>             | (+)-Pinoresinol  | <i>A. koreana</i><br><i>A. marocana</i><br><i>A. nephrolepis</i><br><i>A. sachalinensis</i> | [88]<br>[11]<br>[89]<br>[69][87][90] |
| <b>208</b>             | (+)-Epipinoresinol   | <i>A. sachalinensis</i>   | [69][90]                             |
| <b>209</b>             | Isolariciresinol   | <i>A. pinsapo</i>   | [87][91]                             |
| <b>210</b>             | $\alpha$ -Conidendrin  | <i>A. mariesii</i><br><i>A. sachalinensis</i>   | [92]<br>[90]                         |

Table (cont.)

| No. | Compound class and name   | Sources  | Ref.                 |
|-----|---|--|----------------------|
| 211 | Todolactol B  | <i>A. mariesii</i><br><i>A. sachalinensis</i>                      | [92]<br>[93][94]     |
| 212 | Todolactol C  | <i>A. koreana</i><br><i>A. sachalinensis</i>                       | [88]<br>[93]         |
| 213 | Todolactol D  | <i>A. sachalinensis</i>  | [93]                 |
| 214 | Abiesol A   | <i>A. sachalinensis</i>  | [95]                 |
| 215 | Abiesol B   | <i>A. sachalinensis</i>  | [95]                 |
| 216 | (2R,3R)-5-(2-Formylvinyl)-2,3-dihydro-2-(4-hydroxy-3-methoxyphenyl)-3-(hydroxymethyl)-7-hydroxy-1-benzofuran                                    | <i>A. sachalinensis</i>  | [96]                 |
| 217 | (2S,3S)-3-[( <i>p</i> -Coumaroyloxy)methyl]-2,3-dihydro-7-hydroxy-2-(4-hydroxy-3-methoxyphenyl)-5-(3-hydroxypropyl)-1-benzofuran                | <i>A. sachalinensis</i>  | [96]                 |
| 218 | Sesquipinsapol B  | <i>A. marocana</i><br><i>A. pinsapo</i>                            | [11]<br>[91][97]     |
| 219 | Secoisolariciresinol  | <i>A. marocana</i>   | [11]                 |
| 220 | Sesquimaroanol B  | <i>A. marocana</i>   | [11]                 |
| 221 | Todolactol A  | <i>A. mariesii</i><br><i>A. sachalinensis</i>                      | [92]<br>[90]         |
| 222 | Todolactol-A <i>α</i> - <i>p</i> -coumarate   | <i>A. mariesii</i>   | [92]                 |
| 223 | (7'S)-Todolactol A  | <i>A. pinsapo</i>  | [91]                 |
| 224 | Sesquipinsapol C  | <i>A. pinsapo</i>  | [91]                 |
| 225 | Koreanol  | <i>A. koreana</i>  | [88]                 |
| 226 | <i>α</i> -Intermedianol   | <i>A. koreana</i>  | [88]                 |
| 227 | 4,4',9-Trihydroxy-3,3'-dimethoxy-9,9'-epoxylignan   | <i>A. pinsapo</i>  | [91]                 |
| 228 | Liovil  | <i>A. nephrolepis</i><br><i>A. sibirica</i>                        | [89]<br>[98]         |
| 229 | 3,4-Divanillyltetrahydrofuran   | <i>A. nephrolepis</i>  | [89]                 |
| 230 | <i>t</i> -4-(4'-Hydroxy-3'-methoxybenzoyl)- <i>r</i> -2-(4"-hydroxy-3"-methoxyphenyl)- <i>t</i> -3-(hydroxymethyl)tetrahydrofuran               | <i>A. mariesii</i>   | [92]                 |
| 231 | 8'-Epitanegool  | <i>A. sachalinensis</i>  | [87]                 |
| 232 | (7'S)-7'-Hydroxylariciresinol   | <i>A. marocana</i><br><i>A. pinsapo</i>                            | [11]<br>[91]         |
| 233 | (7'R)-7'-Hydroxylariciresinol   | <i>A. marocana</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i> | [11]<br>[91]<br>[96] |
| 234 | (9'R)-9'-Hydroxylariciresinol   | <i>A. marocana</i><br><i>A. pinsapo</i>                            | [11]<br>[91]         |
| 235 | Olivil  | <i>A. spp.</i>   | [89]                 |
| 236 | (+)-Lariciresinol   | <i>A. marocana</i><br><i>A. sachalinensis</i>                      | [11][87]<br>[96]     |
| 237 | 4,4'-Dihydroxy-3,3'-dimethoxy-9-(vanillyloxy)-7,9'-epoxylignan  | <i>A. nephrolepis</i><br><i>A. sibirica</i>                        | [99]<br>[99]         |
| 238 | 9-(Coumaroyloxy)-4,4',8'-trihydroxy-3,3'-dimethoxy-7,9'-epoxylignan   | <i>A. nephrolepis</i><br><i>A. sibirica</i>                        | [99]<br>[99]         |
| 239 | 9-(Feruloyloxy)-4,4',8'-trihydroxy-3,3'-dimethoxy-7,9'-epoxylignan  | <i>A. sibirica</i><br><i>A. nephrolepis</i>                        | [99]<br>[99]         |
| 240 | <i>t</i> -4-[Hydroxy(4'-hydroxy-3'-methoxyphenyl)methyl]- <i>r</i> -2-(4"-hydroxy-3"-methoxyphenyl)- <i>t</i> -3-(hydroxymethyl)tetrahydrofuran | <i>A. mariesii</i>   | [92]                 |
| 241 | (+)-Lariciresinol- <i>p</i> -coumarate  | <i>A. marocana</i><br><i>A. pinsapo</i><br><i>A. sachalinensis</i> | [11]<br>[91]<br>[96] |

