Synthesis and biological activities of some Schiff's bases from 4-amino-3-(3-hydroxybutyl)-1*H*-1, 2, 4-triazole-5-thione

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Sixteen novel Schiff's bases have been synthesised in high yields from 4-amino-3-(3-hydroxybutyl)-1*H*-1, 2, 4-triazole-5-thione. All the newly synthesised compounds have been characterised by elemental analysis, IR, ^{1}H NMR, ^{13}C NMR and MS. Plant growth-regulating activity tests showed that most compounds have remarkable effects on the growth of wheat and radish at a mass concentration of 50μg mL^{-1}.

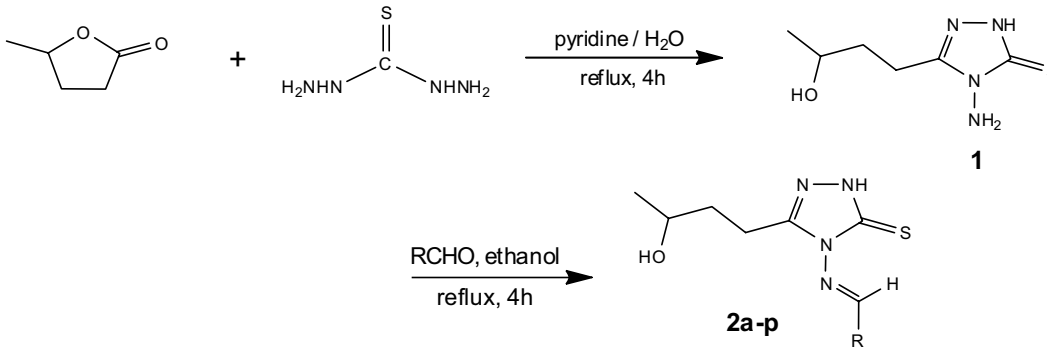
Key words: Schiff's bases, 4-amino-3-(3-hydroxybutyl)-1*H*-1, 2, 4-triazole-5-thione, synthesis, plant growth regulation

1, 2, 4-Triazoles and their heterocyclic derivatives have been reported to have considerable biological activities such as analgesic, antitubercular, anthelmintic, antifungal, plant growth regulating, anticancer and antiviral properties.[1-5] Some Schiff's bases of 1, 2, 4-triazoles possess excellent biological activities, which have been attracting many researchers' attention in recent years.[6-8] In continuation of our studies on N-bridged heterocycles,[9,10] we report here the synthesis and biological activities of some Schiff's bases from 4-amino-3-(3-hydroxybutyl)-1*H*-1, 2, 4-triazole-5-thione.

Almost all of the substituents at the 3-position in 1, 2, 4-triazoles synthesised in the past were alkyl or aryl, which led to their poor water solubility. Our group had synthesised some 1, 2, 4-triazoles and their derivatives with an aliphatic side chain containing hydroxyl groups at the 3-position and improved their water solubility successfully.[11-13] With all these considerations in mind, we have synthesised the title compounds.

The synthesis route is outlined in Scheme 1. It is understandable that the products (**2a–p**) exist in the form of *E* configuration because of low energy. We mixed the 1, 2, 4-triazole (1) with more than 10 differently substituted benzaldehydes, maintaining pH values during the reaction at 5–6 because the acidity of the reaction medium is crucial. In our previous research,[14] we tried to add activated molecular sieves (4Å) and keep the reaction under a nitrogen atmosphere. The result was encouraging as a 50–70% yield of the crude title products was received. The desired products have been obtained in good yields by means of this method and identified on the basis of elemental analysis, IR, ^{1}H NMR, ^{13}C NMR and MS.

The effects of the title compounds **1**, **2a–m** on sprouting of wheat and radish seeds have been investigated. After treating with solutions of 50 μg mL^{-1} and 10 μg mL^{-1} of the title compounds for 7 days (25 °C), the germination percentages have been determined, and from the difference in length between stems and radicels of seedlings treated with the title compounds and those treated only with distilled water, the plant growth regulating activities have been calculated. The equations of the growth regulating percentage are: [the average of sample length (cm) – the average of the controls (cm)]/the average of the controls (cm) ×100%. The results are presented in Table 1.



