Review Article

Review of Compounds and Pharmacological Effects of Delphinium

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Plants of Delphinium are herbal medicine used in the Tibet region with whole grass as a drug, which have the effects of analgesic, antibacterial, antipyretic, and anticancer. The main bioactive compounds are alkaloids, flavonoids, and sterols. This review summarized the compounds and pharmacological effects of Delphinium and provides a reference for further research on Delphinium.

1. Introduction

Delphinium of the Ranunculaceae family is widely distributed in the North temperate zone, with about 350 species worldwide. 173 species (150 endemic) of Delphinium are distributed in China [1]. Delphinium is composed of subgen. Delphinastrum, subgen. Delphinium, and subgen. Oligophyllum, in the world, of which subgen. Delphinastrum has the most species [2]. In China, there are 18 species of Delphinium used as folk medicine, which are used to treat bruises, rheumatism, toothache, and enteritis. In addition, four species of Delphinium can be used as soil pesticides for their effects of killing lice, mosquitoes, and fly larvae [3]. The main compounds of Delphinium are diterpenoid alkaloids, and most of them have physiological activities [4]. In addition, Delphinium also contains chemical constituents such as flavonoids and sterols. In recent years, with the development of analysis methods and increasing focus on Delphinium, more and more chemical constituents and pharmacological activities of Delphinium had been researched. In this paper, the chemical constituents and pharmacological effects of Delphinium were reviewed in order to improve the development and utilization of the Delphinium resources.

2. Chemical Constituents

According to the research studies, the alkaloids are the main constituents with physiological activities in Delphinium and diterpenoid alkaloids are the most characteristic constituents with toxicity [5]. In addition, flavonoids and sterols are also present [6].

2.1. Diterpenoid Alkaloids. Diterpenoid alkaloids are derived from the amination of tetracycline diterpenoids or pentacyclic diterpenoids to heterocyclic systems containing...
β-aminoethanol, methylamine, or ethylamine nitrogen atoms [7]. There are abundant diterpenoid alkaloids in Delphinium, which can be classified into C-18 diterpenoid alkaloids, C-19 diterpenoid alkaloids, and C-20 diterpenoid alkaloids according to the carbon skeleton configuration [5]. Characteristic quaternary carbon signal and substituent signal are important information to distinguish different diterpenoid alkaloids.

C-18 diterpenoid alkaloids are the diterpenoid alkaloids whose C-18 are mostly substituted by C(4)-H/OH or the ester group, and a few of them contain 3,4-epoxide. According to the oxygen-containing groups on C-7, they can be sorted into two types (Figure 2): lappacinitine-type and ranaconitine-type, and C-7 of the ranaconitine-type has an oxygen-substituent group. C4 (δ 30–40, s), C5 (δ 73–84, s), and C11 (δ 47–55, s) are C-18’s characteristic signals [8]. Characteristic signal of the ranaconitine-type on C-7 is at δc 91–93 (s), and the characteristic signal of the lappacinitine-type on C-7 is at δc 45–48 (s).

Most C-19 diterpenoid alkaloids are natural diterpenoid alkaloids and belong to pentacyclic diterpenoid alkaloids. According to the oxygen-containing groups on C-7 and the difference of skeleton, they can be classified into six types (Figure 2): lycocotonine-type, aconitine-type, 7,17-seco type, atisine-type, veatchine-type, and hetisine-type [12]. The C-19 diterpene alkaloid skeletons are complex, and most of them have exocyclic double bond structures. At present, 22 types of C-20 diterpenoid alkaloids were found [12]. The C-20 diterpenoid alkaloids isolated from Delphinium mainly belong to atisine-type, veatchine-type, hetisine-type, hetidine-type, denudatine-type, delnudine-type [13], and vagnognantine-type (Figure 3) [14, 15]. C₁₁ (δ 30–40, s), C₈ (δ 30–50, s), C₁₁ (δ 30–40, s), C₁₆ (δ 143, s), and C₁₇ (δ 5–10, t) are C-20’s characteristic signals. C₁₆ (δ 17–20, s), C₁₇ (δ 13–15, s), C₁₄ (δ 46–49, s), C₁₅ (δ 25–26, s), and C₂₀ (δ 50–54, s) are characteristic signals of atisine-type, and C₁₂ (δ 50–43, s), C₁₉ (δ 48–51, s), C₁₄ (δ 36–53, s), and C₂₀ (δ 69, s) are characteristic signals of hetidine-type [16].

At present, 155 alkaloids were isolated from Delphinium, and the details are shown in Tables 1–3 and Figures 4–6. Based on the references listed in Tables 1–3, it can be summarized that D. antrhiscfolium varietas and D. elatum and its varietas have been further studied in chemistry.

2.2. Amide Alkaloids. The typical groups of amide alkaloids are acyl groups. 9 amide alkaloids were isolated from Delphinium, and the details are shown in Table 4 and Figure 7.