Table (cont.)

| No.             | Compound class and name  | Sources                 | Ref.         |
|-----------------|--|-------------------------|--------------|
| <b>242</b>      | Sesquimaroanol A   | <i>A. marocana</i>      | [11]         |
| <b>243</b>      | Ketomatairesinol   | <i>A. mariesii</i>      | [92]         |
| <b>244</b>      | Matairesinol   | <i>A. marocana</i>      | [11]         |
|                 |  | <i>A. mariesii</i>      | [92]         |
|                 |  | <i>A. nephrolepis</i>   | [89]         |
| <b>245</b>      | Hydroxymatairesinol  | <i>A. mariesii</i>      | [92]         |
|                 |  | <i>A. nephrolepis</i>   | [89]         |
| <b>246</b>      | Sesquipinsapol A   | <i>A. pinsapo</i>       | [91][97]     |
| <b>247</b>      | 4,4'-Dihydroxy-7-(4''-hydroxybenzoyloxy)-3,3'-dimethoxylignan-9,9'-olide | <i>A. nephrolepis</i>   | [99]         |
| <b>248</b>      | 4,4'-Dihydroxy-3,3'-dimethoxy-7-(vanillyloxy)lignan-9,9'-olide           | <i>A. nephrolepis</i>   | [99]         |
|                 |  | <i>A. sibirica</i>      |              |
| <i>Phenols</i>  |  |                         |              |
| <b>249</b>      | Coumaric acid  | <i>A. nephrolepis</i>   | [100]        |
|                 |  | <i>A. sachalinensis</i> | [78]         |
| <b>250</b>      | Coniferyl aldehyde   | <i>A. sachalinensis</i> | [69]         |
| <b>251</b>      | 3,4-Dimethoxycinamaldehyde   | <i>A. marocana</i>      | [11]         |
| <b>252</b>      | Ferulic acid   | <i>A. nephrolepis</i>   | [100]        |
| <b>253</b>      | Abietin  | <i>A. nephrolepis</i>   | [84]         |
|                 |  | <i>A. sibirica</i>      | [84]         |
| <b>254</b>      | $\omega$ -Hydroxypropioguaiacone   | <i>A. marocana</i>      | [11]         |
| <b>255</b>      | Betuloside   | <i>A. webbiana</i>      | [101]        |
| <b>256</b>      | Methyl betuloside  | <i>A. webbiana</i>      | [101]        |
| <b>257</b>      | <i>p</i> -Hydroxybenzoic acid  | <i>A. nephrolepis</i>   | [100]        |
| <b>258</b>      | Protocatechuic acid  | <i>A. nephrolepis</i>   | [100]        |
| <b>259</b>      | Vanillin   | <i>A. nephrolepis</i>   | [89]         |
|                 |  | <i>A. sachalinensis</i> | [69][78]     |
|                 |  | <i>A. sibirica</i>      | [98]         |
| <b>260</b>      | Vanillic acid  | <i>A. mariesii</i>      | [92]         |
|                 |  | <i>A. marocana</i>      | [11]         |
|                 |  | <i>A. nephrolepis</i>   | [100]        |
| <b>261</b>      | Veratraldehyde   | <i>A. marocana</i>      | [11]         |
| <b>262</b>      | Veratric acid  | <i>A. marocana</i>      | [11]         |
| <b>263</b>      | Hexacosylferulate  | <i>A. koreana</i>       | [8]          |
| <b>264</b>      | 3,5-Dinitrobenzoate  | <i>A. alba</i>          | [70]         |
| <i>Steroids</i> |  |                         |              |
| <b>265</b>      | $\beta$ -Sitosterol  | <i>A. alba</i>          | [53]         |
|                 |  | <i>A. firma</i>         | [40][48][71] |
|                 |  | <i>A. koreana</i>       | [8][9]       |
|                 |  | <i>A. mariesii</i>      | [92]         |
|                 |  | <i>A. marocana</i>      | [60][61]     |
|                 |  | <i>A. nordmanniana</i>  | [73]         |
|                 |  | <i>A. pinsapo</i>       | [63]         |
|                 |  | <i>A. sachalinensis</i> | [69][68]     |
| <b>266</b>      | Sitosterol glucoside   | <i>A. koreana</i>       | [8][9]       |
| <b>267</b>      | $\beta$ -Sitosteryl-palmitate  | <i>A. sachalinensis</i> | [68]         |
| <b>268</b>      | $\beta$ -Sitostenone   | <i>A. sachalinensis</i> | [68]         |
| <b>269</b>      | 3 $\beta$ -Hydroxy-7-oxocholest-5-ene                                    | <i>A. marocana</i>      | [61]         |