Scheme 1

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Table 1 Effect of compounds **1, 2a–m** on the plant growth-regulating of wheat and radish

Compounds	Concentrations (μg mL^{-1})	Radish Germ.	Radish Stalk	Radish Radicel	Wheat Germ.	Wheat Stalk	Wheat Radicel
1	50	####	+ + + + +	+ + +	##	******	******
	10	##	**	******	#####	+	+
2a	50	#	+ + + + +	+ + + + +	###	******	******
	10	##	**	*****	#####	***	**
2b	50	##	+ + + + + +	+ + + + + +	###	******	******
	10	###	**	****	#####	**	**
2c	50	##	+ + + + +	+ + + + +	####	******	******
	10	###	***	**	#####	**	***
2d	50	##	+ + + + +	+ + + +	#####	****	***
	10	##	***	**	#####	**	*
2e	50	#	+ + + + + +	+ + + + +	###	******	******
	10	###	******	******	#####	**	*
2f	50	#	+ + +	+ + + +	#####	******	******
	10	###	*	**	####	**	**
2g	50	##	+ + +	+ + +	####	******	******
	10	###	****	*****	#####	***	****
2h	50	##	+ + + + +	+ + + + + +	####	******	******
	10	##	*	*	#####	**	**
2i	50	##	+ + + + +	+ + + + +	####	******	******
	10	###	**	**	#####	***	***
2j	50	#	+ + + +	+ + + + + +	####	******	******
	10	###	**	****	#####	**	*
2k	50	#	+ + + + +	+ + + + +	####	+	+ +
	10	##	+	*	####	***	***
2l	50	##	+ + + + +	+ + + + + +	####	*****	******
	10	##	*	*	#####	***	***
2m	50	#	+ + + + + +	+ + + + + +	###	******	****
	10	###	***	*****	####	**	**

Germ.," # " represents germination rate. #: <10%; ##: 10–30%; ###: 30–50%; ####: 50–70%; #####: 70–90%; ######: >90%.
" * " represents inhibition rate. *: <10%; **: 10–30%; ***: 30–50%; ****: 50–70%; *****: 70–90%; ******: >90%.
" + " represents promotion rate. + : <10%; + + : 10–30%; + + + : 30–50%; + + + + : 50–70%; + + + + + : 70–90%; + + + + + + : >90%.

From the data it is evident that most of the title compounds have remarkable effects on the growth of wheat and radish at a mass concentration of 50μg mL^{-1}. The germination percentages of the monocotyledon (wheat) were much better than the dicotyledon (radish) at two concentration levels. It was interesting to note that almost all of the compounds showed stimulative activities towards the growth of the dicotyledon (radish) at higher concentration, but under the same conditions it expressed inhibitory activities towards the growth of the monocotyledon (wheat). The title compounds show a more pronounced inhibiting effect on the growth of wheat at higher concentration than the similar compounds our group synthesised in the past.[2,14] It is worthy of further study to establish a relationship between structure and activity.

Experimental

Melting points (uncorrected) were taken on an XT-4 melting point apparatus. IR spectra (KBr) were recorded in the 4000–400 cm^{-1} range on a Bruker Quinox 55 spectrophotometer. The ^{1}H NMR and ^{13}C NMR spectra were measured at 25 °C on a Bruker Avance-300 NMR spectrometer respectively in DMSO-d_6 solution using TMS as an internal reference. MS spectra were recorded on an Agilent 1100 LC/MS. Elemental analyses of carbon, hydrogen and nitrogen were determined on a Flash-1112 series elemental analyser. All the reagents used were AR grade.

Synthesis of 4-amino-3-(3-hydroxybutyl)-1H-1, 2, 4-triazole-5-thione (**1**)*: general procedure*

Thiocarbohydrazide was prepared by means of the method from the literature.[2] The thiocarbohydrazide (3.18 g, 30 mmol) was added to a solution of 4-methyl-γ-butyrolactone (1.89 mL, 20 mmol) in pyridine (30 mL) and water (3 mL). The mixture was refluxed for 6 h under stirring. After concentration under reduced pressure, the yellow crude product formed was recrystallised from alcohol to give compound (**1**): Yellow crystals, yield: 76%. M.p. 123–125 °C. IR (cm^{-1}): 3460 (OH), 2953 (CH_3), 1616 (N–C=N), 1565 (N–C=S). ^{1}H NMR (DMSO-d_6, 300 MHz, ppm): 13.40 (s, 1H, N–H), 5.50 (s, 2H, -NH_2), 4.54 (s, 1H, O–H), 3.66 (m, 1H, –OCH), 2.68 (t, 2H, J = 7.02 Hz, –CH_2C=N), 1.67 (m, 2H, –CH_2), 1.08 (d, 3H, J = 6.15 Hz, –CH_3). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 165.9 (N–C=S), 152.9 (N–C = N), 65.5 (CH), 35.2 (CH_2), 23.8 (CH_2), 21.3 (CH_3). MS-ESI (*m/z*): 189(M^+ + 1), 174, 170, 156. Elemental Anal. Calcd for $C_6H_{12}N_4OS$: C, 38.28; H, 6.46; N, 29.76. Found: C, 38.14; H, 6.39; N, 29.68%.