2.3. Other Alkaloids. Except diterpenoid alkaloids and amide alkaloids, one other alkaloid (No.155, antrhiscfoliolsine A, C₂₀H₁₃NO₇, [49]) was isolated from D. antrhiscfoliolum var. majus. The structure is shown in Figure 8.

2.4. Other Compounds. Delphinium also contains compounds such as flavonoids and sterols. In recent years, other compounds isolated from Delphinium had also been reported, and a total of 13 nonalkaloids (Table 5 and Figure 9) were isolated from Delphinium.

3. Biological Activities

Plants of Delphinium are used with whole grass as medicine. According to the ancient Tibetan medicine Jingzhubencao, plants of Delphinium had analgesic, anti-inflammatory, and insecticidal effects [9]. Literature studies showed that plants of Delphinium have many pharmacological effects including antibacterial, antiepileptic, detoxification, and Alzheimer’s disease treatment. In this section, this paper reviews the research studies on the antibacterial, analgesic, anti-inflammatory, antidepressant, and anticancer effects of Delphinium.

3.1. Antibacterial Activity. Hari et al. found that antrhiscfolioline C (5.0 mg/mL) from D. brounanianum had a good inhibiting effect on Bacillus subtilus, Escherichia coli, and Salmonella flexnari, and its MIC were 24.0 µM, 23.4 µM, and 24.2 µM, respectively, in vitro [61]. Ren et al. carried out the bacteriostatic test on the total alkaloids extracted from the roots of Delphinium and found that the MIC of the total alkaloids extracted on S. aureus and Aspergillus niger was 50 mg/mL in vitro [62].

3.2. Analgesic Activity. Zaheer et al. used the eddy current hot plate method and the tail flick reaction method to evaluate the analgesic activity of D. denudatum on Wistar albino rats. The experimental results showed that the response time of rats given D. denudatum ethanol extract and methanol fraction was longer than that of the propylene glycol group, and the effects of the high doses of the ethanol extract (600 mg/kg) and methanol fraction (400 mg/kg) were equal to that of the positive control group, indicating that
D. denudatum had a good analgesic activity [63]. Nesterova et al. investigated chronic immune inflammation which was induced by injecting 0.1 mL of complete Freund’s in outbred male rats, and the results showed that the 40% alcohol extract (0.12 mL/kg) and total alkaloids (0.05 mg/kg) of Delphinium could significantly reduce the frequency of joint

**Figure 2:** The skeleton structures of C-19 diterpene alkaloids.

**Figure 3:** The skeleton structures of C-20 diterpene alkaloids.
Table 1: C-18 diterpenoid alkaloids isolated from Delphinium.

| No. | Compound          | Type     | Source                                      | Molecular formula | Reference |
|-----|-------------------|----------|---------------------------------------------|-------------------|-----------|
| 1   | Anthriscifolcine A| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₆H₃₈NO₇          | [17]      |
| 2   | Anthriscifolcine B| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₄H₃₇NO₆          | [17]      |
| 3   | Anthriscifolcine C| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₅H₃₇NO₇          | [17]      |
| 4   | Anthriscifolcine D| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₆H₃₉NO₇          | [17]      |
| 5   | Anthriscifolcine E| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₄H₃₇NO₆          | [17]      |
| 6   | Anthriscifolcine F| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₅H₃₇NO₈          | [17]      |
| 7   | Anthriscifolcine G| Ranaconitine | D. anthriscifolium var. savatieri         | C₂₄H₃₇NO₆          | [17]      |
| 8   | Naviconine      | Lappacinitine | D. naviculare var. lasiocarpum W. T. Wang. | C₃₅H₄₂N₂O₉        | [19]      |
| 9   | Anthriscifolcone A| Ranaconitine | D. anthriscifolium var. majus            | C₃₀H₴₅NO₉          | [20]      |
| 10  | Anthriscifolcone B| Ranaconitine | D. anthriscifolium var. majus            | C₂₈H₴₃NO₈          | [20]      |
| 11  | Grandifline A   | Ranaconitine | D. grandiflorum Linn                     | C₂₂H₃₃NO₇          | [21]      |
| 12  | Tuguaconitine   | Ranaconitine | D. grandiflorum                          | C₂₃H₃₅NO₇          | [22]      |

Table 2: C-19 diterpenoid alkaloids isolated from Delphinium.

