Design, synthesis and antifungal activity of novel indole derivatives linked with the 1,2,3-triazole moiety *via* the CuAAC click reaction

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A series of novel indole derivatives linked with the 1,2,3-triazole moiety was designed, synthesised by the $CuCl_2$/Zn-catalysed Huisgen cycloaddition and characterised. The antifungal activity of all the prepared compounds against *Colletotrichum capsici* and cotton *Physalospora* pathogens was evaluated and the results indicated that these compounds showed inhibitory effect for fungi and the inhibition ratio of the best was up to 83.3%. The preliminary structure–activity relationship is also discussed in this paper.

Keywords: indole, 1,2,3-triazole, Huisgen cycloaddition, antifungal activity

Preventing and controlling plant diseases, especially those caused by fungi, is an important part of the agricultural industry all over the world.[1] Chemical fungicides are indispensable for the future of agriculture.[2] Yet, with the emergence of resistance and toxicity to existing fungicides, it is extremely important to find new ones.

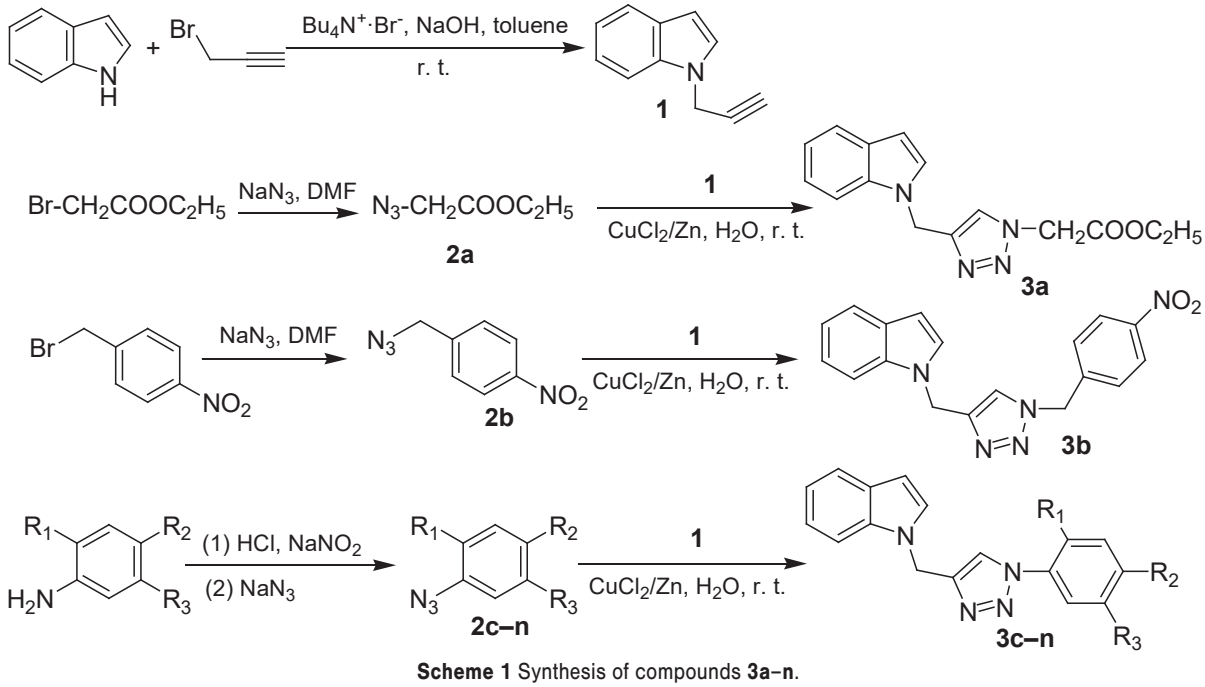
N-heterocyclic building blocks, including triazoles and indoles, play a significant role in the pharmaceutical industry. The indole skeleton is a ubiquitous bioactive heterocycle in nature.[3,4] It features widely in a broad range of pharmacologically and biologically active compounds.[5–7] Many compounds containing the 1,2,3-triazole unit have good inhibitory activities against inflammation,[8] cancer[9] and microbes.[10] Copper(I)-catalysed azide–alkyne cycloaddition (CuAAC) reactions are a convenient and regiospecific approach to 1,4-disubstituted triazoles,[11] making the 1,2,3-triazole unit of increasing interest. The reaction has been widely used in drug discovery and medicinal chemistry.[12–14]