Synthesis of 3-(3-hydroxybutyl)-4-(substituted benzylidene) amino-1H-1, 2, 4-triazole -5-thione (**2**)*: general procedure*

An appropriate aromatic aldehyde (1.1 mmol, distilled under reduced pressure before use) was added to a solution of compound (**1**) (1.0 mmol, 188 mg) in absolute ethanol (20 mL). The pH value was adjusted to 5–6 with diluted HCl, and appropriate activated molecular sieves (4Å) were added. The mixture was stirred and refluxed for 4 h under a nitrogen atmosphere. The mixture was filtered through celite and washed with ethanol. The crude product obtained after concentration under reduced pressure was filtered, dried and recrystallised from 75% ethanol. The pure products (**2a–p**) were afforded.

3-(3-Hydroxybutyl)-4-(benzylidene) amino-1H-1, 2, 4-triazole-5-thione (**2a**): Yellow powder, yield: 67%. M.p. 162–164 °C. IR (cm^{-1}): 3300 (OH, NH), 3139 (ArH), 2926 (CH_3), 1596 (N–C=N), 1516 (N–C=S), 1498 (aromatic ring skeleton vibration), 1273 (C=S). ^{1}H NMR (DMSO-d_6, 300 MHz, ppm): 13.76 (s, 1H, N–H), 9.97 (s, 1H, CH=N), 7.91 (m, 2H, ArH), 7.60 (m, 3H, ArH), 4.51 (s, 1H, O–H), 3.68 (m, 1H, –OCH), 2.80 (t, J = 6.98 Hz, 2H, –CH_2C=N), 1.73 (m, 2H, –CH_2), 1.08 (d, 3H, J = 6.15 Hz, –CH_3). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 163.5 (N–C=S), 161.3 (Ph–CH=N), 151.5 (N–C=N), 132.6, 132.2, 129.2, 128.6, 64.9 (CH), 34.8 (CH_2), 23.5 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 277(M^+ + 1), 276, 259, 174, 156. Elemental Anal. Calcd for $C_{13}H_{16}N_4OS$: C, 56.50; H, 5.84; N, 20.27. Found: C, 56.31; H, 5.78; N, 20.11%.

3-(3-Hydroxybutyl)-4-(4-fluorobenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2b**): Yellow powder, yield: 71%. M.p. 148–150 °C. IR (cm^{-1}): 3289 (OH, NH), 2963 (ArH), 2925 (CH_3), 1595 (N–C=N), 1509 (aromatic ring skeleton vibration), 1465 (N–C=S), 1235 (C=S). ^{1}H NMR (DMSO-d_6, 300 MHz, ppm): 13.76 (s, 1H, N–H), 9.95 (s, 1H, CH=N), 7.99 (dd, 2H, J_1 = 3.62 Hz, J_2 = 8.14 Hz, ArH), 7.42 (dd, 2H, J_1 = 3.41 Hz, J_2 = 8.22 Hz, ArH), 4.53 (s, 1H, O–H), 3.66 (m, 1H, –OCH), 2.77 (t, 2H, J = 6.98 Hz, –CH_2C=N), 1.72 (m, 2H, –CH_2), 1.08 (d, 3H, J = 6.15 Hz, –CH_3). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 162.5 (N–C=S), 161.3 (Ph–CH=N), 151.5 (N–C=N), 131.1, 128.9, 116.6, 116.3, 64.9 (CH), 34.7 (CH_2), 23.4 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 295(M^+ + 1), 294, 277, 174, 156.

Elemental Anal. Calcd for $C_{13}H_{15}FN_4OS$: C, 53.05; H, 5.14; N, 19.03. Found: C, 53.28; H, 5.09; N, 18.85%.