| No. | Compound          | Type     | Source                                      | Molecular formula | Reference |
|-----|-------------------|----------|---------------------------------------------|-------------------|-----------|
| 21  | Anthriscifoldine A| Lycoctonine | D. anthriscifolium var. savatieri         | C₂₅H₃₇NO₇          | [17]      |
| 22  | Anthriscifoldine B| Lycoctonine | D. anthriscifolium var. savatieri         | C₂₅H₃₉NO₇          | [17]      |
| 23  | Anthriscifoldine C| Lycoctonine | D. anthriscifolium var. savatieri         | C₂₇H₄₁NO₇          | [17]      |
| 24  | Naviculine        | Lycoctonine | D. naviculare var. lasiocarpum W. T. Wang. | C₂₆H₄₂NO₇⁺        | [19]      |
| 25  | Naviculine        | Aconitine | D. naviculare var. lasiocarpum W. T. Wang. | C₀₃H₄₆N₂O₉          | [19]      |
| 26  | Grandifline B    | Lycoctonine | D. grandiflorum Linn                     | C₂₃H₃₉NO₈          | [21]      |
| 27  | Grandifline C    | Lycoctonine | D. grandiflorum Linn                     | C₂₄H₄₀NO₇⁺        | [21]      |
| 28  | Olivimine        | Lycoctonine | D. grandiflorum                          | C₂₄H₴₃NO₇          | [22]      |
| 29  | Hohenackeridine  | Lycoctonine | D. grandiflorum                          | C₂₅H₴₁NO₇          | [22]      |
| 30  | 14-O-Methylphilfolfine | Lycoctonine | D. grandiflorum                          | C₂₄H₴₃NO₇⁺        | [22]      |
| 31  | N-Deethylphilpallidine | Lycoctonine | D. grandiflorum                          | C₂₅H₴₁NO₇          | [22]      |
| 32  | Browniine        | Lycoctonine | D. grandiflorum                          | C₂₅H₴₃NO₇          | [22]      |
| 33  | 14-Dehydrobrowniine | Lycoctonine | D. grandiflorum                          | C₂₃H₴₃NO₇          | [22]      |
| 34  | Linearilobin     | Aconitine | D. linearilobum (Trautv.) N. Busch         | C₂₅H₴₆N₂O₉          | [23]      |
| 35  | Melpheline       | Lycoctonine | D. elatum                                | C₂₃H₴₃NO₆          | [26]      |
| 36  | 19-Oxoisodelpheline | Lycoctonine | D. elatum                                | C₂₃H₴₃NO₇          | [26]      |
| 37  | N-Deethyl-19-oxoisodelpheline | Lycoctonine | D. elatum                                | C₂₃H₴₃NO₇          | [26]      |
| 38  | N-Deethyl-19-oxidelpheline | Lycoctonine | D. elatum                                | C₂₃H₴₃NO₇          | [26]      |
| 39  | N-Formyl-4,19-secopacinine | Lycoctonine | D. elatum cv. Pacific Giant              | C₂₃H₴₃NO₇          | [27]      |
| 40  | Iminoisodelpheline | Lycoctonine | D. elatum cv. Pacific Giant              | C₂₃H₴₃NO₇          | [27]      |
| 41  | Iminodelpheline  | Lycoctonine | D. elatum cv. Pacific Giant              | C₂₃H₴₃NO₇          | [27]      |
| 42  | Iminopaciline    | Lycoctonine | D. elatum cv. Pacific Giant              | C₂₃H₴₃NO₇          | [27]      |
| 43  | 6-Dehydrodelaladine | Lycoctonine | D. elatum cv. Pacific Giant              | C₂₃H₴₃NO₇          | [27]      |
| 44  | Elapaciline      | Lycoctonine | D. elatum cv. Pacific Giant              | C₂₃H₴₃NO₇          | [27]      |
| 45  | Yunnanensine A   | Rearranged-type | D. yunnanense                             | C₂₄H₴₈N₂O₉        | [28]      |
| 46  | Iliensine A      | Lycoctonine | D. iliens                                | C₂₄H₴₃NO₁₄        | [29]      |
| 47  | Iliensine B      | Lycoctonine | D. iliens                                | C₂₄H₴₁NO₈          | [29]      |
| 48  | Pseudophnine A   | Lycoctonine | D. pseudoaemulans C. Y. Yang et B. Wang  | C₂₃H₴₈NO₇⁺        | [30]      |
| 49  | Pseudophnine B   | Lycoctonine | D. pseudoaemulans C. Y. Yang et B. Wang  | C₂₄H₳₃NO₇⁺        | [30]      |
| No. | Compound                  | Type          | Source                                      | Molecular formula | Reference |
|-----|---------------------------|---------------|---------------------------------------------|-------------------|-----------|
| 50  | Pseudophnine C            | Lycoctonine   | *D. pseudoaemulans* C. Y. Yang et B. Wang  | C_{27}H_{42}NO_{7} | [30]      |
| 51  | Pseudophnine D            | Lycoctonine   | *D. pseudoaemulans* C. Y. Yang et B. Wang  | C_{28}H_{40}NO_{7} | [30]      |
| 52  | Pseudorenines A           | Lycoctonine   | *D. pseudoaemulans* C. Y. Yang et B. Wang  | C_{30}H_{38}NO_{11} | [30]      |
| 53  | Pseudorenines B           | Lycoctonine   | *D. pseudoaemulans* C. Y. Yang et B. Wang  | C_{30}H_{38}NO_{11} | [30]      |
| 54  | Pseudonidine A            | Lycoctonine   | *D. pseudoaemulans* C. Y. Yang et B. Wang  | C_{26}H_{40}NO_{7} | [30]      |
| 55  | Pseudonidine B            | Lycoctonine   | *D. pseudoaemulans* C. Y. Yang et B. Wang  | C_{26}H_{40}NO_{7} | [30]      |
| 56  | Navicularine              | Lycoctonine   | *D. naviculare var. lasiocarpum*            | C_{27}H_{42}NO_{8} | [31]      |
| 57  | Shawurensine              | Lycoctonine   | *D. shawurense* W. T. Wang                 | C_{28}H_{40}NO_{7} | [32]      |
