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# ANTI-FUNGAL EVALUATION OF SYNTHESIZED 1,3,5-TRIAZINE DERIVATIVES AGAINST PHYTOPATHOGENIC FUNGI

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## ABSTRACT

**Seven mono-, di- and tri-substituted derivatives of *s*-triazine were synthesized by condensation reaction of *s*-triazine with different aromatic amines at different temperature conditions. The synthesized compounds were characterized by various spectral techniques, *i.e.* $^{1}$HNMR, $^{1}$HNMR-$D_2O$, $^{13}$CNMR, elemental analysis and mass spectrometry and screened for their antifungal activity against *Helminthosporium oryzae, Rhizoctonia solani* and *Alternaria brassicae*. Among all the synthesized triazine derivatives; compounds (5c), (7b) and (5a) were found to be the most effective with $ED_{50}$ values 4, 7 and 9 µg/ml against *H. oryzae, R. solani* and *A. brassicae,* respectively.**

**Keywords:** *Alternaria brassicae*, Antifungal activity, *Helminthosporium oryzae, Rhizoctonia solani,* Triazine derivatives



The chemistry of heterocyclic compounds is an interesting area of research due to their specific chemical reactivity, natural abundance and wide range of applications in coordination compounds, photo sensitizers, dyes, polymeric materials, pharmacology, biology, pharmaceutical and other fields (Utreja *et al.,* 2019; Jain *et al.,* 2021). Nitrogen atom bearing heterocyclic compounds are of immense importance in synthetic organic and medicinal chemistry due to their wide existence as bioactive molecules (Kaur *et al.,* 2019; Anamika *et al*., 2018a). Among nitrogen containing heterocycles, triazine is an important scaffold consisting of benzene ring in which three carbon atoms are substituted by three nitrogen atoms (Utreja *et al.* 2020). The three isomers of triazine are distinguished by positions of their nitrogen atoms in the benzene ring: 1,2,3-triazine; 1,2,4-triazine and 1,3,5-triazine; out of which later is the most common, oldest and extensively studied isomeric form (Arshad *et al.,* 2014, Shah *et al.,* 2014). It is also known as *s*-triazine due to the symmetry of three nitrogen atoms in the ring (Kumar *et al.,* 2017).

Triazine and its derivatives play a vital role in the synthesis of agrochemicals (Kaur *et al.,* 2018; Giacomelli *et al.,* 2004). Most of the triazine herbicides such as Simazine, Anilazine, Cyromazine and Atrazine are formed by simple displacement of chlorine atoms with nucleophiles such as amines (Patel *et al.,* 2012). These herbicides inhibit the photosynthetic electron transport in some plants. Among various medicinal and biological properties of new 1,3,5-triazine derivatives herbicidal (Zhou *et al.,* 2003), insecticidal (Upadhyay *et al.,* 2010), fungicidal (Sharma *et al.,* 2016) , antibacterial (Ringott *et al.,* 2011), anti tomato mosaic virus (TMV) (Pandey *et al.,* 2006) etc. activities may be harnessed in agriculture. During the past several decades, increase of invasive fungal infections have been observed in various agricultural crops leading to yield losses of at least 125 million tons of top five food crops *viz*. rice, wheat, soyabean, potatoes and maize (Vibha *et al.,* 2018; Goyal *et al.* 2018). Plant fungal pathogens also pose a serious threat to human health by deteriorating plant quality and quantity. Among various plant pathogens *Rhizoctonia solani*, *Alternaria brassicae* and *Helminthosporium oryzae* causing sheath blight, brown leaf spot and black spot diseases, respectively (Verma *et al.,* 2019). At least 20% of losses are due to *Alternaria* species and most other losses may reach up to 80% of yield (Wan *et al.,* 2018). *R. Solani* causes sheath blight of rice and has wide host range and may reduce yield up to 50% (Chen and Zhu 2011). However, till now no complete source has been identified to curb this disease, therefore, the management relies on chemical control. The disease caused by *Alternaria* is the major factor responsible for low production of cucurbitaceous, brassicaceous and solanaceous family crops. Brown spot caused by *H. oryzae* occurs in all the rice growing states (Mahlein 2016). The control of these plant diseases is extremely important for achieving high crop productivity (Kaur *et al.,* 2017). Extensive efforts have been made to synthesize new compounds for the management of fungal diseases but due to the problems of rapid development in drug resistance, tolerance and side effects *etc.* (Anamika *et al.,* 2018b; Kaur *et al.,* 2016) it is required to develop promising antifungal agents with improved fungicidal profile. Due to the proficient nature of triazine as an antifungal agent, we have derivatized and evaluated the antifungal potential

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of synthesized 1,3,5-triazine derivatives against *R. solani*, *H. oryzae* and *A. brassicae*.