3-(3-Hydroxybutyl)-4-(4-chlorobenzylidene)amino-1H-1,2,4-triazole-5-thione (**2c**): White crystals, yield: 68%. M.p. 174–176 °C. IR (cm^{-1}): 3290 (OH, NH), 2958 (ArH), 2926 (CH_3), 1591 (N–C=N), 1506 (aromatic ring skeleton vibration), 1466 (N–C=S), 1259 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.78 (s, 1H, N–H), 10.04 (s, 1H, CH=N), 7.93 (dd, 2H, J_1 = 3.51 Hz, J_2 = 8.62 Hz. ArH), 7.63 (dd, 2H, J_1 = 3.53 Hz, J_2 = 8.64 Hz, ArH), 4.49 (s, 1H, O–H), 3.66 (m, 1H, –OCH), 2.78 (t, 2H, J = 7.01 Hz, $–CH_2C$=N), 1.72 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.9 (N–C=S), 161.3 (Ph–CH=N), 151.6 (N–C=N), 137.3, 131.2, 130.2, 129.4, 64.9 (CH), 34.7 (CH_2), 23.5 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 311 (M^+ + 1), 293, 282, 174, 156. Elemental Anal. Calcd for $C_{13}H_{15}ClN_4OS$: C, 50.24; H, 4.86; N, 18.03. Found: C, 50.17; H, 4.81; N, 17.95%.

3-(3-Hydroxybutyl)-4-(4-bromobenzylidene)amino-1H-1,2,4-triazole-5-thione (**2d**): Yellow crystals, yield: 67%. M.p. 154–156 °C. IR (cm^{-1}): 3288 (OH, NH), 3041 (ArH), 2926 (CH_3), 1587 (N–C=N), 1511 (aromatic ring skeleton vibration), 1486 (N–C=S), 1275 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.78 (s, 1H, N–H), 10.04 (s, 1H, CH=N), 7.85 (dd, 2H, J_1 = 3.43 Hz, J_2 = 8.49 Hz, ArH), 7.78 (dd, 2H, J_1 = 3.48 Hz, J_2 = 8.56 Hz, ArH), 4.48 (s, 1H, O–H), 3.67 (m, 1H, –OCH), 2.79 (t, 2H, J = 6.99 Hz, $–CH_2C$=N), 1.71 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 162.3 (N–C=S), 161.7 (Ph–CH=N), 152.0 (N–C=N), 132.7, 131.9, 130.8, 126.7, 65.3 (CH), 35.1 (CH_2), 23.9 (CH_2), 21.6 (CH_3). MS-ESI (*m/z*): 353 (M-1), 172, 170. Elemental Anal. Calcd for $C_{13}H_{15}BrN_4OS$: C, 43.95; H, 4.25; N, 15.77. Found: C, 49.87; H, 4.18; N, 15.69%.

3-(3-Hydroxybutyl)-4-(2-chlorobenzylidene)amino-1H-1,2,4-triazole-5-thione (**2e**): Yellow powder, yield: 65%. M.p. 153–155 °C. IR (cm^{-1}): 3306 (OH, NH), 3046 (ArH), 2937 (CH_3), 1585 (N–C=N), 1510 (aromatic ring skeleton vibration), 1494 (N–C=S), 1277 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.83 (s, 1H, N–H), 10.83 (s, 1H, CH=N), 8.16 (d, 1H, J = 7.62 Hz, ArH), 7.65 (m, 2H, ArH), 7.54 (m, 1H, ArH), 4.49 (s, 1H, O–H), 3.69 (m, 1H, –OCH), 2.83 (t, 2H, J = 7.05 Hz, $–CH_2C$=N), 1.74 (m, 2H, $–CH_2$), 1.09 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.2 (N–C=S), 156.5 (Ph–CH=N), 152.0 (N–C=N), 135.1, 133.9, 130.3, 130.1, 127.9, 127.5, 65.0 (CH), 34.8 (CH_2), 23.5 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 311 (M^+ + 1), 293, 282, 174, 156. Elemental Anal. Calcd for $C_{13}H_{15}ClN_4OS$: C, 50.24; H, 4.86; N, 18.03. Found: C, 50.11; H, 4.77; N, 17.90%.