In our previous work, the 1,2,3-triazole moiety was connected to maleimide or paeonol and the compounds obtained exhibited potent antitumour activity[15] or antifungal activity.[16]

Based on all the above considerations and our previous work and in order to find more potent compounds possessing antifungal activity, we have designed and synthesised a series of novel indole derivatives linked with the 1,2,3-triazole moiety using the CuAAC reaction. The reaction was carried out in H_2O using $CuCl_2$/Zn as the catalyst system at room temperature. Furthermore, we evaluated the antifungal activity of these novel indole derivatives against two plant pathogenic fungi, *Colletotrichum capsici* and cotton *Physalospora*, using hexaconazole and flutriafol as the positive controls. Some of these studies are the subject of a patent applied for in China (CN 102816150).

Results and discussion

The synthetic strategy for the preparation of the indole derivatives is illustrated in Scheme 1. The hydrogen atom attached to the nitrogen atom of indole was substituted by prop-2-ynyl to give **1** at room temperature.[17] Azides **2** were prepared starting from different starting materials.[18,19] The CuAAC click reaction of **1** and **2** occurred easily to yield the target compounds **3a–n** at room temperature. The CuAAC reaction



Scheme 1 Synthesis of compounds **3a–n**.

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Table 1 Antifungal activity of **3a–n**, hexaconazole and flutriafol at 20 μg mL^{-1} against *Colletotrichum capsici* and cotton *Physalospora* pathogens

Compound	R_1	R_2	R_3	Inhibitory ratio/%	
				A[a]	B[b]
3a	–	–	–	83.33	42.86
3b	–	–	–	0	25.32
3c	H	H	H	0	14.29
3d	NO_2	H	H	66.67	42.86
3e	H	H	NO_2	33.33	0
3f	H	NO_2	H	0	28.57
3g	CH_3	H	NO_2	66.67	28.57
3h	CH_3	H	H	68.32	50.23
3i	H	CH_3	H	50.00	42.86
3j	H	OH	H	66.67	0
3k	CF_3	H	H	50.00	42.86
3l	F	H	H	34.03	50.12
3m	Cl	H	H	45.01	65.21
3n	H	H	Cl	33.33	57.14
Hexaconazole	–	–	–	100	100
Flutriafol	–	–	–	100	100

[a] *Colletotrichum capsici.*

[b] Cotton *Physalospora.*

is the key procedure for the synthesis of the target molecules. After optimisation of the reaction conditions copper, obtained *in situ* from $CuCl_2$/Zn powder in water, was chosen as the catalyst.[20] Compounds **3a–n** were obtained with good yields and their structures were confirmed by ^{1}H NMR, ^{13}C NMR, IR and MS.

The antifungal activity of all the prepared compounds against *Colletotrichum capsici* and cotton *Physalospora* pathogens was evaluated, using hexaconazole and flutriafol as the positive controls. The inhibition ratios are reported in Table 1**.** The data in Table 1 show that some of the tested compounds exhibited good antifungal activity against the two tested fungi at 0.02 mg mL^{-1}. As shown in Table 1, most compounds exhibited moderate to high activity. Compounds showed better activity towards *Colletotrichum capsici* and the inhibition ratio of **3a**, **3d**, **3g**, **3h** and **3j** exceeds 65%. Comparison of **3b** and **3f** showed that the distance between the phenyl ring and the triazole moiety has almost no effect on the activity. The data showed that the *ortho*-substituent of the phenyl ring is usually beneficial to the activity while the effect is unfavourable when R_2 is an electron-withdrawing group or the hydrogen atom of the *meta*-position is substituted. Compound **3a**, which has no substituted phenyl ring, was the most effective towards *Colletotrichum capsici* and its inhibition ratio is up to 83.33%. The reason for this is worthy of further study.

