

ANTIVIRAL ACTIVITY OF HERBAL PLANTS AND ITS PHYTOCOMPOUNDS: AN OVERVIEW

Senthil. J, Dwarakanath. S. K, Kalaiyarasu. T, Babu. M* and Ashok. K*

Department of Microbiology and Biotechnology,
Faculty of Arts and Science,
Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, India

ABSTRACT

Genetically and functionally different therapeutic applications against the virus have been found in a variety of active phytochemicals. The antiviral mechanism of those agents is often explained by their antioxidant activity, their scavenging capabilities, DNA inhibition, RNA synthesis, or inhibition of viral reproduction. Numerous epidemiological and experimental studies have proven that antiviral actions work against a large number of phytochemicals. Especially in the last decade, several phytochemicals have been identified using various biological tests *in vitro* and *in vivo* studies. On the other hand, the plant has proven to be a powerful source of antiviral agents with some great advantages over traditional medicine therapy due to its extensive therapeutic potential and limited side effects. Plants synthesize and produce a wide variety of biochemical products that have a potential therapeutic index, thus helping to inhibit the growth of virus. This review provides insights into herbal plants and their metabolism, explaining their potential role as the main option in the treatment of viral infections.

Key words: Antiviral activity, *in vitro*, *in vivo* and Ayurveda formulation.

INTRODUCTION

Folk remedies have been used in folk medicine and ethnobotanical literature to describe the use of plant extracts, infusions, and powders for certain diseases caused by microorganisms such as *P. aeruginosa*, *E. coli*, *C. albicans*, *S. aureus*, *M. canis*, *T. mentagrophytes*, *M. smegmatis*, *B. subtilis*, PV-1, PV-2, PV-3, Measles morbilli virus, HSV-1, HSV-2, Coxsackie B4 virus, Semliki forest virus [1-6]. The treatment of viral infections is often unsatisfactory with available antiviral drugs due to the problem of viral resistance, viral

latency, and paradoxical efficacy in recurrent infection among the immunocompromised patients [7]. Ethnopharmacology offers an alternative approach to the discovery of antiviral agents by studying about the herbal plants with a history of traditional uses for medical applications [8]. Detailed investigation and documentation of plants used in local health traditions and ethnographic evaluation to verify their effectiveness and safety may lead to the development of precious herbal medicine for therapeutic values [9]. A number of compounds extracted from herbal plants have shown prominent antiviral properties of the plant extracts, which are given in Table 1 and Table 2.

Virus inhibitor mechanism

A deeper understanding of the many features of viruses about their cytomorphology, multiplication, replication, translation, and many other strategies by reverse transcription can be used to benefit the host in antiviral therapy (Fig. 1).