| 58  | Sharwuphinine B           | Lycoctonine   | *D. shawurense* W. T. Wang                 | C_{28}H_{40}NO_{7} | [33]      |
| 59  | Ajacisine A               | Lycoctonine   | *D. ajacis* L.                            | C_{29}H_{44}N_{2}O_{9} | [34]      |
| 60  | Ajacisine B               | Lycoctonine   | *D. ajacis* L.                            | C_{30}H_{44}N_{2}O_{9} | [34]      |
| 61  | Ajacisine C               | Lycoctonine   | *D. ajacis* L.                            | C_{30}H_{44}N_{2}O_{9} | [34]      |
| 62  | Ajacisine D               | Lycoctonine   | *D. ajacis* L.                            | C_{30}H_{44}N_{2}O_{9} | [34]      |
| 63  | Ajacisine E               | Lycoctonine   | *D. ajacis* L.                            | C_{30}H_{44}N_{2}O_{9} | [34]      |
| 64  | Caerudelphinine A         | Lycoctonine   | *D. caeruleum* Jacq.ex Camb               | C_{25}H_{40}N_{2}O_{8} | [35]      |
| 65  | Grandifloridine B         | Lycoctonine   | *D. grandiflorum*                         | C_{26}H_{44}N_{2}O_{10} | [36]      |
| 66  | Majusine A                | Lycoctonine   | *D. majus* W. T. Wang                     | C_{27}H_{42}N_{2}O_{9} | [37]      |
| 67  | Majusine B                | Lycoctonine   | *D. majus* W. T. Wang                     | C_{28}H_{42}N_{2}O_{9} | [37]      |
| 68  | Majusine C                | Lycoctonine   | *D. majus* W. T. Wang                     | C_{28}H_{42}N_{2}O_{9} | [37]      |
| 69  | Davidisine A              | Lycoctonine   | *D. davidii* Franch.                      | C_{29}H_{44}N_{2}O_{9} | [38]      |
| 70  | Davidisine B              | Lycoctonine   | *D. davidii* Franch.                      | C_{29}H_{44}N_{2}O_{9} | [38]      |
| 71  | Laxicyminine 1            | Lycoctonine   | *D. laxicymosum var. pilostachyum* W. T. Wang | C_{29}H_{39}NO_{7} | [39]      |
| 72  | Laxicyminine 2            | Lycoctonine   | *D. laxicymosum var. pilostachyum* W. T. Wang | C_{29}H_{39}NO_{7} | [39]      |
| 73  | Laxicyminine 3            | Lycoctonine   | *D. laxicymosum var. pilostachyum* W. T. Wang | C_{29}H_{39}NO_{7} | [39]      |
| 74  | Tiantaishansine           | Lycoctonine   | *D. tiantaishanense* W. J. Zhang et G. H. Chen | C_{22}H_{33}NO_{7} | [40]      |
| 75  | Tiantaishannine           | Lycoctonine   | *D. tiantaishanense* W. J. Zhang et G. H. Chen | C_{22}H_{33}NO_{7} | [40]      |
| 76  | Tiantaishanminine         | Lycoctonine   | *D. tiantaishanense* W. J. Zhang et G. H. Chen | C_{22}H_{33}NO_{7} | [40]      |
| 77  | Trifoliolasine A          | Lycoctonine   | *D. trifoliolatum* Finet et Gagnep         | C_{28}H_{38}N_{2}O_{9} | [41]      |
| 78  | Trifoliolasine B          | Lycoctonine   | *D. trifoliolatum* Finet et Gagnep         | C_{28}H_{38}N_{2}O_{9} | [41]      |
| 79  | Trifoliolasine C          | Lycoctonine   | *D. trifoliolatum* Finet et Gagnep         | C_{28}H_{38}N_{2}O_{9} | [41]      |
| 80  | 14-Demethyl-14-isobutyrylanhweidelphinine | Lycoctonine | *D. pentagynum* Lam. | C_{28}H_{48}N_{2}O_{11} | [42]      |
| 81  | 14-Demethyl-14-acetylanhweidelphinine | Lycoctonine | *D. pentagynum* Lam. | C_{28}H_{48}N_{2}O_{11} | [42]      |
| 82  | Giraldine G               | Lycoctonine   | *D. giraldii*                              | C_{29}H_{37}N_{2}O_{11} | [43]      |
| 83  | Giraldine H               | Lycoctonine   | *D. giraldii*                              | C_{29}H_{37}N_{2}O_{11} | [43]      |
| 84  | Giraldine I               | Aconitine     | *D. giraldii*                              | C_{29}H_{37}N_{2}O_{11} | [43]      |
| 85  | Giraldine D               | Lycoctonine   | *D. giraldii*                              | C_{29}H_{37}N_{2}O_{11} | [43]      |
| 86  | Giraldine E               | Lycoctonine   | *D. giraldii*                              | C_{29}H_{37}N_{2}O_{11} | [43]      |
| 87  | Giraldine F               | Lycoctonine   | *D. giraldii*                              | C_{29}H_{37}N_{2}O_{11} | [43]      |
| 88  | Campylocine               | Lycoctonine   | *D. campylocentrum* Maxim.                 | C_{29}H_{37}N_{2}O_{11} | [44]      |
| 89  | Campylotine                | Lycoctonine   | *D. campylocentrum* Maxim.                 | C_{29}H_{37}N_{2}O_{11} | [44]      |
| 90  | Davidisine A              | Lycoctonine   | *D. davidii* Franch.                      | C_{30}H_{38}N_{2}O_{9} | [44]      |
| 91  | Davidisine B              | Lycoctonine   | *D. davidii* Franch.                      | C_{30}H_{38}N_{2}O_{9} | [44]      |
| 92  | Ajadelphine               | Lycoctonine   | *D. honanense var. piliteram* W. T. Wang  | C_{29}H_{39}N_{2}O_{9} | [45]      |
| 93  | Acconine                   | Aconitine     | *D. honanense var. piliteram* W. T. Wang  | C_{29}H_{39}N_{2}O_{9} | [45]      |
| 94  | Siwanine E                | Lycoctonine   | *D. honanense var. piliteram* W. T. Wang  | C_{29}H_{39}N_{2}O_{9} | [45]      |
Table 2: Continued.

