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REVIEW ON HEPATOPROTECTIVE PLANTS "HEPATO GABP 24" (PICRORHIZA KURROA, ANDROGRAPHIS PANICULATA, GLYCYRRHIZA GLABRA, AND BOERHAVIA DIFFUSA) INSIGHTS INTO THEIR BIOACTIVE COMPOUNDS

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ABSTRACT

Picrorhiza kurroa, *Andrographis paniculata*, *Glycyrrhiza glabra*, and *Boerhavia diffusa* have been used extensively in traditional medicine for centuries. Within this review, their medicinal profiles, phytochemical compositions, and pharmacological activities are explored, focusing on their therapeutic potentials. This review presents a comprehensive overview of the bioactive compounds present in these plants, including flavonoids, alkaloids, saponins, and terpenoids, which contribute to their Free radical scavenging and inflammation-reducing, antimicrobial, and hepatoprotective activities. This is discussed in this article how pharmacological mechanisms underlie these effects, as well as their relevance to modern therapeutics. As a result of synthesizing existing research, this review aims to enhance our understanding of the hepatotoxic properties of these plants and how they can be used to develop novel treatments for various diseases. In order to integrate these therapies into contemporary medicine, Further research is needed to evaluate their risk profiles and therapeutic effectiveness.

KEYWORDS: *Picrorhiza kurroa*, *Andrographis paniculata*, *glycyrrhiza glabra*, *Boerhavia diffusa*, Phytochemical composition, Bioactive compounds, Pharmacological properties, Hepatoprotective properties.

INTRODUCTION

Throughout history, herbal remedies have been used to treat a range of ails. Certain factory excerpts and natural substances have the eventuality to either cause liver damage or liver protection (Manfo et al. 2014). Polyherbal phrasings (PHFs) have come decreasingly significant for their part in promoting liver health. This traditional approach involves blending multiple sauces and shops to treat colorful health conditions and enhance overall well- being. Used for centuries across different societies, polyherbal drug remains popular moment. By combining colorful sauces, these phrasings produce a synergistic effect, boosting remedial efficacity while reducing implicit side goods. PHFs are available in different forms, including teas, tinctures, capsules, and topical operations, and are frequently acclimatized to address specific symptoms or individual requirements. Their use in managing liver- related conditions has deep roots in traditional drug. Recent exploration highlights their liver-defensive goods with minimum adverse responses. These phrasings contain bioactive composites, similar as terpenoids, alkaloids, and flavonoids, known for their antioxidant, anti-inflammatory, and hepatoprotective parcels (Aladejana *et al.,* 2023). Because of their safety and efficacity characteristics, traditional medicinal shops have long been employed to address liver conditions. this is generally known that the four shops under review *(Picrorhiza kurroa, Andrographis paniculata, Glycyrrhiza glabra, and Boerhavia diffusa*) are largely regarded for their important liver-defensive rates in Ayurvedic and traditional drug.

Picrorrhiza kurroa Benth., a well- known condiment in Ayurvedic drug, has been traditionally used to treat colorful health conditions. These include liver and upper respiratory diseases, digestive issues like dyspepsia and habitual diarrhea, as well as scorpion stings and complications. In traditional Oriental drug, it has also been employed for a wide range of affections, similar as parasitic infections, skin conditions, complications, rheumatic diseases, order issues, heart failure, and snake or scorpion mouthfuls. The root of the factory is particularly valued for its medicinal parcels, acting as a bitter alcohol. In small quantities, it works as a cholagogue, stomachic, and laxative, while in larger boluses, it exhibits cathartic goods. also, it's known for its operations in managing seditious conditions, skin diseases like leukoderma, poisonous mouthfuls, and issues related to the gastrointestinal and urinary systems (Rathee *et al.*, 2016).

For glories, traditional Asian drugs have effectively employed the factory *Andrographis paniculata*. Due to its alleged" blood purifying" rates, it's employed to treat conditions like

skin eruptions, boils, scabies, and patient, illogical complications where blood" abnormalities" are allowed to be the origin of the illness. The upstanding portion of the factory, which is employed medicinally, is substantially composed of lactones, flavonoids, diterpenoids, and flavonoid glycosides, among other chemical rudiments. It's safe and effective operation for easing the signs of simple upper respiratory tract infections has been demonstrated in controlled clinical trials. It's important to critically assess the stated advantages of *Andrographis paniculata* because numerous of the medical diseases it's used to treat in conventional medical systems are allowed to be tone- limiting (Akbar *et al.*, 2011).