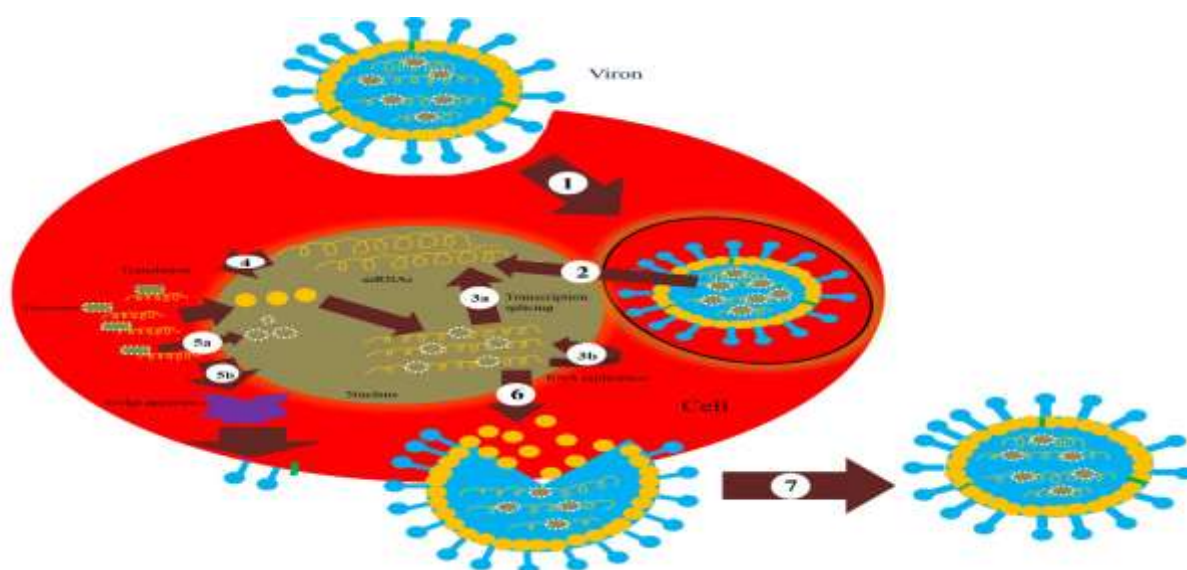


Fig. 1: Virus inhibitor mechanism

Table 1: *In vitro* antiviral activity of herbal plant extracts and its isolated compounds

Name of the plant species/Compounds	Parts used*	Solvent **	Name of the virus	Concentration used	Assay	Ref.
<i>A.sieberiana, C. cajan, C.tomentosa, C.myricoides, C. abyssinica, C. multicorymbosum, C. mesopontica, D. steudtneri, D. inaequalis, E. grantii, E. hirta, E. abyssinica, G. javanica, I. arrecta, L. brevipes, L. nepetaefolia, M. kilimandscharica, M. lutea, P. ternifolia, P. palmate, P. pulchrum, R.vulgaris, S. incanum, T. rhomboidea, V. aenulans, V. amygdalina and V. lasiopus</i>	R,S,SS,L,W P and SD	80% E	PV-1, PV-2, PV-3 and Cocksackie B4 virus	0.2 ml of serial two-fold dilutions of plant extract	MTT	10
<i>C. jagus, S. mombin, P. nitida, S. afzelii, A. conyzoides, H. indicum, T. ivorensis, T. superba, I. asarifolia, B. pinnatum, L. breviflora, T. alnifolia, C. gratissimus, M. barteri, H. opposite, C.portoricensis, E. utile, M. pudica, B. diffusa, M.whitei, P. nigrescens, P. alliacea, P.guineensis, E. indica, S. latifolius and L. multiflora</i>	B,L,S and R	M, 70% AM, NH, DM and EA	Echovirus (E7, E13, and E19)	1000 to 0.01 µg/ml	MTT	11
<i>B.gaudichaudiana, B.spicata, B.subalternans, P.sagittalis, T.minuta and T. absinthioides</i>	L	AE	BVDV, HSV-1, PV- 2 and VSV	30 to 300 µg/ml	MTT	12
<i>C. quadrangularis</i>	S	M	HSV-1 and 2	100, 200, 300 and 400 µg/ml	MTT	13
<i>S. chirata</i>	L	AE	HSV-1		MTT and PCR	14

<p><i>A. figarianum, A. hamulosa, A. asak, A. ehrenbergiana, A. laeta, A. oerfota, A. salicina, A. tortilis, A. aspera, A. procera, A. pungens, A. alba, A. arvensis, A. ochroleuca, A. suberecta, A. javanica, B. monieri, B. aegyptiaca, B. diffusa, B. spectabilis, C. decidua, C. filiformis, C. ambrosioides, C. laucum, C. maxima, C. droserifolia, C. inerme, C. grandis, C. molle, C. epigeus, D. noxia, D. elata, D. regia, D. angustifolia, E. sativa, E. tirucalli, E. hirta, F. benghalensis, F. palmate, F. trineriva, F. parviflora, G. senegalensis, H. tuberculum, I. caerulea, I. cairica, I. tinctoria, J. curcas, J. phonicea, J. procera, M. vulgare, M. balsamina, P. tomentosa, P. uajava, P. crispa, R. communis, R. dentatus, S. obtusifolia, S. occidentalis, S. alexandrina and S. surrattense</i></p>	L,SS,S,R and F	AE, M, EA and DM	Hepatitis B virus	0, 6.25, 12.5, 25 and 50 μ g/ml	MTT	15
<p><i>M. elmer, T. malayana, S. apiculata, A. disticha, T. macrophylla, B. angulate, T. macrophylla, C. lanigerum and A. corniculata</i></p>	WP, L,S and R	DM and M	H1N1 and H3N1	0.78–100 mg/ml	MTT	16
<p><i>F. gummosa, F. assa-foetida, P. ferulacea, B. integerrima, E. arvense, Z. clinopodioides, T. daenensis, H. officinalis, P. granatum, A. capillus-veneris, C. azarolus and P. harmala</i></p>	R,S,L,AP and G	70% E	H1N1	25, 50 and 100 μ g/ml	MTT	17