| No. | Compound                    | Type            | Source                      | Molecular formula | Reference |
|-----|-----------------------------|-----------------|----------------------------|-------------------|-----------|
| 95  | Grandiflorine III           | Aconitine       | D. grandiflorum L.         | C_{26}H_{39}NO_{9} | [48]      |
| 96  | Isotalatizidine             | Aconitine       | D. grandiflorum L.         | C_{23}H_{37}NO_{5} | [48]      |
| 97  | 14-O-Methyl isotalatizidine | Aconitine       | D. grandiflorum L.         | C_{23}H_{40}N_{5}O_{3} | [48] |
| 98  | Anthranoylycoctonine        | Lycoctonine     | D. grandiflorum L.         | C_{26}H_{39}NO_{6} | [48]      |
| 99  | Deoxylycoctonine            | Lycoctonine     | D. grandiflorum L.         | C_{26}H_{39}NO_{6} | [48]      |
| 100 | Umbrosine                   | Lycoctonine     | D. grandiflorum L.         | C_{24}H_{39}NO_{6} | [48]      |
| 101 | Anthriscifoline A           | Lycoctonine     | D. anthriscifolium var. majus | C_{23}H_{37}NO_{5} | [49]      |
| 102 | Anthriscifoline B           | Lycoctonine     | D. anthriscifolium var. majus | C_{27}H_{41}NO_{8} | [49]      |
| 103 | Anthriscifoline C           | Lycoctonine     | D. anthriscifolium var. majus | C_{27}H_{41}NO_{8} | [49]      |
| 104 | Anthriscifoline D           | Lycoctonine     | D. anthriscifolium var. majus | C_{27}H_{39}NO_{8} | [49]      |
| 105 | Anthriscifoline E           | Lycoctonine     | D. anthriscifolium var. majus | C_{26}H_{39}NO_{8} | [49]      |
| 106 | Anthriscifoline F           | Lycoctonine     | D. anthriscifolium var. majus | C_{24}H_{37}NO_{7} | [49]      |
| 107 | Tianshanisine A             | Lycoctonine     | D. tianshanicum W. T. Wang | C_{30}H_{41}NO_{6} | [50]      |
| 108 | Tianshanisine B             | Lycoctonine     | D. tianshanicum W. T. Wang | C_{23}H_{37}NO_{5} | [50]      |
| 109 | Tianshanisine C             | Lycoctonine     | D. tianshanicum W. T. Wang | C_{25}H_{39}NO_{6} | [50]      |
| 110 | Tianshanisine D             | Lycoctonine     | D. tianshanicum W. T. Wang | C_{25}H_{39}NO_{6} | [50]      |
| 111 | Tianshanisine E             | Lycoctonine     | D. tianshanicum W. T. Wang | C_{25}H_{39}NO_{7} | [50]      |
| 112 | Elapacigine                 | Lycoctonine     | Delphinium elatum cv. Pacific Giant | C_{23}H_{37}NO_{7} | [51]      |
| 113 | N-Deethyl-N-formylpaciline  | Lycoctonine     | Delphinium elatum cv. Pacific Giant | C_{25}H_{37}NO_{7} | [51]      |
| 114 | N-Deethyl-N-formylpacinine  | Lycoctonine     | Delphinium elatum cv. Pacific Giant | C_{25}H_{37}NO_{7} | [51]      |
| 115 | N-Formyl-4,19-secoyunnadelphinine | Lycoctonine | Delphinium elatum cv. Pacific Giant | C_{25}H_{37}NO_{7} | [51]      |

