PHYTOCHEMICAL PROFILE OF N-HEXANE FLOWER EXTRACT OF CASSIA FISTULA L.

MALIK FH FERDOSI*, ARSHAD JAVAID1 AND IQRA HAIDER KHAN1

Department of Horticulture, Faculty of Agricultural Sciences, University of the Punjab, Quaid-e-Azam Campus, Lahore 54590, Pakistan

Keywords: Cassia fistula, Flower extract, GC-MS analysis, n-hexane

Abstract

Flowers of Cassia fistula L. were collected from Lahore, Pakistan and extracted in methanol followed by separation of n-hexane soluble compounds in a separating funnel. The separated n-hexane phase was analyzed by GC-MS for identification of various possible phytochemicals. Among the 31 identified compounds, the predominant compound in this fraction was butanoic acid, methyl ester with 17.81% peak area followed by 3-eicosene, (E)- (6.83%), 2-ethylformanilide (6.59%), naphthalene (6.10%), trifluoroacetoxy hexadecane (5.88%), 5-octadecene, (E)- (5.58%), phenylethanalamine (5.09%), 1-hexene-3,5-dione (4.68%) tetratetracontane (3.42%), which were ranked as moderately abundant compounds. Eleven compounds including benzenembutanamine (3.80%), heptadecyl trifluoroacetate (3.65%), heptadecane (3.08%), octadecyl trifluoroacetate (2.30%), 2-pyridolidone, 1-methyl- (1.78%), 1-undecanol (1.64%), ethylene glycol, O.O-di(pivaloyl)- (1.48%), benzyl alcohol (1.38%), hexadecanoic acid, 15-methyl-, methyl ester (1.32%), 1-docosene (1.27%) and heneicosane (1.25%), with their peak areas between 1 and 4% were categorized as less abundant compounds. The remaining 9 compounds with peak areas less than 1% were categorized as least abundant or minor compounds.

Pakistan is rich in a variety of medicinal plants possibly because of diverse climatic zones ranging from arid and semi-arid to temperate and tropical. Around 2000 plant species from Pakistan are known to be medically important (Ullah 2017). Need for medicinal plants is increasing all over the world due to recognition of natural products. These plants and their products are gaining popularity because of low toxicity, availability, low cost and pharmacologically effectiveness as compared to synthetic drugs (Saet et al. 2007). About 40% of drugs, including those to cure cancer, approved during the last 20 years are of natural origin. At present China, France, Italy Japan, UK and USA are the major international markets of medicinal plants trade. Keeping in view the present increase in medicinal plants trade, it is estimated that this trade will reach to $5 trillion by 2050 (Ullah 2017). Many recent studies have shown that plants of Pakistan namely Datura metel L. (Jabeen et al. 2022), Melia azedarach L. (Akbar et al. 2022), Sonchus oleraceous L. (Banaras et al. 2020), Chenopodium quinoa Willd. (Khan and Javaid 2020) and Chenopodium murale L. (Naqvi et al. 2020) contain a variety of potent biologically active compounds.

Golden shower (Cassia fistula L.) is a slow growing tree species belonging to Fabaceae. It is native to Indian Subcontinent. Now it has been distributed in various countries like Bangladesh, Brazil, China, East Africa, Mauritius, Mexico, Nepal, South Africa and West Indies and is being cultivated as an ornamental tree (Bhalodia et al. 2012). It is a very useful plant from medicinal and pharmacological point of view as all parts of this plant have shown various biological activities (Sharma et al. 2020; Ferdosi et al. 2021, 2022). All parts of this plant are known to be used to cure diarrhea and intestinal disorders (Biswa and Ghosh 1973). It also has therapeutic value and exerts