<i>A. paniculata, C. longa, G. pentaphyllum, K. parviflora and P. guajava</i>	R and L	95% E	H5N1	8.2 g/ml, 69.3 g/ml, 135.6 g/ml, 2.2 g/ml, and 90.7 g/ml	MTT and RT-PCR	18
<i>N. nuda</i>	AP	M and CH	HSV-1 and 2	75, 100, 150, 250, 500, 750 and 1000 mg/ml	MTT	19
<i>S. montana, O. vulgare, M. piperita, M. officinalis, T. vulgaris, H. officinalis, S. officinalis and D. canadense</i>	R and L	E and 40% AE	Avian infectious bronchitis (IBV)	50 mg/ml	MTT and RT-PCR	20
<i>A. calamus, C. citratus and M. fatua</i>	R and L	M	Huh7 it-1	5-160 µg/ml	MTT	21
<i>I. brevicuspis, I. theezans, B. erioclada, B. megapotamica, M. ilicifolia, G. marifolia, G. spathulata, A. gratissima, C. sylvestris, C. menthiformis, G. ciliate, P. actinia, P. alata, P. capsularis, P. edulis, P. misera, P. suberosa, P. warmingii, B. decumbens, C. marginatum, S. cernuum, S. nigrescens, S. leprosum, S. uniflora, L. divaricate and Lantana camara</i>	WP, L,S and R	E and AE	HSV-1	1-10 µg/ml	MTT	22
<i>A. indica, M. oleifera and M. alba</i>	L	E	FMDV	200 µg/ml, 100 µg/ml, 50 µg/ml, 25 µg/ml, 12 µg/ml, 6 µg/ml, and 1 µg/ml	MTT	23
<i>P. niruri</i>	L	E	HSV-1	118, 60, and 185 µg/ml	MTT	24
<i>C. sempervirens</i>	WP, L,S and R	80% E	HSV-1	12.5, 25, 50, 100, 200 and 400 µg/ml	MTT	25

<p><i>R. repens, R. communis, W. tinctoria, A. indica, P. daemia, G. sylvestre, W. chinensis, S. indicus, D. zibethinus, T. indicum, C. pentaphylla, C. bonduc, C. alata, E. alsinoides, M. maderaspatana, J. curcas, I. tinctoria, C. ternatea, G. mangostana, L. aspera, W. fruticosa, A. indicum, A. Mexicana, P. murex, M. pubescens, O. corymbosa, S. hispida, C. halicacabum, D. metel, C. inerme and V. trifolia</i></p>	AP and L	M	HSV-1, Influenza virus (FLU), Mouse corona virus (MCV) and feline calicivirus (FCV)	7.8 to 62 µg/ml	MTT	26
<p><i>F. vesca, G. aristata, G. applanatum, G. macrophyllum, G. littoralis, H. maximum, H. cylindrical, H. discolour, H. splendens, H. perforatum, I. aggregate, J. communts, K. microphylla, L. occidentalis, L. groenlandicum, L. oregano, L. dissectum, L. ciliosa, L. involucrate, L. sericeus, L. clavatum, L. americanwn, M. aqurjolium, M. racemosum, M. stellatum, M. uniflora, M. uniflora, N. lutea, O. horridus, O. fragilis, O. purpurea, P. fruticosus, P. lewisii, P. contorta, P. ponderosa, P. major, P. glycyrrhiza, P. munitum, P. tremuloides, P. arguta, P. virginiana, P. virginiana, R. sanguineum, R. nutkana, R. parviflorus, S. bebbiana, S. cerulean, S. racemosa, S. lanceolatum, S. Canadensis, S. betultjolia, S. albus, U. dioica and V. thapsus</i></p>	RZ, WP, L and S	M	bovine coronavirus (BCV), bovine herpesvirus type 1 (BHV1), bovine parainfluenza virus type 3 (BP13), bovine rotavirus (BRV), bovine respiratory syncytial virus (BRSV), vaccinia virus (Poxviridae) and vesicular stomatitis virus (VSV)	NS	MTT	27