Table 3: C-20 diterpenoid alkaloids isolated from Delphinium.

| No. | Compound               | Type        | Source                      | Molecular formula | Reference |
|-----|------------------------|-------------|----------------------------|-------------------|-----------|
| 116 | Yunnanensine B        | Hetisine    | D. yunnanense               | C_{28}H_{37}NO_{7} | [28]      |
| 117 | Yunnanensine C        | Hetisine    | D. yunnanense               | C_{26}H_{35}NO_{6} | [28]      |
| 118 | Grandifloridine A     | Hetisine    | D. grandiflorum             | C_{22}H_{28}N_{2}O_{3} | [36]      |
| 119 | Majusimine A          | Vakognavine | D. majus W. T. Wang         | C_{26}H_{47}NO_{15} | [37]      |
| 120 | Majusimine B          | Vakognavine | D. majus W. T. Wang         | C_{24}H_{45}NO_{14} | [37]      |
| 121 | Majusimine C          | Vakognavine | D. majus W. T. Wang         | C_{24}H_{43}NO_{13} | [37]      |
| 122 | Majusimine D          | Vakognavine | D. majus W. T. Wang         | C_{24}H_{43}NO_{12} | [37]      |
| 123 | Majusidine A          | Hetisine    | D. majus W. T. Wang         | C_{22}H_{29}NO_{5}  | [37]      |
| 124 | Majusidine B          | Hetisine    | D. majus W. T. Wang         | C_{22}H_{29}NO_{4}  | [37]      |
| 125 | Tiantaishandine       | Hetisine    | D. tiantaishanense W. J. Zhang et G. H. Chen | C_{24}H_{31}NO_{7} | [40]      |
| 126 | 2-Dehydrodeacetyldelphinidine | Hetidine     | D. pentagonum Lam.      | C_{24}H_{33}NO_{5} | [42]      |
| 127 | Davidiisine C         | Hetidine    | D. davidi Franc            | C_{22}H_{32}N_{5}O_{14} | [46]      |
| 128 | 12-Epinapelline       | Veatchine   | D. honanense var. piliteram W. T. Wang | C_{22}H_{32}N_{5}O_{13} | [47]      |
| 129 | Anthriscifolin B      | Hetisine    | D. anthriscifolium var. majus | C_{22}H_{32}N_{5}O_{12} | [49]      |
| 130 | Anthriscifolin C      | Hetisine    | D. anthriscifolium var. majus | C_{20}H_{32}N_{5}O_{12} | [49]      |
| 131 | Anthriscifolin A      | Denudatine  | D. anthriscifolium var. savatieri | C_{23}H_{32}NO_{8} | [52]      |
| 132 | Anthriscifolin B      | Denudatine  | D. anthriscifolium var. savatieri | C_{23}H_{32}NO_{8} | [52]      |
| 133 | Anthriscifolin C      | Hetisine    | D. anthriscifolium var. savatieri | C_{23}H_{32}NO_{8} | [52]      |
| 134 | Trichodelphinines A   | Hetisine    | D. tichophorum Franch      | C_{24}H_{32}NO_{5}  | [53]      |
| 135 | Trichodelphinines B   | Hetisine    | D. tichophorum Franch      | C_{24}H_{32}NO_{5}  | [53]      |
| 136 | Trichodelphinines C   | Hetisine    | D. tichophorum Franch      | C_{24}H_{32}NO_{5}  | [53]      |
| 137 | Trichodelphinines D   | Hetisine    | D. tichophorum Franch      | C_{24}H_{32}NO_{5}  | [53]      |
| 138 | Trichodelphinines E   | Hetisine    | D. tichophorum Franch      | C_{24}H_{32}NO_{5}  | [53]      |
| 139 | Trichodelphinines F   | Denvudine   | D. tichophorum Franch      | C_{24}H_{32}NO_{4}  | [53]      |
| 140 | Flexiosine            | Hetisine    | D. flexuosum M. Bieb.       | C_{24}H_{32}NO_{9}  | [54]      |
| 141 | Tatsienenseine A      | Vakognavine | D. tatsienense Franch       | C_{24}H_{45}NO_{13} | [55]      |
| 142 | Tatsienenseine B      | Hetisine    | D. tatsienense Franch       | C_{24}H_{32}NO_{5}  | [55]      |
| 143 | Tatsienenseine C      | Hetisine    | D. tatsienense Franch       | C_{24}H_{32}NO_{5}  | [55]      |
| 144 | 13-(2-Methyl butyryl) azitine | Atisine | D. scabrisforum           | C_{24}H_{32}NO_{3}  | [56]      |
| 145 | Tatsienensine         | Hetisine    | D. tatsienense             | C_{19}H_{32}NO_{2}  | [57]      |
Figure 4: Continued.
swelling in outbred male rats. On the 14th day, the rats in the total alkaloids (0.05 mg/kg) treatment group of Delphinium had no pain when their joints were bended, which indicated a good analgesic effect of Delphinium [64]. Through the hot-plate method and the acetic acid writhing method, Suslov et al. found that the water extract (0.5 g/kg) and the alcohol extract (0.25 g/kg) of D. grandiflorum L. var. leiocarpum could prolong the pain threshold of mice, which was similar to the effect of acetaminophen (0.2 g/kg), and performed a good analgesic effect [65].