3-(3-Hydroxybutyl)-4-(4-nitrobenzylidene)amino-1H-1,2,4-triazole-5-thione (**2f**): Yellow powder, yield: 71%. M.p. 188–189 °C. IR (cm^{-1}): 3332 (OH, NH), 3139 (ArH), 2946 (CH_3), 1592 (N–C=N), 1519 (aromatic ring skeleton vibration), 1512 (N–C=S), 1344 (NO_2), 1275 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.86 (s, 1H, N–H), 10.38 (s, 1H, CH=N), 8.38 (dd, 2H, J_1 = 3.62 Hz, J_2 = 8.73 Hz, ArH), 8.18 (dd, 2H, J_1 = 3.64 Hz, J_2 = 8.79 Hz, ArH), 4.56 (s, 1H, O–H), 3.69 (m, 1H, –OCH), 2.83 (t, 2H, J = 7.02 Hz, $–CH_2C$=N), 1.74 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.8 (N–C=S), 159.9 (Ph–CH=N), 152.3 (N–C=N), 149.9, 138.7, 130.0, 124.7, 65.4 (CH), 35.2 (CH_2), 23.9 (CH_2), 21.6 (CH_3). MS-ESI (*m/z*): 320 (M-1), 284, 256, 173. Elemental Anal. Calcd for $C_{13}H_{15}N_5O_3S$: C, 48.59; H, 4.70; N, 21.79. Found: C, 48.47; H, 4.61; N, 21.53%.

3-(3-Hydroxybutyl)-4-(3-nitrobenzylidene)amino-1H-1,2,4-triazole-5-thione (**2g**): Yellow powder, yield: 69%. M.p. 160–162 °C. IR (cm^{-1}): 3317 (OH, NH), 3113 (ArH), 2954 (CH_3), 1587 (N–C=N), 1512 (aromatic ring skeleton vibration), 1529 (N–C=S), 1346 (NO_2), 1276 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.84 (s, 1H, N–H), 10.30 (s, 1H, CH=N), 8.70 (s, 1H, ArH), 8.69 (m, 1H, ArH), 8.34 (m, 1H, ArH), 7.86 (t, 1H, ArH), 4.51 (s, 1H, O–H), 3.70 (m, 1H, –OCH), 2.82 (t, 2H, J = 6.98 Hz, $–CH_2C$=N), 1.74 (m, 2H, $–CH_2$), 1.09 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.4 (N–C=S), 160.3 (Ph–CH=N), 151.7 (N–C=N), 148.4, 134.5, 134.0, 130.9, 126.7, 122.6, 64.9 (CH), 34.8 (CH_2), 23.5 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 322 (M^+ + 1), 304, 275, 156. Elemental Anal. Calcd for $C_{13}H_{15}N_5O_3S$: C, 48.59; H, 4.70; N, 21.79. Found: C, 48.38; H, 4.77; N, 21.68%.

3-(3-Hydroxybutyl)-4-(2-nitrobenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2h**): Yellow powder, yield: 67%. M.p. 173–175 °C. IR (cm^{-1}): 3328 (OH, NH), 3121 (ArH), 2943 (CH_3), 1576 (N–C=N), 1513 (aromatic ring skeleton vibration), 1499 (N–C=S), 1349 (NO_2), 1281 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.85 (s, 1H, N–H), 10.88 (s, 1H, CH=N), 8.18 (m, 2H, ArH), 7.89 (m, 2H, ArH), 4.47 (s, 1H, O–H), 3.68 (m, 1H, –OCH), 2.80 (t, 2H, J = 7.03 Hz, $–CH_2C$=N), 1.72 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.9 (N–C=S), 160.6 (Ph–CH=N), 151.8 (N–C=N), 149.7, 136.0, 135.4, 130.2, 128.7, 121.9, 64.7 (CH), 34.4 (CH_2), 23.6 (CH_2), 21.3 (CH_3). MS-ESI (*m/z*): 322 (M^+ + 1), 304, 275, 174, 156. Elemental Anal. Calcd for $C_{13}H_{15}N_5O_3S$: C, 48.59; H, 4.70; N, 21.79. Found: C, 48.37; H, 4.75; N, 21.61%.