*Author for correspondence: <malikferdosi@yahoo.com>. 1Department of Plant Pathology, Faculty of Agricultural Sciences, University of the Punjab, Quaid-e-Azam Campus, Lahore54590, Pakistan.
analgesic and antipyretic effects (Patel et al. 1965). Bark extract possesses antioxidant, antibacterial and anti-inflammatory activities (Ilavarasan et al. 2005, Chaerunisaa et al. 2020). Leaf extract of C. fistula exhibits hepatoprotective, antimicrobial, hypoglycemic and wound healing properties (Bhakta et al. 1998, 1999). Fruits, flowers and seeds have been used to treat various ailments such as abdominal pain, fever, and skin diseases (Bahorun et al. 2005). Duraipandiyann et al. (2011) isolated a compound rhein from flowers of C. fistula that exhibited significant larvicidal and antifeedant potential against Helicoverpa armigera. Studies regarding phytochemical analysis and bioactivities of C. fistula from Pakistan are very few. Therefore, the present study was undertaken to explore phytochemical profile of n-hexane fraction of methanolic leaf extract of C. fistula through GC-MS analysis.

Flowers of C. fistula were collected from Lahore, Pakistan during May 2020. The collected flowers were shade dried and 50 g dry material was soaked in 200 ml of methanol for two weeks. After filtration, methanol was evaporated on a rotary evaporator and the obtained biomass was mixed in 100 ml water. This mixture was partitioned with 100 ml n-hexane in a separating funnel. Once the two layers were completely differentiated, the n-hexane layer was separated, filtered and preserved for identification of the compounds through GC-MS analysis.

GC-MS analysis was carried out on a gas chromatograph (GC) machine model 7890B, Agilent Technologies (USA), assembled with mass spectroscopy (MS) machine model 5977, Agilent Technologies (USA), for the identification of different compounds from the sample. The column used was DB 5 MS (30 m × 0.25 μm × 0.25 μm). Injection volume was 1 μl and carrier gas was helium. Oven ramping; initial temperature was 80°C and then raised 10°C per min up to 300°C. Inlet temperature was 280°C. MS conditions were as mode: scan 50...500, the source temperature was 230°C and quadrupole temperature was 150°C. Chemical compounds were identified by comparison of their spectra with library and arranged in the ascending order of their retention times and retention indices. The relative abundance was reported by using their peak areas.

GC-MS chromatogram of n-hexane fraction of methanolic flower extract of C. fistula exhibited the presence of 31 compounds (Fig. 1). Details of these compounds such as retention time, peak area percentages, molecular formulae and molecular weights are presented in Table 1. The predominant compound in this fraction was butanoic acid, methyl ester with 17.81% peak area. This compound belongs to fatty acids methyl ester group. Mostly members of this group possess antifungal, antibacterial (Suresh et al. 2014, Ali et al. 2017), and insecticidal activities (de Meloa et al. 2018). Fatty acids methyl ester namely methyl olate, methyl linoleate and methyl palmitate of vegetable oils reduced growth of Paracoccidioides spp. (Pinto et al. 2017).

Eight compounds namely phenylethanolamine (5.09%), 5-octadecene, (E)- (5.58%), naphthalene (6.10%), 3-eicosene, (E)- (6.83%), trifluoracetoxo hexadecane (5.88%), tetratetracontane (3.42%), 2-ethylformanilide (6.59%) and 1-hexene-3,5-dione (4.68%) were ranked as moderately abundant compounds with their peak areas from 4 to 7% (Table 1). Naragani et al. (2016) identified 5-octadecene, (E)- from secondary metabolites of Streptomyces cheonanensis with strong antimicrobial potential against Escherichia coli, Staphylococcus epidermis, S. aureus, Penicillium citrinum and Aspergillus flavus. Similarly, naphthalene was isolated from a medicinal plant Mussaenda frondosa with potent insecticidal properties (Vadivel and Gopalakrishnan 2011). Balachandar et al. (2018) reported that 3-eicosene, (E)- found to be very effective against E. coli, P. aeruginosa, B. subtilis, B. circulans and S. aureus. Likewise, 1-hexene-3,5-dione was identified from the extracts of Quercus crassifolia and tested against bacterial pathogens where it showed the best antibacterial potential against Streptococcus thermophilus, Lactobacillus bulgaricus and E. coli (Valencia-Avilés et al. 2019).
Table 1. Compounds identified in n-hexane fraction of methanolic flower extract of *C. fistula* through GC-MS analysis.