In conclusion, a series of novel indole derivatives linked with the 1,2,3-triazole moiety was designed and synthesised using the CuAAC reaction. Most of the products exhibited good antifungal activity towards *Colletotrichum capsici*. Though the activity was less than the positive controls, it still gave some useful indicators for the further study of related chemical fungicides.

Experimental

Melting points were determined with a YUHUA X-3 melting point apparatus and are uncorrected. IR spectra were recorded on a Bio-rad FTS-40 spectrometer. ^{1}H and ^{13}C spectra were recorded on a Bruker Avance 400 MHz spectrometer operating at 400.13 and 100.61 MHz respectively. NMR spectra were recorded in $CDCl_3$ or DMSO-d_6 at room temperature (20 ± 2 °**C**). ^{1}H and ^{13}C chemical shifts are quoted in parts per million downfield from TMS. ESI-MS were recorded on a Bruker Esquire 3000 instrument. High-resolution mass spectra (HRMS) were obtained on a MicrOTOF-Q II mass spectrometer with an ESI source (Waters, Manchester). All reagents were obtained from commercial sources and used without further purification. All reactions were monitored by thin-layer chromatography (TLC).

*Synthesis of 1-(prop-2-ynyl)-1*H*-indole* (**1**)

Compound **1** was synthesised according to the literature.[17]

Synthesis of **2a–n***; general procedure*

Compounds **2a–n** were synthesised according to the literature.[18,19]

Synthesis of indole-1,2,3-triazole compounds **3a–n***; general procedure*

A mixture of **1** (1.0 mmol), **2** (1.0 mmol) and $CuCl_2$ (10 mol%)/Zn powder (10 mol%) in water (12 mL) was vigorously stirred at room temperature. After completion of the reaction, the mixture was diluted with saturated aqueous NH_4Cl (20 mL) and extracted with CH_2Cl_2 (3 × 10 mL). The combined organic phases were successively washed with water and brine, dried over Na_2SO_4 and concentrated *in vacuo*. The crude product was purified by column chromatography on silica gel using ethyl acetate/petroleum ether as eluent.

Ethyl 2-{4-[(indol-1-yl)methyl]-1,2,3-triazol-1-yl}acetate (**3a**): White solid; yield 84%; m.p. 80–81 °C; IR (KBr) (ν cm^{-1}): 3146, 3102, 3060, 2981, 2927, 2904, 1758, 1610, 1566, 1512, 1483, 1462, 1435, 1376, 1216, 747, 726; ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.00 (s, 1H, =CH–H), 7.53–7.58 (m, 2H, ArH), 7.45 (d, *J* = 4.0 Hz, 1H, =CH–H), 7.12 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, ArH), 7.01 (t, *J* = 4.0 Hz, 8.0 Hz, 1H, ArH), 6.45 (d, *J* = 4.0 Hz, 1H, =CH–H), 5.49 (s, 2H, CH_2–H), 5.33 (s, 2H, CH_2–H), 4.11–4.16 (m, 2H, CH_2–H), 1.18 (t, *J* = 8.0 Hz, 16.0 Hz, 3H, CH_3–H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 167.6, 144.2, 136, 129.1, 128.7, 125.1, 121.6, 120.9, 119.6, 110.5, 101.4, 61.9, 50.8, 41.2, 14.3; ESI-MS: 285 [M + 1]$^+$; HRMS calcd for $C_{15}H_{16}N_4O_2Na$: [M + Na]$^+$: 307.1165; found: 307.1167.

*1-{[1-(4-Nitrobenzyl)-1*H*-1,2,3-triazol-4-yl]methyl}-1*H*-indole* (**3b**): White solid; yield 90%; m.p. 104–106 °C; IR (KBr) (ν cm^{-1}): 3122, 3080, 2953, 2854, 1607, 1520, 1483, 1463, 1436, 1375, 1347, 808, 742, 720; ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.22 (d, *J* = 12.0 Hz, 2H, ArH), 8.14 (s, 1H, =CH–H), 7.52–7.57 (m, 2H, ArH), 7.49 (d, *J* = 8.0 Hz, 2H, ArH), 7.45 (d, *J* = 4.0 Hz, 1H, =CH–H), 7.12 (t, *J* = 4.0 Hz, 8.0 Hz, 1H, ArH), 7.02 (t, *J* = 4.0 Hz, 8.0 Hz, 1H, Ar–H), 6.44 (s, 1H, =CH–H), 5.73 (s, 2H, CH_2–H), 5.48 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 147.6, 144.6, 143.8, 136.0, 129.4, 129.1, 128.7, 124.3, 124.2, 121.6, 120.9, 119.6, 110.5, 101.5, 52.3, 41.3; ESI-MS: 334 [M + 1]$^+$; HRMS calcd for $C_{18}H_{15}N_5O_2Na$: [M +Na]$^+$: 356.1118; found: 356.1114.