3-(3-Hydroxybutyl)-4-(4-methoxybenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2i**): Yellow crystals, yield: 65%. M.p. 136–138 °C. IR (cm^{-1}): 3276 (OH, NH), 3085 (ArH), 2942 (CH_3), 1596 (N–C=N), 1518 (aromatic ring skeleton vibration), 1510 (N–C=S), 1259 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.69 (s, 1H, N–H), 9.73 (s, 1H, CH=N), 7.87 (dd, 2H, J_1 = 3.68 Hz, J_2 = 8.79 Hz, ArH), 7.12 (dd, 2H, J_1 = 3.69 Hz, J_2 = 8.79 Hz, ArH), 4.49 (s, 1H, O–H), 3.86 (s, 3H, $–OCH_3$), 3.68 (m, 1H, –OCH), 2.75 (t, 2H, J = 6.92 Hz, $–CH_2C$=N), 1.72 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.12 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 163.9 (N–C=S), 162.9, 161.3 (Ph–CH=N), 151.3 (N–C=N), 130.6, 124.6, 114.7, 64.9 (CH_2), 55.6 (OCH_3), 34.7 (CH_2), 23.4 (CH), 21.3 (CH_3). MS-ESI (*m/z*): 307 (M^+ + 1), 289, 174, 156, 134. Elemental Anal. Calcd for $C_{14}H_{18}N_4O_2S$: C, 54.88; H, 5.92; N, 18.29. Found: C, 54.74; H, 5.85; N, 18.13%.

3-(3-Hydroxybutyl)-4-(2-methoxybenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2j**): Yellow powder, yield: 62%. M.p. 159–161 °C. IR (cm^{-1}): 3325 (OH, NH), 3057 (ArH), 2954 (CH_3), 1604 (N–C=N), 1519 (N–C=S), 1497 (aromatic ring skeleton vibration), 1261 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.72 (s, 1H, N–H), 10.31 (s, 1H, CH=N), 7.90 (m, 1H, ArH), 7.61 (m, 1H, ArH), 7.21 (m, 1H, ArH), 7.11 (m, 1H, ArH), 4.51 (s, 1H, O–H), 3.89 (s, 3H, $–OCH_3$), 3.67 (m, 1H, –OCH), 2.77 (t, 2H, J = 7.01 Hz, $–CH_2C$=N), 1.71 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.18 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 163.1 (N–C=S), 160.8 (Ph–CH=N), 156.1, 151.7 (N–C=N), 132.4, 131.1, 118.9, 115.9, 112.8, 65.1 (CH), 55.2 (OCH_3), 34.5 (CH_2), 23.6 (CH_2), 21.4 (CH_3). MS-ESI (*m/z*): 307 (M^+ + 1), 289, 174, 156. Elemental Anal. Calcd for $C_{14}H_{18}N_4O_2S$: C, 54.88; H, 5.92; N, 18.29. Found: C, 54.69; H, 5.87; N, 18.14%.

3-(3-Hydroxybutyl)-4-(4-hydroxybenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2k**): Yellow crystals, yield: 63%. M.p. 214–216 °C. IR (cm^{-1}): 3144 (OH, NH), 3021 (ArH), 2951 (CH_3), 1587 (N–C=N), 1509 (aromatic ring skeleton vibration), 1497 (N–C=S), 1279 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.66 (s, 1H, N–H), 10.36 (s, 1H, Ar–OH), 9.59 (s, 1H, CH=N), 7.75 (dd, 2H, J_1 = 3.69 Hz, J_2 = 8.61 Hz, ArH), 6.94 (dd, 2H, J_1 = 3.61 Hz, J_2 = 8.61 Hz, ArH), 4.46 (s, 1H, O–H), 3.66 (m, 1H, –OCH), 2.74 (t, 2H, J = 7.02 Hz, $–CH_2C$=N), 1.71 (m, 2H, $–CH_2$), 1.07 (d, 3H, J = 6.12 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 164.6 (N–C=S), 161.7, 161.2 (Ph–CH=N), 151.2 (N–C=N), 130.8, 123.0, 11.0, 64.9 (CH), 34.7 (CH_2), 23.5 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 293 (M^+ + 1), 275, 209, 174, 156. Elemental Anal. Calcd for $C_{13}H_{16}N_4O_2S$: C, 53.41; H, 5.53; N, 19.16. Found: C, 53.30; H, 5.49; N, 19.33%.