| Sl. No. | Names of compounds                                     | Molecular formula | Molecular weight | Retention time (min) | Peak area (%) |
|---------|--------------------------------------------------------|-------------------|------------------|----------------------|---------------|
| 1       | Decane                                                 | C\textsubscript{10}H\textsubscript{22} | 142.28           | 4.983                | 0.62          |
| 2       | Benzyl alcohol                                         | C\textsubscript{8}H\textsubscript{10}O | 108.14           | 5.492                | 1.38          |
| 3       | 2-Pyrrolidinone, 1-methyl-                             | C\textsubscript{5}H\textsubscript{9}NO | 99.13            | 5.568                | 1.78          |
| 4       | Benzene, 1,2-diethyl-                                  | C\textsubscript{10}H\textsubscript{14} | 134.22           | 5.812                | 0.90          |
| 5       | Aniline, N-methyl-                                    | C\textsubscript{6}H\textsubscript{8}N | 107.15           | 5.941                | 0.71          |
| 6       | Benzene, 4-ethyl-1,2-dimethyl-                          | C\textsubscript{10}H\textsubscript{14} | 134.22           | 6.208                | 0.63          |
| 7       | Benzene, 1,2,4,5-tetramethyl-                           | C\textsubscript{10}H\textsubscript{14} | 134.22           | 6.715                | 0.62          |
| 8       | 1-Undecanol                                            | C\textsubscript{11}H\textsubscript{23}O | 172.31           | 7.642                | 1.64          |
| 9       | Naphthalene                                            | C\textsubscript{10}H\textsubscript{8} | 128.17           | 7.729                | 6.10          |
| 10      | 1-Hexadecanol                                          | C\textsubscript{16}H\textsubscript{32}O | 242.44           | 10.391               | 3.42          |
| 11      | Hexadecane                                             | C\textsubscript{16}H\textsubscript{34} | 226.44           | 10.492               | 0.72          |
| 12      | Pentadecane                                            | C\textsubscript{15}H\textsubscript{32} | 212.41           | 11.768               | 0.90          |
| 13      | Phenylethanolamine                                     | C\textsubscript{10}H\textsubscript{11}NO | 137.08           | 11.868               | 5.09          |
| 14      | 5-Octadecene, (E)-                                    | C\textsubscript{15}H\textsubscript{36} | 252.5            | 12.90                | 5.58          |
| 15      | Heneicosane                                            | C\textsubscript{22}H\textsubscript{44} | 296.6            | 14.129               | 1.25          |
| 16      | 3-Eicosene, (E)-                                      | C\textsubscript{20}H\textsubscript{40} | 280.5            | 15.160               | 6.83          |
| 17      | Heptacosane                                            | C\textsubscript{27}H\textsubscript{56} | 307.03           | 16.265               | 0.77          |
| 18      | Ethylene glycol, O,O-di(pivaloyl)-                      | C\textsubscript{23}H\textsubscript{46}O \textsubscript{4} | 330.3           | 16.375               | 1.48          |
| 19      | Hexadecanoic acid, 15-methyl-, methyl ester            | C\textsubscript{18}H\textsubscript{36}O \textsubscript{2} | 284.47          | 16.512               | 1.32          |
| 20      | Trifluoroacetoxyl hexadecane                           | C\textsubscript{23}H\textsubscript{37}F\textsubscript{3}O \textsubscript{2} | 338.4            | 17.210               | 5.88          |
| 21      | Cyclooctene, 1,2-dimethyl-                              | C\textsubscript{18}H\textsubscript{38} | 138.5            | 18.152               | 0.67          |
| 22      | Heptadecyl trifluoroacetate                            | C\textsubscript{27}H\textsubscript{37}F\textsubscript{3}O \textsubscript{2} | 352.47          | 19.077               | 3.65          |
| 23      | Heptadecane                                            | C\textsubscript{17}H\textsubscript{36} | 240.46           | 19.127               | 3.08          |
| 24      | Hexacosane                                             | C\textsubscript{26}H\textsubscript{54} | 366.7            | 19.99                | 4.05          |
| 25      | Octadecyl trifluoroacetate                             | C\textsubscript{26}H\textsubscript{37}F\textsubscript{3}O \textsubscript{2} | 366.50          | 20.796               | 2.30          |
| 26      | Tetrahexaoctane                                        | C\textsubscript{26}H\textsubscript{50} | 619.2            | 20.838               | 4.32          |
| 27      | Benzenoheptane                                         | C\textsubscript{10}H\textsubscript{14}N | 121.17           | 20.962               | 3.80          |
| 28      | Butanoic acid, methyl ester                            | C\textsubscript{2}H\textsubscript{10}O \textsubscript{2} | 102.13          | 21.788               | 17.81         |
| 29      | 2-Ethylformanilide                                     | C\textsubscript{6}H\textsubscript{11}NO | 149.19           | 21.907               | 6.59          |
| 30      | 1-Undecosene                                           | C\textsubscript{22}H\textsubscript{44} | 308.58           | 22.379               | 1.27          |
| 31      | 1-Hexene-3,5-dione                                     | C\textsubscript{6}H\textsubscript{10}O \textsubscript{2} | 112.12           | 23.340               | 4.68          |
Table 2. Properties of compounds identified in \textit{n}-hexane fraction of methanolic flower extract of \textit{C. fistula} as reported in the literature.