*1-[(1-Phenyl-1*H*-1,2,3-triazol-4-yl)methyl]-1*H*-indole* (**3c**): White solid; yield 86%; m.p. 98–99 °C; IR (KBr) (ν cm^{-1}): 3126, 3081, 2942, 1611, 1596, 1512, 1501, 1483, 1463, 1443, 1396, 760, 745, 725; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.0 Hz, ArH), 7.57 (d, *J* = 8.0 Hz, 16.0 Hz, 3H, ArH), 7.40–7.43 (m, 4H, ArH), 7.20–7.24 (m, 2H, ArH), 7.11–7.14 (m, 1H, CH–H), 6.56 (d, *J* = 4.0 Hz, 16.0 Hz, 1H, CH–H), 5.52 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.5, 136.7, 135.9, 129.7, 128.9, 128.8, 127.9, 122.0, 121.2, 120.4, 120, 119.9, 109.6, 102.2, 42.0; ESI-MS: 275 [M + 1]$^+$; HRMS calcd for $C_{17}H_{14}N_4Na$: [M + Na]$^+$: 297.1111; found: 297.1115.

*1-{[1-(2-Nitrophenyl)-1*H*-1,2,3-triazol-4-yl]methyl}-1*H*-indole* (**3d**): White solid; yield 90%; m.p. 94–96 °C; IR (KBr) (ν cm^{-1}): 3144, 3065, 2924, 2855, 1608, 1588, 1534, 1508, 1484, 1462, 1446, 1359, 764, 743, 721; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (d, *J* = 8.0 Hz, 1H, ArH), 7.68 (dd, *J* = 8.0 Hz, 40.0 Hz, 3H, ArH), 7.40–7.48 (m, 3H, ArH), 7.20–7.25 (m, 2H, ArH), 7.13 (t, *J* = 4.0 Hz, 8.0 Hz, 1H, CH_2–H), 6.56 (d, *J* = 4.0 Hz, 1H, CH–H), 5.55 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.3, 144.3, 135.9, 133.8, 130.9, 129.9, 128.8, 127.8, 127.8, 125.5, 123.5, 122, 121.1, 119.8, 109.5, 102.3, 41.9; ESI-MS: 320 [M + 1]$^+$; HRMS calcd for $C_{17}H_{13}N_5O_2Na$: [M + Na]$^+$: 342.0961; found: 342.0958.

*1-{[1-(3-Nitrophenyl)-1,2,3-triazol-4-yl]methyl}-1*H*-indole* (**3e**): White solid; yield 80%; m.p. 161–163 °C; IR (KBr) (ν cm^{-1}): 3132,

3098, 2925, 2854, 1610, 1533, 1493, 1483, 1462, 1350, 1040, 810, 750, 738; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.47 (d, *J* = 4.0 Hz, 1H, ArH), 8.23–8.26 (m, 1H, ArH), 8.03 (d, *J* = 8.0 Hz, 1H, CH–H), 7.64–7.68 (m, 3H, ArH), 7.40 (d, *J* = 8.0 Hz, 1H, ArH), 7.20–7.25 (m, 2H, ArH), 7.13 (d, *J* = 8.0 Hz, 16.0 Hz, 1H, CH–H), 6.57 (s, 1H, CH–H), 5.55 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.9, 145.5, 137.5, 136.0, 131.9, 129.1, 128.7, 126.4, 123.6, 122.6, 121.6, 120.9, 119.6, 115.1, 110.5, 101.6, 41.1; ESI-MS: 320 [M + 1]$^+$; HRMS calcd for $C_{17}H_{13}N_5O_2Na$: [M + Na]$^+$: 342.0961; found: 342.0966.