## MATERIALS AND METHODS

The melting points of synthesized compounds were determined with an Electronics India 934 digital melting point apparatus in open capillaries and were uncorrected. The $^{1}H$ NMR and $^{13}C$ NMR spectra were recorded at 25°C in DMSO-$d_6$ on a Bruker Avance II 400 instrument at 400 and 100 MHz, respectively, using tetramethyl silane (TMS) as an internal standard. The IR spectra were recorded in the range 400 - 4000 $cm^{-1}$ on a Perkin Elmer Spectrum Two-IR Fourier-Transform spectrophotometer from samples prepared as potassium bromide (KBr) pellets. The mass spectrum data were collected using Calimero Instrument operating in ESI mode and elemental analysis (C<H<N) were recorded on FLASH EA 112 (Thermo Electron Corporation) analyzer and the results are quoted in %.

### Synthesis of triazine derivatives (3, 5a-c, 7a-b, 8)

#### *General procedure for the synthesis of mono-substituted triazine derivative (3)*

To the stirring solution of *s*-triazine **(1)** (0.1 mol) in dry acetone (6.0 ml), an aqueous solution of 10% KOH was added at 0-5°C. Further, 2,4-dinitroaniline **(2)** (0.1 mol) dissolved in acetone (10.0 ml) was added dropwise to the above stirring solution and the mixture was continued to stir till the completion of the reaction (monitored with thin layer chromatography (TLC)). After completion of reaction, the reaction mixture was poured onto crushed ice and precipitates so formed were filtered, washed with water and diethyl ether to remove the unreacted amine left in the reaction. Recrystallization from acetone offered the pure product 4,6-dichloro-*N*-(2,4-dinitrophenyl)-1,3,5-triazin-2-amine (3).

#### *General procedure for the synthesis of di-substituted triazine derivatives (5a-c)*

A solution of *s*-triazine (1) (0.1 mol), dissolved in acetone (6.0 ml), was mixed with solution of aromatic amines (4a-c) (0.2 mol) in acetone (6.0 ml) with continuous stirring at room temperature. Further, slow addition of 10% NaOH (4 drops) was made and the reaction mixture was continued to stir till the completion of reaction and was monitored with the help of thin layer chromatography. After completion of reaction, the reaction mixture was poured onto crushed ice and solid so formed was filtered, dried and recrystallization from acetone was furnished to get the pure products (5a-c).

#### *General procedure for the synthesis of tri-substituted triazine derivatives (7a-b)*

To a solution of disubstituted triazine derivative (5a) (0.1 mol), dissolved in dioxane (6.0 ml), solution of aromatic amines (6a-b) (0.1 mol), dissolved in dioxane (3.0 ml), was added. Dropwise addition of an aqueous solution of 10% NaOH (6.0 ml) was made within 2h and refluxed at 80-100°C. On completion of reaction (TLC), mixture so obtained was poured onto crushed ice followed by neutralization with 10% NaOH (pH = 7). Precipitates so formed were filtered, dried and recrystallization from methanol offered the pure products **(7a-b)**.

#### *General procedure for the synthesis of tri-substituted triazine derivative (8)*

A solution of *s*-triazine (1) (0.1 mol) and 4-nitroaniline (4a) (0.3 mol), in acetic acid (20.0 ml), was refluxed at 80-100 °C. After completion of reaction (TLC), the reaction mixture was poured onto crushed ice followed by neutralization with 10% NaOH (pH = 7). The precipitates so formed were filtered and washed with water to remove the unreacted reactants from the crude mixture obtained. Recrystallization from acetone and methanol offered the pure product (8).

### Antifungal activity assay

All the synthesized compounds were evaluated *in vitro* against different fungal pathogens *viz. H. oryzae, R. solani* and *A. brassicae* employing poison food technique. Stock solutions of the synthesized compounds (a.i. basis) were prepared in absolute alcohol. Final concentrations 5, 10, 50, 100, 250 and 500 µg/ml were prepared from the stock solution. The required quantity of individual compound was added to 100 ml sterilized melted PDA medium and the medium was gently shaken along with the compounds. The compounds amended medium was poured in sterilized Petri plates of 90 mm size. After solidification of medium, 5 mm mycelial discs were cut with the help of sterilized cork borer from 7 days old culture of test pathogens and was placed in the center of each Petri plate. The inoculated plates were incubated in the incubator in inverted position. The Petri plates containing unamended medium and inoculated with test pathogens served as control. The fungicides, Propiconazole was taken as standard check against *R. solani and H. oryzae*, whereas, Mancozeb was used as standard against *A. brassicae*. Each treatment was replicated thrice, the inoculated Petri plate were sealed with paraffin' film to minimize the chances of contamination and were incubated at 25±2 °C for 5-7 days. The colony diameter was measured from two perpendicular sides

and the average values were calculated after 5-7 days of incubation. The efficacy of synthesized compounds was expressed as percent inhibition in mycelial growth over control, It was calculated by using the following formula (Dawar *et al.,* 2020):

$$Pi = \frac{C\text{-}T}{C} \times 100$$

Where Pi = Percent inhibition in colony growth, C = Colony growth in control (mm), T = Colony growth in treated test concentration (mm).