| Sl. No. | Names of compounds | Bioactivity | Reference |
|---------|--------------------|-------------|-----------|
| 1       | Decane             | Antimicrobial | Ubaid \textit{et al.} (2016) |
| 2       | Benzyl alcohol     | Anti-inflammatory, antimicrobial and antioxidant | Shaaban \textit{et al.} (2012) |
| 3       | 2-Pyrrolidinone, 1-methyl- | Pesticidal | Deb and Kumar (2019) |
| 4       | Benzene, 1,2-diethyl- | Unknown | | |
| 5       | Aniline, N-methyl- | Unknown | | |
| 6       | Benzene, 4-ethyl-1,2-dimethyl- | Larvicidal | Ojewumi \textit{et al.} (2017) |
| 7       | Benzene, 1,2,4,5-tetramethyl- | Unknown | | |
| 8       | 1-Undecanol        | Antioxidant | Qader \textit{et al.} (2012) |
| 9       | Naphthalene        | Insecticidal | Vadivel and Gopalakrishnan (2011) |
| 10      | 1-Hexadecanol      | Antioxidant | Amudha \textit{et al.} (2018) |
| 11      | Hexadecane         | Antioxidant, antibacterial and antifungal | Arora \textit{et al.} (2017) |
| 12      | Pentadecane        | Antibacterial | Arora \textit{et al.} (2017) |
| 13      | Phenylethanolamine | Unknown | | |
| 14      | 5-Octadecene, (E)- | Antimicrobial | Naragani \textit{et al.} (2016) |
| 15      | Heneicosane        | Antimicrobial | Vanitha \textit{et al.} (2020) |
| 16      | 3-Eicosene, (E)-   | Antibacterial | Balachandar \textit{et al.} (2018) |
| 17      | Heptacosane        | Antibacterial | Konovalova \textit{et al.} (2013) |
| 18      | Ethylene glycol, O,O-di(pivaloyl)- | Unknown | | |
| 19      | Hexadecanoic acid, 15-methyl-, methyl ester | Antioxidant | Prabhu \textit{et al.} (2018) |
| 20      | Trifluoroacetoxy hexadecane | Antifungal | Ibrahim \textit{et al.} (2017) |
| 21      | Cyclooctene, 1,2-dimethyl- | Unknown | | |
| 22      | Heptadecyl trifluoroacetate | Antimicrobial | Thekkangil and Suchithra, (2020) |
| 23      | Heptadecane        | Antifungal | Amudha \textit{et al.} (2018) |
| 24      | Hexacosane         | Antibacterial and antifungal | Devender and Ramakrishna, (2017) |
| 25      | Octadecyl trifluoroacetate | Unknown | | |
| 26      | Tetratetracontane  | Antioxidant and cytoprotective activities | Amudha \textit{et al.} (2018) |
| 27      | Benzenebutanamine  | Anticancer | Gromek \textit{et al.} (2016) |
| 28      | Butanoic acid, methyl ester | Antimicrobial | Abdelillah \textit{et al.} (2013) |
| 29      | 2-Ethylformanilide | Unknown | | |
| 30      | 1-Docosene         | Antibacterial | Kumar \textit{et al.} (2011) |
| 31      | 1-Hexene-3,5-dione | Antibacterial | Valencia-Avilés \textit{et al.} (2019) |
Compounds with their peak areas between 1 and 4% were categorized as less abundant compounds. These included benzyl alcohol (1.38%), 2-pyrrolidinone, 1-methyl- (1.78%), 1-undecanol (1.64%), heneicosane (1.25%), ethylene glycol, O,O-di(pivaloyl)- (1.48%), hexadecanoic acid, 15-methyl-, methyl ester (1.32%), heptadecyl trifluoroacetate (3.65%), heptadecane (3.08%), octadecyl trifluoroacetate (2.30%), benzenebutanamine (3.80%) and 1-docosene (1.27%) (Table 1). Recently, 2-pyrrolidinone, 1-methyl- was isolated from the essential oils of Artemisia annua with excellent pesticidal activity against a stored grain pest Tribolium castaneum (Deb and Kumar 2019). Similarly, Vanitha et al. (2020) identified the heneicosane from the leaf extracts of Plumbago zeylanica and tested it against a wide range of fungal and bacterial pathogens. The findings revealed the highest inhibitory potential against A. fumigatus and S. pneumoniae.