*1-{[1-(4-Nitrophenyl)-1,2,3-triazol-4-yl]methyl}-1*H-*indole* (**3f**): White solid; yield 85%; m.p. 162–163 °C; IR (KBr) (ν cm^{-1}): 3132, 3087, 2939, 2855, 1616, 1598, 1521, 1484, 1462, 1434, 1398, 1345, 829, 748, 718; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.33 (d, *J* = 8.0 Hz, 2H, ArH), 7.83 (d, *J* = 8.0 Hz, 2H, ArH), 7.65 (t, *J* = 8.0 Hz, 16.0 Hz, 2H, ArH), 7.39 (d, *J* = 8.0 Hz, 1H, ArH), 7.20–7.24 (m, 2H, ArH), 7.14 (t, *J* = 4.0 Hz, 16.0 Hz, 1H, CH–H), 6.58 (d, *J* = 4.0 Hz, 1H, CH_2–H), 5.55 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.1, 146.4, 140.8, 135.8, 128.8, 127.8, 125.4, 122.1, 121.2, 120.3, 112.0, 119.8, 109.4, 102.5, 41.9; ESI-MS: 320 [M + 1]$^+$; HRMS calcd for $C_{17}H_{13}N_5O_2Na$: [M + Na]$^+$: 342.0961; found: 342.0957.

*1-{[1-(2-Methyl-5-nitrophenyl)-1,2,3-triazol-4-yl]methyl}-1*H-*indole* (**3g**): White solid; yield 85%; m.p. 115–117 °C; IR (KBr) (ν cm^{-1}): 3150, 3094, 3057, 2940, 1612, 1521, 1485, 1462, 1441, 1376, 1347, 823, 796, 738, 652; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.21–8.23 (m, 1H, ArH), 8.13 (d, *J* = 4.0 Hz, 1H, ArH), 7.64 (d, *J* = 8.0 Hz, 1H, =CH–H), 7.51 (d, *J* = 8.0 Hz, 1H, ArH), 7.40 (t, *J* = 4.0 Hz, 8.0 Hz, 2H, ArH), 7.20–7.25 (m, 2H, ArH), 7.12 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, =CH–H), 5.56 (s, 1H, =CH–H), 5.57 (s, 2H, CH_2–H), 2.27 (s, 3H, CH_3–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 146.3, 145.3, 141.5, 136.5, 135.8, 132.5, 128.8, 127.8, 124.3, 123.3, 122.0, 121.2, 121.1, 119.8, 109.4, 102.4, 41.9, 18.5; ESI-MS: 334 [M + 1]$^+$; HRMS calcd for $C_{18}H_{15}N_5O_2Na$: [M + Na]$^+$: 356.1118; found: 356.1114.

*1-[(1-*o*-Tolyl-1,2,3-triazol-4-yl)methyl]-1*H-*indole* (**3h**): White solid; yield 86%; m.p. 82.6–83.7 °C; IR (KBr) (ν cm^{-1}): 3135, 3085, 3055, 2929, 2862, 2793, 1707, 1611, 1585, 1556, 1504, 1484, 1463, 1440, 1399, 1382, 764, 741; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63 (d, *J* = 8.0 Hz, 1H, CH–H), 7.40 (d, *J* = 8.0 Hz, 1H, ArH), 7.17–7.36 (m, 7H, ArH), 7.11 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, CH–H), 6.54 (d, *J* = 4.0 Hz, 1H, CH–H), 6.52 (s, 2H, CH_2–H), 2.11 (s, 3H, CH_3–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.6, 136.2, 135.9, 133.6, 131.5, 129.9, 128.8, 127.9, 126.8, 125.9, 123.4, 121.9, 121.1, 119.8, 109.5, 102.2, 42.1, 17.8; ESI-MS: 289 [M + 1]$^+$; HRMS calcd for $C_{18}H_{16}N_4Na$: [M + Na]$^+$: 311.1267; found: 311.1262.