3-(3-Hydroxybutyl)-4-(2-hydroxybenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2l**): Yellow powder, yield: 61%. M.p. 155–157 °C. IR (cm^{-1}): 3106 (OH, NH), 3061 (ArH), 2946 (CH_3), 1597 (N–C=N), 1516 (aromatic ring skeleton vibration), 1487 (N–C=S), 1285 (C=S). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.70 (s, 1H, N–H), 10.41 (s, 1H, Ar–OH), 10.15 (s, 1H, CH=N), 7.87 (m, 1H, ArH), 7.44 (m, 1H, ArH), 6.97 (m, 2H, ArH), 4.20 (s, 1H, O–H), 3.67 (m, 1H, –OCH), 2.76 (t, 2H, J = 6.99 Hz, $–CH_2C$=N), 1.72 (m, 2H, $–CH_2$), 1.08 (d, 3H, J = 6.15 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.2 (N–C=S), 160.4, 158.4 (Ph–CH=N), 151.5 (N–C=N), 134.2, 127.3, 119.6, 118.5, 116.7, 64.9 (CH), 34.7 (CH_2), 23.4 (CH_2), 21.3 (CH_3). MS-ESI (*m/z*): 293 (M^+ + 1), 275, 173, 209, 174, 156. Elemental Anal. Calcd for $C_{13}H_{16}N_4O_2S$: C, 53.41; H, 5.53; N, 19.16. Found: C, 53.34; H, 5.49; N, 19.03%.

3-(3-Hydroxybutyl)-4-(4-trifluoromethylbenzylidene)amino-1H-1, 2, 4-triazole-5- thione (**2m**): Yellow powder, yield: 70%. M.p. 172–173 °C. IR (cm^{-1}): 3326 (OH, NH), 3032 (ArH), 2909 (CH_3), 1583 (N–C=N), 1513 (aromatic ring skeleton vibration), 1496 (N–C=S), 1283 (C=S), 1124 ($–CF_3$). ^1H NMR (DMSO-d_6, 300 MHz, ppm): 13.83 (s, 1H, N–H), 10.27 (s, 1H, CH=N), 8.13 (dd, 2H, J_1 = 3.66 Hz, J_2 = 8.16 Hz, ArH), 7.93 (dd, 2H, J_1 = 3.67 Hz, J_2 = 8.18 Hz, ArH), 4.42 (s, 1H, O–H), 3.68 (m, 1H, –OCH), 2.81 (t, 2H, J = 7.01 Hz, $–CH_2C$=N), 1.73 (m, 2H, $–CH_2$), 1.09 (d, 3H, J = 6.12 Hz, $–CH_3$). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 161.4 (N–C=S), 160.7 (Ph–CH=N), 151.8 (N–C=N), 136.2, 132.1, 131.7, 129.1, 126.1($–CF_3$), 64.9 (CH), 34.8 (CH_2), 23.5 (CH_2), 21.2 (CH_3). MS-ESI (*m/z*): 343 (M-1), 173, 172, 170. Elemental Anal. Calcd for $C_{14}H_{15}F_3N_4OS$: C, 48.83; H, 4.39; N, 16.27. Found: C, 48.75; H, 4.31; N, 16.09%.

3-(3-Hydroxybutyl)-4-(4-methylbenzylidene)amino-1H-1, 2, 4-triazole-5-thione (**2n**): Yellow crystals, yield: 62%. M.p. 165–167 °C. IR (cm^{-1}): 3299 (OH, NH), 2921 (CH_3), 1597 (N–C=N), 1490 (aromatic ring skeleton vibration), 1463 (N–C=S), 1262 (C=S). ^{1}H NMR (DMSO-d_6, 300 MHz, ppm): 13.73 (s, 1H, N–H), 9.87 (s, 1H, CH=N), 7.79 (dd, 2H, J_1 = 3.67 Hz, J_2 = 8.07 Hz, ArH), 7.38 (dd, 2H, J_1 = 3.62 Hz, J_2 = 8.07 Hz, ArH), 4.38 (s, 1H, O–H), 3.68 (m, 1H, –OCH), 2.77 (t, 2H, J = 7.02 Hz, –CH_2C=N), 2.40 (s, 3H, Ar–CH_3), 1.71 (m, 2H, –CH_2), 1.08 (d, 3H, J = 6.15 Hz, –CH_3). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 163.7 (N–C=S), 161.3 (Ph–CH=N), 151.5 (N–C=N), 142.9, 129.8, 129.5, 128.6, 64.9 (CH), 34.7 (CH_2), 23.5 (CH_2), 21.3 (CH_3), 21.2(CH_3). MS-ESI (*m/z*): 291 (M^+ + 1), 273, 174, 156. Elemental Anal. Calcd for $C_{14}H_{18}N_4OS$: C, 57.91; H, 6.25; N, 19.29. Found: C, 57.79; H, 6.17; N, 19.06%.