The least abundant compounds with peak areas less than 1% included decane (0.62%), benzene, 1,2-diethyl- (0.90%), aniline, N-methyl- (0.71%), benzene, 4-ethyl-1,2-dimethyl- (0.63%), benzene, 1,2,4,5-tetramethyl- (0.62%), hexadecane (0.72%), pentadecane (0.9%), heptacosane (0.77%) and Cyclooctene, 1,2-dimethyl- (0.67%) (Table 1). Decane was isolated from the extracts of Camponotus fellah (Ubaid et al. 2016) whereas, hexadecane and pentadecane were identified from the extracts of Cenchrus setigerus (Arora et al. 2017) where they exhibited antimicrobial activities against many pathogens. Similarly, Ojewumi et al. (2017) worked on
lemon grass and reported the presence of benzene, 4-ethyl-1,2-dimethyl- which is used on commercial scale in the formulation of mosquito repellent creams.

It may be concluded from the present study that n-hexane fraction of flower extract of *C. fistula* is a rich source of bioactive compounds. Most of the compounds in this fraction namely Hexadecane; 5-Octadecene, (E)-; butanoic acid, methyl ester; 1-Hexene-3,5-dione and heptadecyl trifluoracetate, possess antimicrobial properties. However, some compounds are also antioxidant (hexadecanoic acid, 15-methyl-, methyl ester), anticancer (benzenebutanamine), anti-inflammatory (benzyl alcohol), pesticidal (2-pyrrrolidinone, 1-methyl-) and larvicidal (benzene, 4-ethyl-1,2-dimethyl- in nature.

References

Akbar M, Javaid A, Khalil T and Iqbal MS 2022. Isolation of herbicidal compounds from *Melia azedarach* L. to control *Rumex dentatus* L. weed in wheat. Allelopath. J. 55(2): 163-176.