The effect of factors, synthesized 'compounds' and 'concentration' and their interaction on percent disease inhibition were analyzed by using CPCS1 software. The $ED_{50}$ value of each compound was also calculated by plotting percent inhibition in colony growth against each concentration of the synthesized compound.

## RESULTS AND DISCUSSION

### Chemistry

The mono-substituted triazine derivatives were synthesized by reaction of *s*-triazine (**1**) with aromatic amine (**2**) in the presence of base KOH at 0 °C to afford the corresponding mono-substituted derivative of triazine (**3**) as shown in scheme 1. All the synthesized derivatives were obtained in good to average yield and their identity was confirmed by various spectral techniques.

### Scheme 1

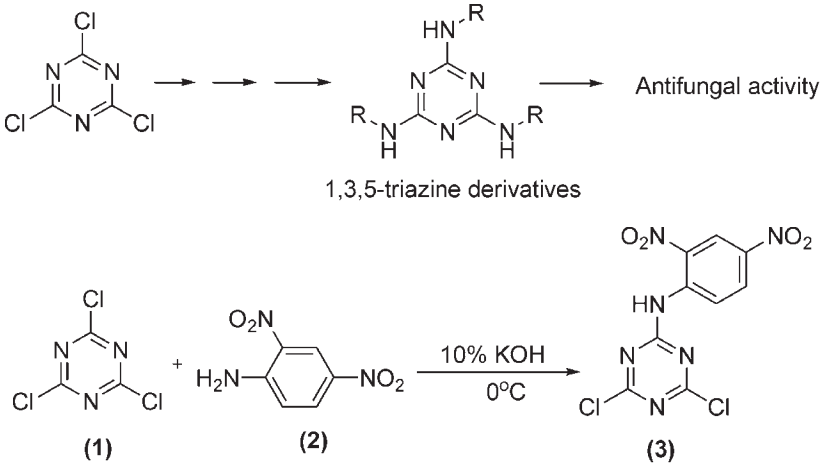
**4,6-Dichloro-*N*-(2,4-dinitrophenyl)-1,3,5-triazin-2-amine (3):** White solid, $R_f$: 0.65 (hexane: ethylacetate/70:30), Yield: 80%, acetone, m.p. 280-282 °C. IR (KBr) $\upsilon_{max}$: 800 (C-Cl str), 1259 (C-N str), 1331 (N-O str), 1405 (C=C str), 1585 (N=O str), 1699 (C=N str) and 3076 (=C-H str) $cm^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 8.05 (d, *J* = 9.16 Hz, 1H, Ar-H), 8.64 (m, 1H, Ar-H), 8.86 (d, *J* = 2.44 Hz, 1H, Ar-H) and 11.40 (bs, 1H, $D_2O$ exchangeable –NH) ppm. $^{13}$CNMR (DMSO-$d_6$, 100 MHz) δ: 119.74, 123.38, 128.63, 129.30, 135.07, 149.79, 149.89 and 171.3 ppm. MS *m/z* 331 ($M^+$). Anal. Calcd for $C_9H_4Cl_2N_6O_4$ (%): C: 32.65, H: 1.22, N: 25.38. Found: C: 32.44, H: 1.47, N: 25.64.

The di-substituted triazine derivatives **(5a-c)** were obtained by stirring solution of triazine **(1)** in acetone with different aromatic amines **(4a-c)** in the presence of base NaOH at room temperature as shown in scheme 2. Considerable variations in nature of substituent (R) were introduced so as to understand the scope and limitation of reaction.

### Scheme 2

**6-Chloro-*N*$^2$, *N*$^4$-*bis*(4-nitrophenyl)-1,3,5-triazin-2,4-diamine (5a):** Grey solid, $R_f$: 0.7 (hexane:ethylacetate/80:20), Yield: 90%, acetone, m.p. 297-300 °C. IR (KBr) $\upsilon_{max}$: 794 (C-Cl str), 1228 (C-N str), 1381 (N-O str), 1425 (C=C str), 1574 (N=O str), 1616 (C=N str) and 3348 (N-H str) $cm^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 7.89-7.91 (m, 4H, Ar-H), 8.30-8.32 (m, 4H, Ar-H), and 11.68 (s, 2H, $D_2O$ exchangeable -NH) ppm. $^{13}$CNMR (DMSO-$d_6$, 100 MHz) δ: 119.63, 122.74, 124.30, 131.10, 137.46, 141.09 and 163.63 ppm. MS *m/z* 388 ($M^+$). Anal. Calcd for $C_{15}H_{10}ClN_7O_4$ (%): C: 46.46, H: 2.60, N: 25.29. Found: C: 46.23, H: 2.43, N: 25.42.