<i>B. variabilis</i> <i>B. Gates</i> , <i>B. intermedia</i> , <i>C. xanthocarpa</i> , <i>E. deciduum</i> , <i>L. hasslerianum</i> , <i>O. pulchella</i> , <i>S. adstringens</i> and <i>X. aromatica</i>	L	AE	Equine herpesvirus 1 (EHV-1), herpes simplex virus 1 (HSV-1) and swine herpesvirus 1 (SuHV-1)	250 to 31.2 µg/ml	MTT	28
<i>P. longum</i> and <i>P. nigrum</i>	SS	M and CH	Vesicular stomatitis Indiana virus and Human para influenza viruses	200, 600, 1000 and 2000 µg/ml	MTT	29
<i>C. metuliferus/ alkaloids</i>	F	NS	Infectious Bursal Disease Virus (IBDV)	100 50 25 12.5 6.25 3.125 1.562 0.781 0.391 0.195 mg/ml	MTT	30
<i>A. paniculata</i> , <i>A. sessilis</i> , <i>C. manghas</i> , <i>C. gigantean</i> , <i>B. chinensis</i> , <i>C. caudatus</i> , <i>E. scaber</i> , <i>A. indica</i> , <i>C. uariegatum</i> , <i>E. hirta</i> , <i>E. indica</i> , <i>P. amboinicus</i> , <i>M. aruensis</i> , <i>O. tenuijlorum</i> , <i>O. aristatus</i> , <i>L. indica</i> , <i>H. rosa-sinensis</i> , <i>E. michelii</i> , <i>B. excels</i> , <i>L. ollaria</i> , <i>M. jalapa</i> , <i>F. malaccensis</i> , <i>P. sarmentosum</i> , <i>P. minus</i> , <i>H. auricularia</i> , <i>M. elliptica</i> , <i>S. americanum</i> , <i>C. asiatica</i> , <i>P. odorata</i> , <i>C. speciosus</i> and <i>E. elatior</i>	WP, L,S and R	E	HSV-1 and vesicular stomatitis virus (VSV)	0.1 to 0.5 mg/ml	MTT	31
<i>C. Myrica</i> and <i>U. Lactuca</i>	SW	A	HSV-1 and 2	NS	MTT	32
<i>T. aurea</i>	S	E	encephalomyocarditis virus (EMCV), HSV-1 and vaccinia virus	166.6 µg/ml	MTT	33

<i>G. thunbergii</i>	AP	E	HSV-1, HIV-1, dengue virus type 2 (DENV2) and human enterovirus 71 (E71)	100 or 200µg/ml	MTT, Qrtpr, cell cycle analysis and western blot	34
<p>* Root – R, Stem – S, Fruit – F, Seeds – SS, Leaves – L, Bract – B, Aerial part – AP, Gum – G, Rhizome – RZ, Flowers – FL, Seaweed - SW and whole plant – WP</p> <p>** Ethanol – E, Methanol – M, Aqueous methanol – AM, n-hexane – NH, Dichloromethane – DM, Ethyl acetate – EA, Aqueous extract – AE and Chloroform – CH</p> <p>*** Not specified - NS</p>						

Table 2: *in vivo* antiviral activity of herbal plant extracts and its isolated compounds

Name of the plant/parts	Solvents/compounds	Name of the virus	Animal model	Concentration	Ref.
<i>C. edulis</i> / Lupeol, Oleuropein, Carissol, β -amyrin and Acyclovir	M	HSV-1	Balb/C mice	The groups were administered with the test drug or acyclovir or placebo orally three times a day for seven consecutive days	35