3-(3-Hydroxybutyl)-4-(4-N, N-dimethylaminobenzylidene)amino-1H-1, 2, 4-triazole-5- thione (**2o**): Light yellow powder, yield: 59%. M.p. 182–184 °C. IR (cm^{-1}): 3324 (OH, NH), 3096 (ArH), 2912 (CH_3), 1594 (N–C=N), 1496 (aromatic ring skeleton vibration), 1492 (N–C=S), 1283 (C=S). ^{1}H NMR (DMSO-d_6, 300 MHz, ppm): 13.59 (s, 1H, N–H), 9.39 (s, 1H, CH=N), 7.70 (dd, 2H, J_1 = 3.69 Hz, J_2 = 8.79 Hz, ArH), 6.82 (dd, 2H, J_1 = 3.66 Hz, J_2 = 8.79 Hz, ArH), 3.66 (m, 1H, –OCH), 3.03 (s, 6H, NCH_3), 2.72 (t, 2H, J = 6.98 Hz, –CH_2C=N), 1.71 (m, 2H, –CH_2), 1.09 (d, 3H, J = 6.15 Hz, –CH_3). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 165.2 (N–C=S), 161.3 (Ph–CH=N), 153.2, 151.2 (N–C=N), 130.4, 118.8, 111.6, 65.0 (CH), 39.8 (NCH_3), 34.8 (CH_2), 23.4 (CH_2), 21.3 (CH_3). MS-ESI (*m/z*): 320 (M^+ + 1), 174, 156, 147, 146. Elemental Anal. Calcd for $C_{15}H_{21}N_5OS$: C, 56.40; H, 6.63; N, 21.92. Found: C, 56.28; H, 6.59; N, 21.78%.

3-(3-Hydroxybutyl)-4-(3-methoxy-4-hydroxybenzylidene)amino-1H-1, 2, 4-triazole- 5-thione (**2p**): Yellow powder, yield: 63%. M.p. 181–183 °C. IR (cm^{-1}): 3388 (OH, NH), 3104 (ArH), 2944 (CH_3), 1587 (N–C=N), 1507 (aromatic ring skeleton vibration), 1497 (N–C=S), 1282 (C=S). ^{1}H NMR (DMSO-d_6, 300 MHz, ppm): 13.67 (s, 1H, N–H), 10.01 (Ar–OH), 9.59 (s, 1H, CH=N), 7.48 (s, 1H, ArH), 7.33 (m, 1H, ArH), 6.93 (m, 1H, ArH), 4.55 (s, 1H, –OH), 3.85 (s, 3H, –OCH_3), 3.67 (m, 1H, –OCH), 2.76 (t, 2H, J = 6.99 Hz, –CH_2C=N), 1.72 (m, 2H, –CH_2), 1.08 (d, 3H, J = 6.18 Hz, –CH_3). ^{13}C NMR (DMSO-d_6, 75 MHz, ppm): 164.6 (N–C=S), 161.3 (Ph–CH=N), 151.4, 151.1 (N–C=N), 148.2, 124.3, 123.4, 115.7, 110.5, 64.9 (CH), 55.7 (OCH_3), 34.8 (CH_2), 23.5 (CH_2), 21.3 (CH_3). MS-ESI (*m/z*): 323 (M^+ + 1), 305, 174, 156, 150. Elemental Anal. Calcd for $C_{14}H_{18}N_4O_3S$: C, 52.16; H, 5.63; N, 17.38. Found: C, 51.99; H, 5.56; N, 17.26%.

Biological evaluation

Similar seeds were picked out and rinsed with sterilised distilled water four times, then dipped in distilled water for 3 hours at room temperature. All subsequent manipulations were carried out under a horizontal laminar flow. Twenty seeds of each species were chosen and placed individually in Petri dishes of 9 cm diameter containing two pieces of filter paper and 5 mL solution of the tested compounds **1**, **2a–m** or the blank, and all of them were incubated in a growth chamber at 25 °C, with a natural photoperiod and an uninterrupted supply of sterilised distilled water. Experiments were run in duplicate. Growth measurements were carried out after 7 days.

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