**6-Chloro-*N*$^2$, *N*$^4$-*bis*(4-chlorophenyl)-1,3,5-triazin-2,4-diamine (5b):** Off-white crystalline solid, $R_f$: 0.65 (hexane:ethylacetate/80:20), Yield: 85%, acetone, m.p. 185-188 °C. IR (KBr) $\upsilon_{max}$: 790 (C-Cl str), 1220 (C-N str), 1375 (N-O str), 1417 (C=C str), 1536 (N=O str) and 3394 (N-H str) $cm^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 7.46-7.48 (m, 4H, Ar-H), 7.62-7.65 (m, 4H, Ar-H) and 11.26 (s, 2H, $D_2O$ exchangeable –NH) ppm. $^{13}$CNMR




**Scheme 1. Synthesis of mono-substituted triazine derivatives (3)**

(DMSO-$d_6$, 100 MHz) δ: 122.65, 122.74, 122.84, 127.98, 128.66, 128.73, 129.78, 130.04, 135.75, 135.86, 136.09, 149.81, 153.94, 163.55 and 168.71 ppm. MS *m/z* 366 ($M^+$). Anal. Calcd for $C_{15}H_{10}Cl_3N_5$ (%): C: 49.14, H: 2.75, N: 19.10. Found: C: 49.35, H: 2.36, N: 19.42.

**6-Chloro-*N*$^2$, *N*$^4$-*bis*(4-bromophenyl)-1,3,5-triazin-2,4-diamine (5c):** White solid, $R_f$: 0.65 (hexane:ethylacetate/80:20), Yield: 85%, acetone, m.p. 276-278 °C. IR (KBr) $\upsilon_{max}$: 501 (C-Br str), 789 (C-Cl str), 1228 (C-N str), 1373 (N-O str), 1441 (C=C str), 1587 (N=O str), 1689 (C=N str), 3039 (=C-H str) and 3248 (N-H str) $cm^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 7.49-7.63 (m, 4H, Ar-H), 7.74 (s, 4H, Ar-H) and 9.88 (s, 2H, $D_2O$ exchangeable –NH) ppm. $^{13}$CNMR (DMSO-$d_6$, 100 MHz) δ: 114.42, 115.91, 122.55, 122.78, 131.11, 131.53, 131.73, 136.61, 138.41, 153.98 and 162.14 ppm. MS *m/z* 455 ($M^+$). Anal. Calcd for $C_{15}H_{10}Br_2ClN_5$(%): C: 39.55, H: 2.21, N: 15.37. Found: C: 39.15, H: 2.41, N: 15.12.

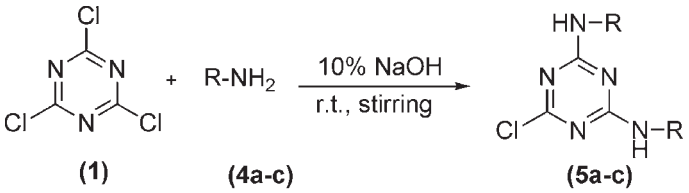
Further, trisubstituted derivatives of triazine were synthesized by two different ways (i) by reacting disubstituted triazine derivative with aromatic amines (ii) by direct reaction of triazine with aromatic amine under reflux conditions.

In the first approach, di-substituted triazine derivative (**5a)** was refluxed with different aromatic amines **(6a-b)** using base NaOH and solvent dioxane at 80-100 °C to furnish the target tri-substituted triazine derivatives **(7a-b)** as outlined in scheme 3. To understand the scope and limitation of reaction considerable variation in electron withdrawing groups (mono and trisubstituted) were introduced and synthesized compounds were isolated in good synthetic yield.

## Scheme 3

***N*$^2$-(2-Chlorophenyl)-*N*$^4$, *N*$^6$-*bis*(4-nitrophenyl)-1,3,5-triazin-2,4,6-triamine (7a):** White solid, $R_f$: 0.72 (hexane:ethylacetate/80:20), Yield: 83%, methanol, m.p. 280-284 °C. IR (KBr) $\upsilon_{max}$: 749 (C-Cl str), 1255 (C-N str), 1314 (N-O str), 1417 (C=C str), 1556 (N=O str), 1605 (C=N str), 3125 (=C-H str) and 3383 (N-H str) $cm^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 7.39-7.85 (m, 4H, Ar-H), 7.97 (d, *J* = 8.5 Hz, 4H, Ar-H), 8.28 (d, *J* = 9.0 Hz, 4H, Ar-H), 10.35 (bs, 2H, $D_2O$ exchangeable –NH) and 10.80 (bs, 1H, $D_2O$ exchangeable –NH) ppm. $^{13}$CNMR (DMSO-$d_6$, 100 MHz) δ: 119.77, 122.96, 123.14, 124.25, 124.93, 125.02, 128.05, 133.75, 135.04, 139.10, 142.44, 144.04, 145.07, 149.70, 154.04, 161.15, 163.96, 165.04, 169.05, 180.17 and 182.79 ppm. MS *m/z* 479 ($M^+$). Anal. Calcd for $C_{21}H_{15}ClN_8O_4$ (%): C: 52.67, H: 3.16, N: 23.40. Found: C: 52.42, H: 3.25, N: 23.26.