<i>C. longa</i>	90% E	DENV	ddY mice	10 mice (5 male and 5 female mice) each group. Group 1, mice were administered with 500 mg/kgBW of extract in 0.5% CMC. Group 2, mice were administered with 1000 mg/kgBW of extract in 0.5% CMC. Group 3, mice were administered with 0.5% CMC only. Extract was admitted orally admitted orally once day for 14 days.	36
<i>G. glabra</i> / diammonium glycyrrhizinate, an extract of liquorice roots	NS	COVID-19	animal and clinical trials	NS	37
<p>* Root – R, Stem – S, Fruit – F, Seeds – SS, Leaves – L, Bract – B, Aerial part – AP, Gum – G, Rhizome – RZ, Flowers – FL, Seaweed - SW and whole plant – WP</p> <p>** Ethanol – E, Methanol – M, Aqueous methanol – AM, n-hexane – NH, Dichloromethane – DM, Ethyl acetate – EA, Aqueous extract – AE and Chloroform – CH</p> <p>*** Not specified - NS</p>					

CONCLUSION

Plants are significant for food as well as for medication. Understanding of taxonomic classification, ecology, nature conservation of herbs and pathways for the synthesis of secondary metabolism for the development of medicine. Ethnobotany, phytochemistry, plant physiology and ecology research are needed to protect the world population from current and future infections.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1. **Ieven, M., Vanden Berghe, DA., Mertens, F., Vlietinck, AJ. and Lammens, E.** (1979). Screening of higher plants for biological activities. I. Antimicrobial activity. *Planta Medica*. **36:** 311-321.
2. **Chagnon, M.** (1984). Inventaire pharmacologique g6n6ral des plantes m6dicinales Rwandaises. *Journal of Ethnopharmacology*. **12:** 239-251.
3. **Van Puyvelde, L., Geysen, D., Ayobangira, FX., Hakizamungu, E., Nshimiyimana, A. and Kalisa, A.** (1985). Screening of medicinal plants of Rwanda for acaricidal activity. *Journal of Ethnopharmacology*. **13:** 209-215.
4. **Boily, Y. and Van Puyvelde, L.** (1986). Screening of medicinal plants of Rwanda (Central Africa) for antimicrobial activity. *Journal of Ethnopharmacology*. **16:** 1 - 13.
5. **Vanden Berghe, DA., Vlietinck, AJ. and Vanhoof, L.** (1986). Plant products as potential antiviral agents. *Bull Inst Pasteur*. **84:** 101-147.
6. **Hakizamungu, E., Van Puyvelde, L., W6ry, M., De Kimpe, N. and Schamp, N.** (1988). Antitrichomonas activity of *Sandaracop imaradiene*. *Phytotherapy Research*. **2:** 207-208.
7. **Field, AK. and Biron, KK.** (1994). The end of innocerice revisited: resistance of herpesvirus to antiviral drugs. *Clin Microbiol Rev*. **7:** 1-13.
8. **Vlietinck, AJ. and Vanden Berghe, DA.** (1991). Can ethnopharmacology contribute to the development of antiviral drugs? *J Ethnopharmacol*. **32:** 141-53.