3.3. Anti-Inflammatory Activity. Nesterova et al. found that the alkaloids and flavonoids in Delphinium had a good inhibitory effect on the inflammatory response through the experiment of the mice peritonitis model in the inflammatory exudation phase in vivo. Aqueous fraction of flavonoids (25.0 mg/kg) had a good therapeutic effect on the edema reaction caused by histamine (0.1%), and alkaloids (0.05 mg/kg) showed a good anti-inflammatory effect on the inflammatory reaction caused by 5-hydroxytryptamine (0.5 mg/kg) [66]. Andreeva and Liu established an acute inflammation model with increased capillary permeability induced by acetic acid in ICR male mice, and the results showed that the high- (1.5 g/kg), medium- (1.0 g/kg), and low-dose groups (0.5 g/kg) of the total flavonoids extracted from D. grandiflorum with ethanol had good anti-inflammatory activity [67].

3.4. Spiritual Influence

3.4.1. Antidepressant Activity. Ebrahimzadeh et al. demonstrated that the extract (250 mg/kg, 500 mg/kg, and 1000 mg/kg) of D. elbursense had good antidepressant activity by using the forced swimming experiment and the tail suspension experiment in mice. The results revealed that the extract at 1000 mg/kg had the same inhibitory activity as imipramine at 15 mg/kg in the control group [68].

3.4.2. Antianxiety Activity. Mohammad et al. found that the D. denudatum extract (200 and 400 mg/kg) had a certain therapeutic effect on anxiety in Wistar albino rats and a better synergistic effect toward the Amaranthus spinosus extract (100 mg/kg) [69].

3.5. Anticancer Activity. Zheng et al. used the MTT method to determine the antithepataoma activity of the ethyl acetate extract from D. caeruleum in vitro. After giving 25, 50, 100, and 200 µg/mL of HepG2 cells for 12, 24, and 48 hours, they found that the ethyl acetate extract from D. caeruleum had good anti-tumor cancer activity and had a good dose-effect and time-effect relationship on HepG2 cells and had less toxicity to L-02 cells. IC_{50} of the ethyl acetate extract from D. caeruleum on HepG2 cells was 28.8 µg/mL [70].

3.6. Antipulmonary Fibrosis Activity. In the study on pulmonary fibrosis induced by bleomycin in SD rats, Lin et al. found that after 14 days of gavage with 4 g/kg, 2 g/kg, and 1 g/kg extracts of D. trichophorum, the expression of collagen in the tissues during the pathological process of pulmonary fibrosis could be inhibited and the symptoms of pulmonary fibrosis in rats could be improved [71].

3.7. Antifeedant Activity. Shan et al. determined the antifeed activity of 12 alkaloids isolated from D. naviculare var. lasiocarpum on Spodoptera exigua, and the results showed that the chemical shawurensine had a strong antifeed activity with an EC_{50} of 0.45 mg/cm^2 [31]. González and Guadano extracted 5 alkaloids from Delphinium for activity determination against Spodoptera littoralis and Leptinotarsa decemlineata by choice feeding assays, and the results showed that cardiopetamine had the strongest activity against S. littoralis with the EC_{50} of 5.48 nmol/cm^2 and 15-acetylcardiopetamine had the strongest activity against L. decemlineata with the EC_{50} of 12.86 nmol/cm^2 [72].

Figure 4: C-18 diterpenoid alkaloids isolated from Delphinium.
Figure 5: Continued.
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Figure 5: Continued.
FIGURE 5: Continued.
Figure 5: C-19 diterpenoid alkaloids isolated from Delphinium.
Figure 6: Continued.
Figure 6: C-20 diterpenoid alkaloids isolated from Delphinium.
Table 4: Amide alkaloids isolated from *Delphinium*.