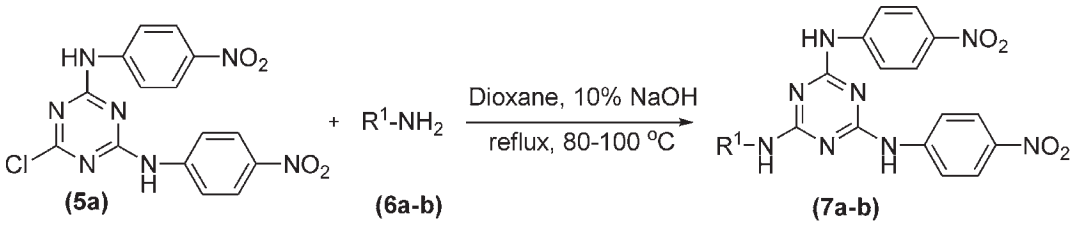
***N*$^2$, *N*$^4$-*bis*(4-Nitrophenyl)-*N*$^6$-(2,4,6-trichlorophenyl)-1,3,5-triazin-2,4,6-triamine (7b):** White solid, $R_f$: 0.68 (hexane:ethylacetate/80:20), Yield: 80%, methanol, m.p. 288-290 °C. IR (KBr) $\upsilon_{max}$: 761 (C-Cl str), 1262 (C-N str), 1332 (N-O str), 1462 (C=C str), 1589 (N=O str), 1697 (C=N str) and 3065 (=C-H str) $cm^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 7.97 (d, *J* = 9.0




(1) (4a-c) (5a-c)

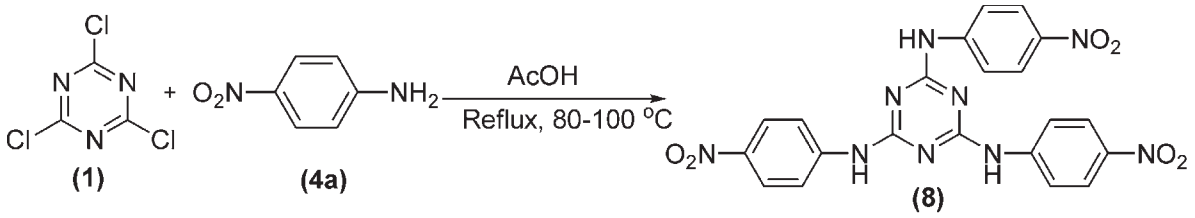
**(4a)**: R-$NH_2$ = 4-nitroaniline
**(4b)**: R-$NH_2$ = 4-chloroaniline
**(4c)**: R-$NH_2$ = 4-bromoaniline

**Scheme 2. Synthesis of di-substituted triazine derivatives (5a-c)**




**(6a)**: $R^1$-$NH_2$ = 2-chloroaniline
**(6b)**: $R^1$-$NH_2$ = 2,3,5-trichloroaniline

**Scheme 3. Synthesis of tri-substituted triazine derivatives (7a-b) from (5a)**




**Scheme 4. Synthesis of tri-substituted triazine derivatives (8) from triazine (1)**

Hz, 4H, Ar-H), 8.20 (d, *J* = 9.0 Hz, 4H, Ar-H), 10.49 (s, 2H, Ar-H) and 13.02 (s, 3H, $D_2O$ exchangeable –NH) ppm. $^{13}$CNMR (DMSO-$d_6$, 100 MHz) δ: 115.24, 116.19, 116.44, 119.75, 123.37, 128.64, 129.27, 129.76, 129.90, 135.07, 145.07 and 149.80 ppm. MS *m/z* 548 ($M^+$). Anal. Calcd for $C_{21}H_{13}Cl_3N_8O_4$ (%): C: 46.05, H: 2.39, N: 20.46. Found: C: 46.30, H: 2.20, N: 20.14.

In second approach for the synthesis of trisubstituted triazine derivatives, acetic acid was added to a solution of *s*-triazine **(1)** and 4-nitroaniline **(4a)** and refluxed for 4 h (Scheme 4). After completion of reaction, reaction mixture was poured onto crushed ice followed by neutralization with 10% NaOH (pH = 7). Precipitates so formed were filtered and washed with water to remove excess of unreacted amine left in the reaction. Recrystallization of crude solid from acetone offered the pure product **(8)**.

## Scheme 4

***N*$^2$, *N*$^4$, *N*$^6$-*tris*(4-Nitrophenyl)-1,3,5-triazin-2,4,6-triamine (8):** Yellow solid, $R_f$: 0.6 (hexane:ethylacetate/70:30), Yield: 88%, acetone, m.p. 270-271 °C. IR (KBr) $\upsilon_{max}$: 794 (C-Cl str), 1239 (C-N str), 1317 (N-O str), 1416 (C=C str), 1551 (N=O str), 1617 (C=N str), 3076 (=C-H str) and 3346 (N-H str) cm$^{-1}$. $^1$HNMR (DMSO-$d_6$, 400 MHz) δ: 7.96 (s, 6H, Ar-H), 8.26 (s, *J* = 9.5 Hz, 6H, Ar-H) and 10.97 (s, 3H, $D_2O$ exchangeable –NH) ppm. $^{13}$CNMR (DMSO-$d_6$, 100 MHz) δ: 120.05, 124.69, 142.24, 144.63, 163.76 and 168.60 ppm. MS *m/z* 489 ($M^+$). Anal. Calcd for $C_{21}H_{13}N_9O_6$ (%): C: 51.54, H: 3.09, N: 25.76. Found: C: 51.25, H: 3.29, N: 25.42.