9. **Vijayan, P., Raghu, G., Ashok, G., Dhanaraj, SA. and Suresh, B.** (2004). Antiviral activity of medicinal plants of Nilgiris. *Indian J Med Res.* **120**: 24-29.
10. **Vlietinck, AJ., Van Hoof, L., Tott, J., Lasure, A., Vanden Berghe, D., Rwangabo, PC. and Mvukiyumwami, J.** (1995). Screening of hundred Rwandese medicinal plants for antimicrobial and antiviral properties. *Journal of Ethnopharmacology.* **46**: 31-47.
11. **Omonike, O., Ogbole., Toluwanimi, E., Akinleye., Peter, A., Segun., Temitope, C., Faleye. and Adeniji, AJ.** (2018). *In vitro* antiviral activity of twenty-seven medicinal plant extracts from Southwest Nigeria against three serotypes of echoviruses. *Virology Journal.* **15(110)**: 2-8.
12. **María, FVJ., Flavia, R., Liliana, VM., Rodolfo, HC., Virginia, SM. and Cavallaro, LV.** (2013). *In vitro* antiviral activity of plant extracts from Asteraceae medicinal plants. *Virology Journal.* **10(245)**: 2-10.
13. **Balasubramaniana, P., Jayalakshmi, K., Vidhyab, N., Prasada, R., Khaleefathullah, A., Sheriff, G., Kathiravana, K., Rajagopala. and Sureban, SM.** (2010). Antiviral activity of ancient system of ayurvedic medicinal plant *Cissus quadrangularis* L. (Vitaceae). *Journal of Basic and Clinical Pharmacy.* **001**:37-40.
14. **Verma, H., Patil, PR., Kolhapure, RM. and Gopalkrishna. P.**(2008). Antiviral activity of the Indian medicinal plant extract, *Swertia chirata* against Herpes Simplex Viruses: A study by *in vitro* and molecular approach. *Indian Journal of Medical Microbiology.* **26(4)**: 322-326.
15. **Ahmed Hassan, A., Parvez, MK., Al-Dosari, MS. and Al-Rehaily, AJ.** (2017). *In vitro* evaluation of novel antiviral activities of 60 medicinal plants extracts against hepatitis B virus. *Experimental and Therapeutic Medicine.* **14**: 626-634.
16. **Rajasekaran, D., Palombo, EA., Chia Yeo, T., Lim Siok Ley, D. and Lee, TC.** (2013). Identification of traditional medicinal plant extracts with novel antiinfluenza activity. *PLoS ONE.* **8(11)**: e79293.
17. **Mohammad-Taghi, M., KARIMI, A., Lorigooini, Z., Pourgheysari, B., Alidadi, S. and Hashemi, S.** (2017). *In vitro* anti influenza virus activity, antioxidant potential and total phenolic content of twelve Iranian medicinal plants. *Marmara Pharmaceutical Journal.* **21(4)**: 843-851.

18. **Benjaporn, S., Teerapong, P., Yingmanee, T. and Kidsadagon, P.** (2017). Antiviral activity of five Asian medicinal plant crude extracts against highly pathogenic H5N1 avian influenza virus. *Asian Pacific Journal of Tropical Medicine*. **10(9)**: 871-876.
19. **Daniel, T., Kalina, S., Daniela, D., Anton, H., Kapchina-Totevab, V. and Stoyan, S.** (2015). Antiviral activity of medicinal plant *Nepeta nuda*. *Biotechnology and Biotechnological Equipment*. **29(S1)**: S39S43.
20. **Lelešius, R., Agneta, K., Rūta, M., Tomas, D., Nicola, T., Ragažinskienė, O., Loreta, K., Maruška, A. and Šalomskas, S.** (2019). *In vitro* antiviral activity of fifteen plant extracts against avian infectious bronchitis virus. *BMC Veterinary Research*. **15(178)**: 2-10.
21. **Rosmalena, R., Berna, E., Beti, ED., Fithriyah, F., Hidayati, D., Marissa, A., Hanafi, M., Puspa, DL., Vivitri, DP. and Seto, D.** (2019). The antiviral effect of Indonesian medicinal plant extracts against Dengue Virus *in vitro* and *in silico*. *Pathogens*. **8(85)**: 2-11.
22. **Montanha, JA., Patrícia, M., Bordignon, SAL., Schenkel, EP. and Roehe, PM.** (2004). Antiviral activity of Brazilian plant extracts. *Acta Farm. Bonaerense*. **23 (2)**: 183-186.
23. **Imrana, I., Imran, A., Ashrafa, M., Javeeda, A., Neelma, M. and Rasheeda, B.** (2016). *In vitro* evaluation of antiviral activity of leaf extracts of *Azadirachta indica*, *Moringa oleifera*, and *Morus alba* against the foot and mouth disease virus on BHK-21 cell line. *Science Asia*. **42(2016)**: 392-396.
24. **Faral-Tello, P., Mirazo, S., Dutra, C., P´erez´, P., Geis-Asteggiante, L., Frabasile, S., Elina, K., Danilo, D., Cavallaro, L., Horacio, H. and Arbiza, J.** (2012). Cytotoxic, virucidal, and antiviral activity of South American plant and algae extracts. *The Scientific World Journal*. **12(2012)**:1-5.
25. **Emami, SA., Tayarani-Najaran, Z., Masoud, Sabouri, SG., Pezhman, KK. and Mehrangiz, KK.** (2009). Antiviral activity of obtained extracts from different parts of *Cupressus sempervirens* against Herpes Simplex Virus Type1. *Iranian Journal of Basic Medical Sciences*. **12(3-4)**:133-139.
26. **Vimalanathan, S., Ignacimuthu, S. and Hudson, JB.** (2009). Medicinal plants of Tamil Nadu (Southern India) are a rich source of antiviral activities. *Pharmaceutical Biology*. **47(5)**: 422-429.