Ali A, Javaid A and Shoaib A 2017. GC-MS analysis and antifungal activity of methanolic root extract of *Chenopodium album* against *Sclerotium rolfsii*. Planta Daninha 35: Article ID e017164713

Amudha P, Jayalaksmi M, Pushpabarathi N and Vanitha V 2018. Identification of bioactive components in *Enhalus acoroides* seagrass extract by Gas Chromatography–Mass Spectrometry. Asian J. Pharm. Clin. Res. 11: 131-137.

Arora S, Kumar G and Meena S 2017. GC-MS analysis of bioactive compounds from the whole plant hexane extract of *Cenchrus setigerus* Vahl. Pharma Sci. Monit. 8: 137-146.

Bahoran T, Neergheen VS and Aruoma OI 2005. Phytochemical constituents of *Cassia fistula*. Afr. J. Biotechn. 4: 1530-1540.

Balachandar R, Karmegam N, Saravanan M, Subbaiya R and Gurumoorthy P 2018. Synthesis of bioactive compounds from vermicastr isolated *Actinomycetes* species and its antimicrobial activity against human pathogenic bacteria. Microb. Pathog. 121: 155-165.

Banaras S, Javaid A and Khan IH 2020. Potential antifungal constituents of *Sonchus oleraceus* against *Macrophomina phaseolina*. Int. J. Agric. Biol. 24(5): 1376-1382.

Bhakta T, Mukherjee PK, Mukherjee K and Pal M 1998. Studies on *in vivo* wound healing activity of *Cassia fistula* linn. Leaves (Leguminosae) in rats, Nat. Prod. Sci. 4: 84-87.

Bhakta T, Mukherjee PK, Mukherjee K, Banerjee S, Mandal SC, Maity TK, Pal M and Saha BP 1999. Evaluation of hepatoprotective activity of *Cassia fistula* leaf extract. J. Ethnopharmacol. 66: 277-282.

Bhalodia NR, Nariya PB, Acharya RN and Shukla VI 2012. *In vitro* antibacterial and antifungal activities of *Cassia fistula* Linn. fruit pulp extracts. Ayu 33: 123-129.

Biswas K and Ghosh AB 1973. Advancement of learning. Vol. 2. Calcutta India: Calcutta University. Bharatia Banawasadih p. 336.

Chauhanisaa AY, Susilawatib Y, Muhamince M, Milandab T, Hendrianid R and Subaranaas A 2020. Antibacterial activity and subchronic toxicity of *Cassia fistula* L. barks in rats. Toxicol. Rep. 7: 649-657.

de Meloa AR, Garciaa IJP, Serrãob JE, Santosa HL, Limaa LARS and Alves SN 2018. Toxicity of different fatty acids and methyl esters on *Culex quinquefasciatus* larvae. Ecotoxicol. Environ. Saf. 154: 1-5.

Deb M and Kumar D 2019. Chemical composition and bioactivity of the essential oils derived from *Artemisia annua* against the red flour beetle. Biosci. Biotechnol. Res. Asia 16: 463-476.

Devender R and Ramakrishna H 2017. GC-MS analysis of bioactive compounds in methanolic extract of *Leucas lavandulaefolia* Rees. A potential folklore medicinal plant. J. Pharmacogn. Phytochem. 6: 405-406.

Duraipandiyavan V, Ignacimuthu S and Paulraj MG 2011. Antifeedant and larvicidal activities of Rhein isolated from the flowers of *Cassia fistula* L. Saudi J. Biol. Sci. 18: 129-133.