## Antifungal activity

Triazine **(1)** and its derivatives *viz.* **(3), (5a), (5b), (5c), (7a), (7b)** and **(8)** were evaluated for their *in vitro* antifungal potential against different pathogens *viz. Helminthosporium orzyae*, *Rhizoctonia solani* and *Alternaria brassicae* by employing posion food technique at different concentration levels 5, 10, 50, 100, 250 and 500 µg/ml. The results have also been expressed in terms of $ED_{50}$ values *i.e.* effective dose where 50 percent of inhibition of mycelial growth of pathogens occurs.

The per cent mycelial growth inhibition at different concentrations of tested compounds and $ED_{50}$ values in case of *H. orzyae* were calculated and are represented in Table 1. Order of ranking of antifungal potential of all synthesized compounds against *H. oryzae* is Propiconazole > **(5c)** > **(8)** > **(3)** > **(5a)** > **(7a)** > **(7b)** > **(5b)** > Triazine. It revealed that 6-chloro-*N*$^2$, *N*$^4$-*bis*(4-bromophenyl)-1,3,5-triazin-2,4-diamine (**5c**) displayed maximum efficacy with $ED_{50}$ value of 4 **µg**/ml while triazine **(1)** was found to be least effective with $ED_{50}$ value of 230 **µg**/ml which was very high as compared to the standard check (Propiconazole).

The per cent mycelial inhibition and $ED_{50}$ values in case of *R. solani* are represented in Table 2. Perusal of Table 2 reveals that, in case of *R. solani* order of ranking of all synthesized compounds for their fungicidal action was Propiconazole > **(7b)** > **(8)** > **(5a)** > **(5c)** > Triazine **(1)** > **(7a)** > **(3)** > **(5b)**, so clearly compound (**7b**) was found to be most effective ($ED_{50}$ = 7 µg/ml) followed by (**8**) with $ED_{50}$ value 8 µg/ml. Compound (**7a**) exhibited very weak fungicidal action with the highest $ED_{50}$ value of 184 µg/ml amongst all the screened compounds.

Table 3 displays the results of per cent mycelial inhibition of colony growth and $ED_{50}$ values in case of *A. brassicae*. Decreasing order of $ED_{50}$ values of all synthesized triazine derivatives against *A. brassicae* was as follows: Mancozeb (75WG) > (**5a**) > (**5b**) > (**5c**) > (**7b**) > (**7a**) > (**8**) > (**3**) > Triazine (**1**). It can therefore be concluded that compound (**5a**) exhibited maximum fungicidal potential against *A. brassicae* with $ED_{50}$ value 9 µg/ml while triazine displayed lowest efficacy amongst all as its $ED_{50}$ value was found to be very high *i.e.* 258 µg/ml.

To summarize, evaluation of the antifungal activity of the synthesized compounds showed that halogen-substituted derivatives are more efficient against fungi. It is clear that all the compounds exhibited concentration dependent behavior in their evaluation against each fungi *i.e.* maximum fungicidal potential was shown by the compounds at the highest concentration (500 **µg**/ml) and their efficacy decreased as the concentration was decreased. Among all the synthesized triazine derivatives; (**5c**), (**7b**) and (**5a**) were found to be most effective compounds against *H. oryzae, R, solani* and *A. brassicae*, respectively with 100% mycelial growth inhibition at concentration level 500 µg/ml with $ED_{50}$ values 4, 7 and 9 µg/ml, whereas compound (**3**),

**Table 1. Effect of different concentrations of triazine (1) and its derivatives (3, 5a-c, 7a-b, 8) on the mycelial growth of *H. oryzae***

| Compound No. | Per cent mycelial growth inhibition | | | | | | |
|---|---|---|---|---|---|---|---|
| | Concentration (µg/ml) | | | | | | |
| | 5 | 10 | 50 | 100 | 250 | 500 | $ED_{50}$ |
| (3) | 46.29 | 49.24 | 59.04 | 62.62 | 72.69 | 100.00 | 13 |
| (5a) | 35.01 | 47.29 | 58.57 | 65.68 | 78.31 | 82.28 | 13 |
| (5b) | 30.26 | 36.58 | 47.97 | 63.06 | 77.30 | 100.00 | 83 |
| (5c) | 56.28 | 62.05 | 67.46 | 73.03 | 80.82 | 100.00 | 4 |
| (7a) | 44.71 | 48.31 | 64.19 | 66.47 | 67.86 | 85.16 | 14 |
| (7b) | 46.85 | 49.09 | 64.63 | 80.37 | 83.88 | 100.00 | 20 |
| (8) | 50.22 | 52.46 | 66.96 | 68.42 | 72.69 | 100.00 | 5 |
| Triazine (1) | 5.23 | 32.45 | 36.36 | 38.97 | 51.66 | 76.94 | 230 |
| Propiconazole | - | - | - | 100.00 | - | - | 2 |
| CD (5 %) | 1.71 | 2.22 | 3.95 | 2.14 | 1.29 | 0.91 | -- |