Table (cont.)

| No.           | Compound class and name                                  | Sources   | Ref.                         |
|---------------|--|---|------------------------------|
| <b>270</b>    | Campesterol  | <i>A. alba</i><br><i>A. firma</i>   | [53]<br>[40][48]             |
| <b>271</b>    | (22 <i>S</i> )-5 <i>a</i> -Ergostane-3 <i>a</i> ,22-diol | <i>A. pinsapo</i>   | [63]                         |
| <i>Others</i> |  |   |                              |
| <b>272</b>    | 4,4-Dimethyl-2-cyclohepten-1-one                         | <i>A. balsamea</i>  | [102]                        |
| <b>273</b>    | Maltol   | <i>A. alba</i><br><i>A. koreana</i><br><i>A. mariesii</i><br><i>A. sibirica</i> | [98]<br>[8]<br>[103]<br>[98] |
| <b>274</b>    | Methyl ( <i>Z</i> )-octadec-9-enoate                     | <i>A. sachalinensis</i>   | [68]                         |
| <b>275</b>    | Oleic acid   | <i>A. marocana</i>  | [61]                         |
| <b>276</b>    | 10-Nonacosanol   | <i>A. nordmanniana</i>  | [73]                         |
| <b>277</b>    | (+)-Pinitol  | <i>A. pindrow</i>   | [104]                        |

died without completing metamorphosis or attaining sexual maturity. The active compound, juvabione (**134**), was isolated and identified as the methyl ester of todomatuic acid (**133**) in 1966 [4–6].

**3.2. Antitumor Activity.** The aqueous preparation of mixed parts of *A. alba* and *Viscum album* showed antiproliferative effects on L-1210 cells. Furthermore, the extracts significantly prolonged the life and reduced the tumor growth of the treated rats [7].

Eight compounds, **3**, **16**, **20**, **68**, **263**, **265**, **266**, and **273**, isolated from *A. koreana* were evaluated *in vitro* against four cultured human tumor cell lines. Compound **68** displayed general cytotoxic activities against A549, SK-OV-3, SK-MEL-2, and HCT-15 tumor cell lines with *ED*<sub>50</sub> values of 2.93, 3.01, 3.18, and 2.96 µg/ml, respectively. Compounds **3** and **16** exhibited marginal activities, while **20** showed weak activity, and the other four were negative [8][9].

Compounds **21** and **22** isolated from *A. sachalinensis* showed complete inhibition of the catalytic activity of Topo II at 200 µM. Moreover, the inhibitory effects were dose-dependent. The *IC*<sub>50</sub> values were comparable to a Topo II inhibitor, etoposide [10].

Methyl esters **10a** and **13a**, derived from **10** and **13**, strongly inhibited tumor promoter-induced phenomena *in vitro* and *in vivo*, although **10** and **13** themselves showed no remarkable activity [44]. The hexaacetate and pentaacetate derivatives of compounds **220** and **242**, resp., showed moderate cytotoxicity against the cancer lines P-338, A-549, HT-29, and MEL-28 [11].

**3.3. Antibacterial Activity.** The crude resins extracts of *A. cilicia* were found to be highly active against seven bacteria. The activity was similar to the standard antibiotic, amoxicillin [14]. In another study, the CHCl<sub>3</sub>, acetone, and MeOH extracts of leaves, resins, barks, cones, and fruits of this species inhibited the development of eleven bacteria [18].

The essential oils of *Abies* species were mostly found to have antibacterial activities. The essential oils of the species *A. alba* and *A. firma* showed a modest activity, and those from the species *A. koreana*, *A. cilicica* subsp. *cilicica*, *A. cilicica* subsp. *isaurica*, *A. nordmanniana* subsp. *nordmanniana*, and *A. nordmanniana* subsp. *bornmuelleriana*

had the potent activity against the bacteria and yeast species tested [12]. Recently, the essential oil of *A. balsamea* was also found to be active against *Staphylococcus aureus*. The active compounds are three minor constituents,  $\alpha$ -pinene,  $\beta$ -caryophyllene, and  $\alpha$ -humulene [15].