| No. | Compound                                                                 | Type   | Source                  | Molecular formula | Reference |
|-----|---------------------------------------------------------------------------|--------|-------------------------|-------------------|-----------|
| 146 | Benzoic acid 2-[(4-methoxy-2-methyl-1,4-dioxobutyl) amino]-methyl ester  | Amide  | *D. grandiflorum* Linn  | C<sub>14</sub>H<sub>17</sub>N<sub>5</sub> | [21]      |
| 147 | N-Cinnamoyl-2-phenylethylamine                                            | Amide  | *D. grandiflorum* L.   | C<sub>17</sub>H<sub>17</sub>N<sub>5</sub> | [48]      |
| 148 | Delamide A                                                                | Amide  | *D. brunonianum*       | C<sub>13</sub>H<sub>13</sub>N<sub>4</sub> | [58]      |
| 149 | Delamide B                                                                | Amide  | *D. brunonianum*       | C<sub>14</sub>H<sub>17</sub>N<sub>6</sub> | [58]      |
| 150 | Delamide C                                                                | Amide  | *D. brunonianum*       | C<sub>13</sub>H<sub>15</sub>N<sub>5</sub> | [58]      |
| 151 | Delamide D                                                                | Amide  | *D. brunonianum*       | C<sub>13</sub>H<sub>15</sub>N<sub>5</sub> | [58]      |
| 152 | Delamide E                                                                | Amide  | *D. brunonianum*       | C<sub>13</sub>H<sub>15</sub>N<sub>5</sub> | [58]      |
| 153 | Benzoic,4-[(3,4-dimethoxybenzoyl) amino]-3-hydroxy-methyl ester           | Amide  | *D. brunonianum* Royle | C<sub>17</sub>H<sub>17</sub>N<sub>6</sub> | [59]      |
| 154 | Benzoic acid 2-[(4-methoxy-3-methyl-1,4-dioxobutyl) amino]-methyl ester   | Amide  | *D. brunonianum* Royle | C<sub>14</sub>H<sub>17</sub>N<sub>5</sub> | [59]      |

**Figure 7:** Amide alkaloids isolated from *Delphinium*.

**Figure 8:** Other alkaloids isolated from *Delphinium*. 
| No. | Compound | Type | Source | Molecular formula | Reference |
|-----|----------|------|--------|-------------------|-----------|
| 156 | β-Carotene | | D. grandiflorum Linn | C_{34}H_{56}NO_{4} | [21] |
| 157 | 3,5-Dihydroxy-4′-methoxyflavon-7-yl-O-β-D-glucopyranosyl-(1→4)-α-L-rhamnopyranoside | Flavonoid | D. grandiflorum Linn | C_{21}H_{18}NO_{8} | [21] |
| 158 | β-D-Galactopyranoside,4-hydroxyphenyl | Sterol | D. honanense var. piliteram W. T. Wang | C_{11}H_{12}NO_{5} | [47] |
| 159 | β-Sitosterol | | | | |
| 160 | 4′,7-Dimethoxy-5-hydroxyflavone | Flavonoid | D. grandiflorum L. | C_{27}H_{34}O_{3} | [48] |
| 161 | Kaempferol-7-O-α-L-pyranorhamnoside | Flavonoid | D. grandiflorum L. | C_{23}H_{20}O_{10} | [60] |
| 162 | 5,7,3′,4′-Tetrahydroxy-8-methoxyflavone | Flavonoid | D. grandiflorum L. | C_{16}H_{12}O_{7} | [60] |
| 163 | Tachioside | Phenolics | D. grandiflorum L. | C_{13}H_{18}O_{8} | [60] |
| 164 | 6-Methoxycoumarin | Coumarin | D. grandiflorum L. | C_{10}H_{4}O_{3} | [60] |
| 165 | para-Hydroxybenzoic acid | | D. brunonianum Royle | C_{7}H_{6}O_{3} | [59] |
| 166 | Benzoic acid | | D. brunonianum Royle | C_{7}H_{6}O_{2} | [59] |
| 167 | Cinnamic acid | | D. brunonianum Royle | C_{8}H_{8}O_{3} | [59] |
| 168 | Dibutyl phthalate | | D. brunonianum Royle | C_{16}H_{12}O_{4} | [59] |
3.8. Antiparasite Activity. Reina et al. found that delphi-graciline extracted from *D. gracile* had antileishmanicidal activity *in vitro*, and its IC$_{50}$ was 7.3 μg/mL [73].

4. Summary and Analysis

*Delphinium* is rich in germplasm resources and has a wide range of pharmacological effects. In recent years, 168 compounds were isolated from plants of *Delphinium*, including 155 alkaloids and 13 nonalkaloids. The alkaloids in the genus *Delphinium* are mainly diterpene alkaloids, including 20 C-18 diterpenoid alkaloids, 95 C-19 diterpenoid alkaloids, and 30 C-20 diterpenoid alkaloids. The study of chemical composition for *Delphinium* mainly focuses on *D. anthriscifolium* varietas, *D. elatum*, *D. grandiflorum*, *D. brunonianum*, *D. tiantaishanense*, and *D. pseudoaemulans.*
Although there are many research studies, the pharmacological effects on the antibacterial, analgesic, anti-inflammatory, antidepressant, anticancer, antipulmonary fibrosis, antifeeded, and antiparasite effects of Delphinium are mainly on the crude extracts and few on compounds.

5. Future Prospects

The genus Delphinium is rich in new and novel compounds, but the current research is only focused on several species. In the future, more new compounds should be investigated from other species in depth. The pharmacological effects of Delphinium are extensive, but the current research is limited to extracts, so it is necessary to focus on the effects of the compounds from Delphinium and the structure-activity relationship in the future.

Data Availability

The data supporting this article are from previously reported studies, which have been cited. The data are available from the corresponding author upon request.

Conflicts of Interest

All authors declare that they have no conflicts of interest.

Authors’ Contributions

Sitan Chen and Lijun Meng contributed equally to this work.

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