Ferdosi MFH, Javaid A, Khan IH, Ahmad S, Shad N, (2021). Analysis of n-butanol flower extract of *Cassia fistula* through GC-MS and identification of antimicrobial compounds. Pak. J. Phytopathol. 33(1): 103-107.
Ferdosi MFH, Ahmed H, Khan IH and Javaid A 2022. Fungicidal potential of flower extract of Cassia fistula against Macrophomina phaseolina and Sclerotium rolfsii. J. Anim. Plant Sci. 32(4): DOI: 10.36899/JAPS.2022.4.0506
Ilavarasan R, Malika M and Venkataraman S 2005. Anti-inflammatory and antioxidant activities of Cassia fistula Linn bark extracts. Afr. J. Tradit. Complement. Altern. Med. 2: 70-85.
Jabeen N, Khan IH and Javaid A 2022. Fungicidal potential of leaf extract of Datura metel L. to control Sclerotium rolfsii Sacc. Allelopathy J. 56(1): 59-68.
Khan IH and Javaid A 2020. Anticancer, antimicrobial and antioxidant compounds of quinoa inflorescence. Adv. Life Sci. 8(1): 68-72.
Naqvi SF, Khan IH and Javaid A 2020. Hexane soluble bioactive components of Chenopodium murale stem. Pak. J. Weed Sci. Res. 26(4): 425-432.
Naragani K, Mangamuri U, Muvva V, Poda S and Munaganti RK 2016. Antimicrobial potential of Streptomyces cheonanensis VUK-a from mangrove origin. Int. J. Pharm. Pharm. Sci. 8: 53-57.
Ojewumi ME, Banjo MG, Ogunbiyi TA, Ayoola AA, Awolu OO and Ojewumi EO 2017. Analytical investigation of the extract of lemon grass leaves in repelling mosquito. Int. J. Pharm. Sci. Res. 8: 1000-1008.
Patel DG, Karbhari SS, Gulati OD and Gokhale SD 1965. Antipyretic and analgesic activities of Aconitum spicatum and Cassia fistula. Arch. Int. Pharmacodyn. Ther. 157: 22-27.
Pinto MEA, Araujo SG, Morais MI, and Lima LARS 2017. Antifungal and antioxidant activity of fatty acid methyl esters from vegetable oils. Anais da Academia Brasileira de Ciências 89: 1671-1681.
Saet BL, Kwang HC and Su NK 2007. The antimicrobial activity of essential oil from Dracocephalum foetidum against pathogenic microorganisms. J. Microbiol. 45: 53-57.
Sharma A, Kumar A and Jaitak V 2020. Pharmacological and chemical potential of Cassia fistula L. - a critical review. J. Herb. Med. DOI: https://doi.org/10.1016/j.jhermed.2020.100407
Suresh A, Praveen kumar R, Thangaraj R, Oscar FL, Baldev E, Dhanasekaran D and Thauffuddin N 2014. Microalgal fatty acid methyl ester a new source of bioactive compounds with antimicrobial activity. Asian Pac. J. Trop. Dis. 4: S979-S984.
Ubaid JM, Kadhim MJ and Hameed IH 2016. Study of bioactive methanolic extract of Camponotus fellah using gas chromatography–mass spectrum. Int. J. Toxicol. Pharmacol. Res. 8: 434-439.
Ullah N 2017. Medicinal plants of Pakistan: challenges and opportunities. Int. J. Complement. Alt. Med. 6: Article ID 00193.
Vadivel E and Gopalakrishnan S 2011. GC-MS analysis of some bioactive constituents of Mussaenda frondosa Linn. Int. J. Pharm. Bio. Sci. 2: 313-320.
Valencia-Avilés E, Martínez-Flores HE, García-Pérez M, Meléndez-Herrera E and García-Pérez ME 2019. Investigation of the antibacterial activity and subacute toxicity of a Quercus crassifolia polyphenolic bark extract for its potential use in functional foods. J. Food Sci. 84: 1692-1702.
Vanitha V, Vijayakumar S, Nilavukkarasi M, Punitha VN, Vidhya E and Praseetha PK 2020. Heneicosane-A novel microbicidal bioactive alkane identified from Plumbago zeylanica L. Ind. Crop Prod. 154: Article ID 112748.

(Manuscript received on 03 December 2021; revised on 17 May 2022)