27. **McCutcheon, AR., Roberts, TE., Gibbonsb, E., Ellis, SM., Babiukb, LA., Hancockc, REW. and Towersa, GHN.** (1995). Antiviral screening of British Columbian medicinal plants. *Journal of Ethnopharmacology*. **49 (1995)**: 101-110.
28. **Marina, A., Padilla., Simoni, IC., Hoe, VMH., Fernandes, MJB., Arns, CW., Brito, JR. and Lago, JHG.** (2018). *In vitro* antiviral activity of Brazilian Cerrado plant extracts against animal and human herpesviruses. *Journal of Medicinal Plants Research*. **12(10)**: 106-115.
29. **Priya, NC. and Saravana Kumari, P.** (2017). Antiviral activities and cytotoxicity assay of seed extracts of *Piper longum* and *Piper nigrum* on human cell lines. *Int. J. Pharm. Sci. Rev. Res.* **44(1)**:197-202.
30. **Anne, A. Anyanwu, N., Jimam, S., Omale, S. and Wannang, NN.** (2017). Antiviral activities of *Cucumis metuliferus* fruits alkaloids on Infectious Bursal Disease Virus (IBDV). *The Journal of Phytopharmacology*. **6(2)**: 98-101.
31. **ALI, I., Muhammad Mukram MI., Ei-sharkawyl, SH., Hamidi, JA., Ismaili, NH., Ahmadi, FBH. and Lajisi. NH.** (1996). Antiviral and cytotoxic activities of some plants used in Malaysian indigenous medicine. *Pertanika J. Trop. Agric. Sci.* **19(2/3)**: 129-136.
32. **Abdel-Latif Zaid, SA., Hamed, NNE., Abdel-Wahab, KSE., El-Magd, EKA. and Salah El-Din, RAL.** (2016). Antiviral activities and phytochemical constituents of Egyptian marine seaweeds (*Cystoseira myrica* (S.G. Gmelin) *C. agardh* and *Ulva lactuca* Linnaeus) aqueous extract. *The Egyptian Journal of Hospital Medicine*. **64**: 422- 429.
33. **Jiménez-González, FJ., Veloza, LA. and Sepúlveda-Arias, JC.** (2013). Anti-infectious activity in plants of the genus *Tabebuia*. *Univ. Sci.* **18(3)**: 257-267.
34. **Choi, J.,Kim, YS., Kim, JH. and Chung, HS.** (2019). Antiviral activity of ethanol extract of *Geranii herba* and its components against influenza viruses *via* neuraminidase inhibition. *Scientific Reports*. **9**:12132.
35. **Tolo1, FM., Rukunga, GW., Muli, FW., Ochora, JM., Irungu, BN., Muthaura, CN., Wanjiku, CK., Mungai, GM., Ngoc, Q., Hashimoto, K. and Asakawa, Y.** (2010). The antiviral activity of compounds isolated from Kenyan *Carissa edulis* (Forssk.) Vahl. *Journal of Medicinal Plants Research*. **4(15)**: 1517-1522.

36. **Ichsyani, M., Ridhanya, A., Risanti, A., Desti, H., Ceria, R., Putri, DH., Sudiro, TM. and Dewi, BE.** (2017). Antiviral effects of *Curcuma longa* L. against dengue virus *in vitro* and *in vivo*. *IOP Conference Series: Earth and Environmental Science*. **101(2017)**: 012005.

37. **Redeploying plant defences.** (2020). *Nature Plants*. 6(2020):177. (<https://doi.org/10.1038/s41477-020-0628-0>).