**Table 2. Effect of different concentrations of triazine (1) and its derivatives (3, 5a-c, 7a-b, 8) on the mycelial growth of *R. solani***

| Compound No. | Per cent mycelial growth inhibition | | | | | | |
|---|---|---|---|---|---|---|---|
| | Concentration (µg/ml) | | | | | | |
| | 5 | 10 | 50 | 100 | 250 | 500 | $ED_{50}$ |
| (3) | 5.27 | 7.15 | 12.54 | 16.40 | 73.81 | 98.68 | 188 |
| (5a) | 40.10 | 45.95 | 61.19 | 70.44 | 79.66 | 100.00 | 21 |
| (5b) | 1.24 | 1.86 | 4.61 | 12.73 | 23.81 | 34.59 | 350 |
| (5c) | 13.53 | 45.72 | 58.45 | 70.06 | 81.20 | 100.00 | 23 |
| (7a) | 12.80 | 16.13 | 20.10 | 27.40 | 67.71 | 86.92 | 184 |
| (7b) | 36.69 | 69.66 | 71.45 | 85.23 | 86.54 | 100.00 | 7 |
| (8) | 47.07 | 52.31 | 71.79 | 74.79 | 88.76 | 100.00 | 8 |
| Triazine (1) | 29.23 | 52.73 | 49.37 | 55.28 | 100.00 | 100.00 | 55 |
| Propiconazole | - | - | - | 100.00 | - | - | 5 |
| CD (5 %) | 1.48 | 1.27 | 2.01 | 2.93 | 3.57 | 1.69 | -- |

**Table 3. Effect of different concentrations of triazine (1) and its derivatives (3, 5a-c, 7a-b, 8) on the mycelial growth of *A. brassicae***

| Compound No. | Per cent mycelial growth inhibition | | | | | | |
|---|---|---|---|---|---|---|---|
| | Concentration (µg/ml) | | | | | | |
| | 5 | 10 | 50 | 100 | 250 | 500 | $ED_{50}$ |
| (3) | 11.15 | 20.14 | 29.39 | 37.97 | 53.47 | 80.25 | 217 |
| (5a) | 38.08 | 52.31 | 63.70 | 69.43 | 72.95 | 100.00 | 9 |
| (5b) | 40.59 | 50.18 | 68.94 | 81.49 | 90.18 | 100.00 | 10 |
| (5c) | 32.50 | 40.59 | 52.85 | 68.46 | 81.76 | 100.00 | 40 |
| (7a) | 12.83 | 30.56 | 37.26 | 64.79 | 72.17 | 88.06 | 73 |
| (7b) | 17.22 | 28.51 | 35.73 | 81.68 | 85.45 | 100.00 | 65 |
| (8) | 11.15 | 20.14 | 36.48 | 52.05 | 69.91 | 89.03 | 93 |
| Triazine (1) | 16.62 | 24.64 | 31.90 | 37.95 | 49.06 | 79.79 | 258 |
| Mancozeb | 76.50 | 80.76 | 82.43 | 96.90 | 100.00 | 100.00 | 2 |
| CD (5%) | 1.85 | 2.01 | 2.32 | 1.81 | 2.35 | 2.22 | -- |