*1-[(1-*p*-Tolyl-1,2,3-triazol-4-yl)methyl]-1*H-*indole* (**3i**): White solid; yield 87%; m.p. 92–94 °C; IR (KBr) (ν cm^{-1}): 3125, 3082, 3055, 2921, 2864, 1612, 1549, 1518, 1485, 1466, 1445, 1397, 1381, 1354, 818, 757, 740, 728; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64 (d, *J* = 8.0 Hz, 1H, ArH), 7.51 (s, 1H, =CH–H), 7.40–7.45 (m, 3H, ArH), 7.19–7.22 (m, 4H, ArH), 7.12 (t, *J* = 4.0 Hz, 8.0 Hz, 1H, =CH–H), 6.54 (s, 1H, =CH–H), 5.49 (s, 2H, CH_2–H), 2.35 (s, 3H, CH_3–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.3, 138.9, 135.9, 134.5, 130.2, 128.9, 127.9, 122.0, 121.2, 120.3, 112.0, 119.8, 109.6, 102.2, 42.0, 21.1; ESI-MS: 289 [M + 1]$^+$; HRMS calcd for $C_{18}H_{16}N_4Na$: [M + Na]$^+$: 311.1267; found: 311.1265.

*4-{4-[(1*H-*Indol-1-yl)methyl]-1*H-*1,2,3-triazol-1-yl}phenol* (**3j**): White solid; yield 84%; m.p. 172–173 °C; IR (KBr) (ν cm^{-1}): 3423, 3132, 3105, 2943, 2841, 2710, 1601, 1518, 1479, 1469, 1427, 1381, 1063, 839, 753, 665; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.0 Hz, 1H, CH–H), 7.40–7.48 (m, 4H, ArH), 7.22 (d, *J* = 12.0 Hz, 3H, ArH), 7.13 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, ArH), 6.92 (d, *J* = 12.0 Hz, 2H, CH–H), 6.56 (s, 1H, OH–H), 5.53 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 158.2, 144.7, 135.9, 129.1, 129.1, 128.7, 122.4, 122.0, 121.6, 120.9, 119.6, 116.4, 110.6, 101.5, 41.1; ESI-MS: 291 [M + 1]$^+$; HRMS calcd for $C_{17}H_{14}N_4ONa$: [M + Na]$^+$: 313.1065; found: 313.1060.

*1-({1-[2-(Trifluoromethyl)phenyl]-1,2,3-triazol-4-yl}methyl)-1*H-*indole* (**3k**): White solid; yield 91%; m.p. 84–85 °C; IR (KBr) (ν cm^{-1}): 3158, 3064, 2941, 2860, 1645, 1609, 1558, 1510, 1485, 1465, 1441, 1366, 1317, 770, 741; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (d, *J* = 8.0 Hz, 1H, ArH), 7.62–7.69 (m, 3H, ArH), 7.40–7.44 (m, 3H, ArH), 7.20–7.25 (m, 2H, ArH), 7.12 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, CH–H), 6.54–6.55 (d, *J* = 4.0 Hz, 1H, CH–H), 5.55 (s, 1H, CH_2–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.6, 135.9, 134.5, 133.1, 130.6, 128.9, 128.8, 127.8, 127.3, 126.2, 125.9, 124.6, 121.9, 121.1, 119.8, 109.5, 102.2, 41.9; ESI-MS: 343 [M + 1]$^+$; HRMS calcd for $C_{18}H_{13}F_3N_4Na$: [M + Na]$^+$: 365.0985; found: 365.0980.

*1-{[1-(2-Fluorophenyl)-1,2,3-triazol-4-yl]methyl}-1*H-*indole* (**3l**): White solid; yield 84%; m.p. 88–89.7 °C; IR (KBr) (ν cm^{-1}): 3129, 3083, 3025, 1672, 1611, 1597, 1555, 1512, 1483, 1474, 1462, 1425, 1395, 1240, 1049, 758, 744, 719; ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.61 (s, 1H, CH–H), 7.66 (d, *J* = 8.0 Hz, 1H, ArH), 7.51–7.59 (m, 4H, ArH), 7.41 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, ArH), 7.15 (t, *J* = 4.0 Hz, 16.0 Hz, 1H, CH–H), 7.03 (t, *J* = 4.0 Hz, 16.0 Hz, 1H, CH–H), 5.57 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 155.3, 152.9, 144.6, 136.0, 131.7, 131.6, 129.1, 128.7, 126.2, 121.6, 120.9, 119.6, 117.6, 117.4, 110.5, 101.6, 40.9; ESI-MS: 293 [M + 1]$^+$; HRMS calcd for $C_{17}H_{13}FN_4Na$: [M + Na]$^+$: 315.1016; found: 315.1014.