Six compounds, **1**, **37**, **48–51**, isolated from *A. mariesii*, and two compounds, **44** and **56**, from *A. sachalinensis*, showed antimicrobial activity against Gram-positive bacteria and actinomycetes [17][19].

**3.4. Antifungal Activity.** The mycelial growth of several edible fungi was inhibited greatly by the lipophilic extract and volatile oil of *A. sachalinensis* [20]. From the volatile wood-oil, an active principle was isolated and identified as juvabione (**134**), which strongly inhibited the mycelial growth of six fungi tested at an application of 300  $\mu\text{g}/\text{ml}$  [21]. Based on this result, **134**, crude hexane extract, and volatile oil from the wood of *A. sachalinensis*, as well as their saponified products, were assayed for antifungal activities against six species of pathogenic fungi causing turfgrass diseases. At a concentration of 200  $\mu\text{g}/\text{g}$ , all the substances tested showed weak or complete inhibitions of the growths of five species [22].

**3.5. Anti-ulcerogenic Activity.** Five extracts of the dried *A. pindrow* leaves either tended to decrease or decreased the number of ulcers per stomach, severity per stomach, and ulcer index on the cold-restrained gastric ulcer model in rats [23]. In another experiment using aspirin-induced ulcer on albino rats, petroleum ether, benzene, and  $\text{CHCl}_3$  extracts of this plant offered protection [24].

**3.6. Anti-inflammatory Activity.** In acute or sub-acute inflammation models, the rat paw oedema can be significantly inhibited by five different extracts of *A. pindrow* leaves [23][25][26]. (+)-Pinitol (**277**) may be responsible for the anti-inflammatory effect in carrageenin-induced paw oedema in rats [104]. Moreover, the different extracts of this plant can reduce the granuloma pouch induced by phlogistic agent in both exudate volume and the weight of granuloma tissue [26]. The benzene extract of *A. pindrow* had significant mast cell-protective action [24]. The MeOH and petroleum ether extracts of *A. webbiana* leaves also showed anti-inflammatory effect in carrageenan-induced rat paw edema [30].

**3.7. Antihypertensive Activity.** Petroleum ether extract of *A. pindrow* leaves produced a transient fall in blood pressure with no significant change in heart rate and respiration of anaesthetized dog. But this fall in blood pressure could be blocked by atropine [23][27].

**3.8. Antitussive Activity.** The MeOH extract of *A. webbiana* exhibited significant antitussive activity in a dose-dependent manner on a cough model induced by  $\text{SO}_2$  gas in mice. The extract showed maximum inhibition of cough frequency by 71.69 and 78.67%, respectively, when compared with the control group, and was comparable in effect to codeine phosphate, a prototype antitussive agent [28]. In another experiment on histamine-induced bronchospasm in guinea-pigs, the benzene, acetone, and EtOH extracts of *A. pindrow* leaves showed bronchoprotective activities [24].

**3.9. CNS Activities.** **3.9.1 Analgesic Activity.** Pretreatment of 200 mg/kg, i.p., of five different extracts of *A. pindrow* leaves showed significant analgesic activities after 45–90 min of administration [23].

**3.9.2 Pentobarbitone Hypnosis.** Five fractions of *A. pindrow* leaves significantly enhanced pentobarbitone sleeping time [23]. The same synergistic effects were

observed with the MeOH extract of *A. webbiana* leaves on pentobarbitone sodium- and diazepam-induced sleep in mice [30].

**3.9.3 Swim-Stress Immobility in Mice.** The acetone extract of *A. pindrow* leaves significantly decreased immobility, while the EtOH extract showed a significant increase of immobile phase.

**3.9.4 Anxiolytic Activity.** In several experimental paradigms of anxiety *viz.* open-field exploratory behavior, elevated plus maze, and elevated zero maze tests, the EtOH extract of *A. pindrow* leaves showed significant anxiolytic effects [29].

**3.10. Toxicity Study.** The  $LD_{50}$  values of petroleum ether, benzene,  $CHCl_3$ , acetone, and EtOH extracts of *A. pindrow* leaves were 360, 250, 325, 850, 425 mg/kg, respectively [23]. The  $LD_{50}$  values of MeOH,  $CHCl_3$ , and petroleum ether exacts of *A. webbiana* leaves were 985.67, 1387.14, and greater than 3200 mg/kg [30].

**4. Conclusions.** – Though *ca.* 50 *Abies* species are distributed all over the world, only 19 species were investigated. Phytochemical studies on the plants of this genus had led to the isolation of 277 compounds including terpenoids, flavonoids, lignans, phenols, and steroids *etc.* Moreover, the crude extracts and some chemical constituents of *Abies* species were found to possess nine different biological activities. Thus, much attention should be paid to *Abies* species on further phytochemical and pharmacological studies.

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