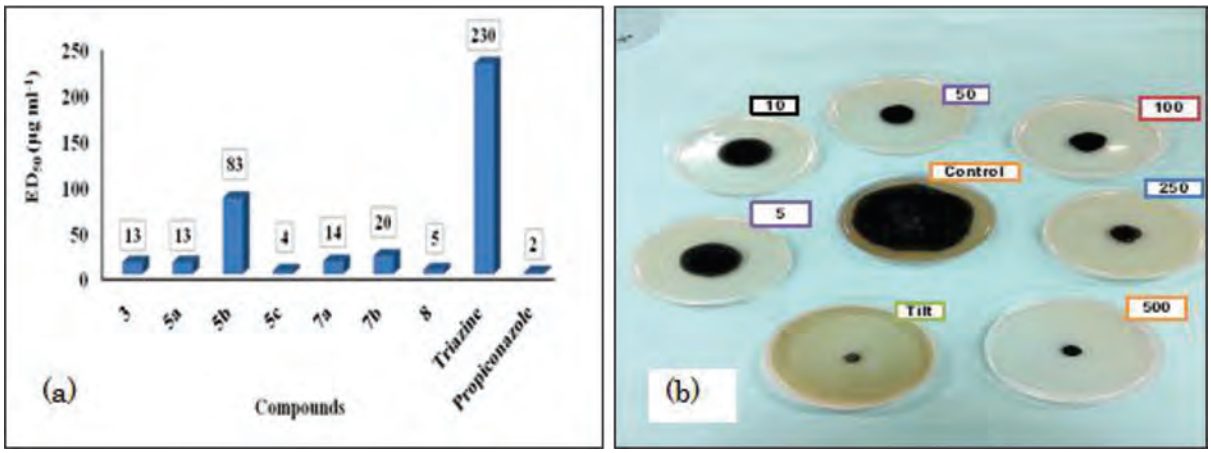



**Fig. 1(a). $ED_{50}$ values of triazine and its derivatives against *H. oryzae* (b) Pictorial presentation of compound (5c) showing best activity at different concentrations.**

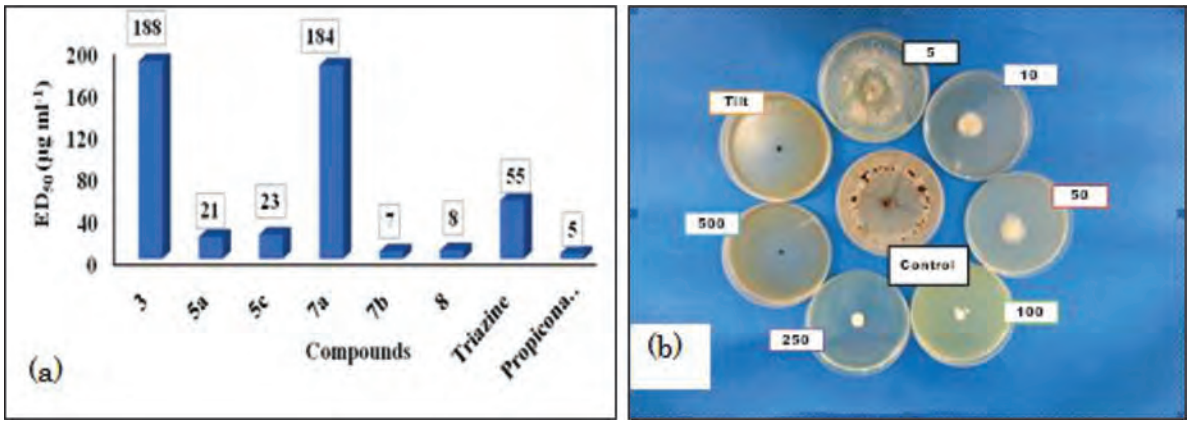



**Fig. 2. (a) $ED_{50}$ values of triazine and its derivatives against *R. solani* (b) Pictorial presentation of compound (7b) showing best activity at different concentrations.**

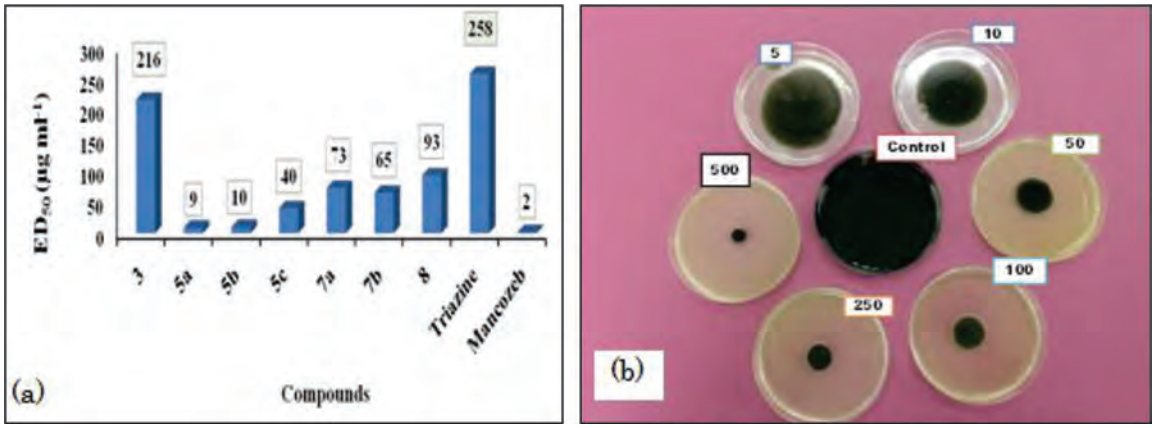



**Fig. 3(a). $ED_{50}$ values of triazine and its derivatives against *A. brassicae* (b) Pictorial presentation of compound (5a) showing best activity at different concentrations.**

triazine (**1**) was found to be least effective with $ED_{50}$ values 188, 230 and 258 µg/ml respectively. However, none of the compounds was found to be equally or more effective than the standard checks Propiconazole and Mancozeb.

## Authors' contribution

Conceptualization and designing of research work (DU, RR); Execution of field/lab experiments and data collection (KK); Analysis of data and interpretation (KK, DU, RR); Preparation of manuscript (KK, DU, RR)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