*1-{[1-(2-Chlorophenyl)-1,2,3-triazol-4-yl]methyl}-1*H-*indole* (**3m**): White solid; Yield 82%; m.p. 79–80 °C; IR (KBr) (ν cm^{-1}): 3148, 3055, 2949, 2854, 1696, 1611, 1591, 1582, 1552, 1512, 1493, 1461, 1433, 1376, 1309, 776, 758, 745, 718, 690; ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.58 (s, 1H, CH–H), 7.74 (d, *J* = 8.0 Hz, 1H, ArH), 7.52–7.66 (m, 5H, ArH), 7.50 (d, *J* = 4.0 Hz, 1H, CH–H), 7.15 (t, *J* = 4.0 Hz, 8.0 Hz, 1H, ArH), 7.03 (d, *J* = 8.0 Hz, 16.0 Hz, 1H, ArH), 6.47 (d, *J* = 4.0 Hz, 1H, CH–H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 144.0, 136.1, 134.8, 132.0, 131.0, 129.1, 128.8, 128.8, 128.8, 126.1, 121.6, 120.9, 119.6, 110.6, 101.6, 41.0; ESI-MS: 310 [M + 1]; HRMS calcd for $C_{17}H_{13}ClN_4Na$: [M +Na]$^+$: 331.0721; found: 331.0725.

*1-{[1-(3-Chlorophenyl)-1,2,3-triazol-4-yl]methyl}-1*H-*indole* (**3n**): White solid; yield 93%; m.p. 104–106 °C; IR (KBr) (ν cm^{-1}): 3142, 3098, 2939, 2852, 1685, 1593, 1508, 1492, 1462, 1433, 1398, 798, 778, 749, 716; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (d, *J* = 8.0 Hz, 2H, ArH, CH–H), 7.52 (d, *J* = 8.0 Hz, 2H, ArH), 7.38–7.41 (m, 3H, ArH), 7.23 (t, *J* = 8.0 Hz, 16.0 Hz, 2H, ArH), 7.14 (t, *J* = 8.0 Hz, 16.0 Hz, 1H, CH–H), 6.58 (d, *J* = 4.0 Hz, 1H, CH–H), 5.54 (s, 2H, CH_2–H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.8, 137.6, 135.8, 135.5, 130.8, 128.9, 128.8, 127.8, 122.0, 121.2, 120.6, 119.9, 119.8, 118.4, 109.4, 102.4, 42.0; ESI-MS: 310 [M + 1]$^+$; HRMS calcd for $C_{17}H_{13}ClN_4Na$: [M + Na]$^+$: 331.0721; found: 331.0724.

Antifungal activity

The antifungal activity of the target compounds against *Colletotrichum capsici* and cotton *Physalospora* pathogens, using hexaconazole and flutriafol as the positive controls, was evaluated by the College of Life Science, Henan Normal University. The procedures were carried out as described below.

A stock solution of each compound was prepared at 0.2 mg mL^{-1} using DMSO as a solvent. A working solution (0.02 mg mL^{-1}) was then prepared by diluting the stock solution (0.1 mL) with sterilised water (0.9 mL) in a 10 cm diameter Petri dish. Potato dextrose agar (PDA, 9 mL) was then added to prepare the plate. Before the plate solidification, the PDA was completely mixed by turning around the Petri dish in the sterilised operation disk six times to decentralise the compounds in PDA evenly. Then 0.8 mm of diameter of the fungi cake was vaccinated on the plate and cultured in the incubator at 32 °C. After 24 h, the diameter of fungi spread was measured. Growth inhibition was then calculated using the positive controls.

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