Glycyrrhiza glabra L., generally appertained to as liquorice or licorice, is a traditional medicinal factory famed for its multitudinous health benefits, with its use proved across centuries. The factory's roots and rhizomes are particularly valued due to their high content of bioactive composites, which contribute to both its remedial and culinary operations as a spice and spicing agent. Besides *G. glabra*, other species similar as Chinese liquorice (Glycyrrhiza uralensis), Russian liquorice (Glycyrrhiza echinata), and G. inflata are also extensively employed in traditional drug. Liquorice holds significant profitable value in the global spice trade, both as a raw material and as reused root excerpts. (Karkanis *et al.*, 2016).

Boerhaavia diffusa L., generally known as Punarnava, is a imperishable creeping condiment extensively set up across India and is also cultivated in regions like West Bengal. This factory is distributed encyclopedically, including the Philippines, U.S.A., Brazil, and corridor of Africa, thriving in open areas at low and medium mound. Out of the 40 species of this rubric, five are set up in India *B. diffusa, B. chinensis, B. erecta, B. rependa, and B. rubicunda. B. diffusa* holds great significance in traditional drug systems like Ayurveda and Unani. It's named Punarnava, meaning rejuvenator, as the factory regenerates with fresh shoots after rains. In Brazil, it's known as Erva tostao and is considerably used in traditional remedies. It's a crucial component in colorful Ayurvedic phrasings, emphasizing its medicinal value (Chaudhary *et al.*, 2011). The pharmacological conduct, mechanisms of action, and scientific data pertaining to these shops' hepatoprotective benefits are reviewed in this composition.

Table 1: Hepatoprotective plants.

Botanical name	Family	Local name
Picrorhiza kurrooa	Plantaginaceae	Katukarohini
Andrographis paniculata	Acanthacea	Kiriyatta
Glycyrrhiza glabra	Fabaceae	Mulenthi
Boerhavia diffusa	Nyctaginaceae	Punarnava

1. *Picrorhiza kurooa*

A vital medicinal herb, *Picrorhiza kurroa*, is known for its substantial traditional and contemporary medical benefits. High-altitude Himalayan locations are ideal for its growth. This herb, which is self-propagating and a member of the Scrophulariaceae family, is in danger of going extinct because of overharvesting. It is also referred to as Kutka or Kutki. It has hard, spreading roots that are 6 to 10 inches long and have a harsh flavor. Oval in shape and ranging in length from 2 to 4 inches, its leaves have pointy points or serrated edges. The fruit is oval in shape and about ½ inch long, with white or pale purple flowers that grow on long spikes. Numerous medicinal qualities of *P. kurroa,* such as cholagogue, anthelmintic, antioxidant, cardiotonic, and anti-inflammatory, hepatoprotective, antiperiodic, stomachic, carminative, and anti-amoebic properties make it valuable. It also works well for leukoderma, inflammatory diseases, snake bites, scorpion stings, and a number of gastrointestinal and urinary issues (Salma *et al.,* 2017).

Phytochemistry

After much research into the phytochemical makeup of *Picrorhiza kurroa,* 132 active components from its roots, stem, leaves, and seeds have been identified through a variety of analyses. Kutkin, which comprises picrosides I, II, and III as well as kutkoside, is the main constituent of this species. Furthermore, phytochemicals such veronicoside, pikuroside, cucurbitacins, 4-hydroxy-3-methoxy acetophenone, and phenolic compounds have been found in a variety of *P. kurroa* preparations (Sharma *et al.,* 2012). Drosin and apocyanin are two more phytochemicals that have been found. Apocynin, a catechol group member, controls neutrophil oxidative burst and has anti-inflammatory properties. Cucurbitacins are cytotoxic and have anticancer effects, according to Simons *et al.* (1990).

Pharmacological activity

1.1 Hepatoprotective activity

The primary constituents of the liver's parenchymal tissue, liver cells make up 70–85% of the liver's bulk. Liver damage is caused by elevated serum transaminase enzyme levels, which indicate hepatocyte death (Navarro and Senior, 2006). Research on rats exposed to carbon tetrachloride (Kaur *et al.,* 2012) and Amanita poisoning (Dwivedi *et al.,* 1992) has shown that *Picrorhiza kurroa* has important hepatoprotective properties. The plant-based extract improves hepato-protection by increasing intestinal absorption, which in turn boosts health-promoting activities (Jia *et al.,* 2015)

1.2Anti-inflammatory activities

Redness, swelling, pain, and occasionally decreased function are signs of inflammation, a localized tissue reaction to stimulation or infection. Root extracts containing the active phytoconstituent apocynin have demonstrated anti-inflammatory qualities. A 29.8% inhibition rate of oedema indicates that *Picrorhiza kurroa* is an efficient anti-inflammatory drug. The use of rhizome extract from *P. kurroa* considerably decreased inflammation in the joints. Furthermore, it can be regarded as an excellent natural pain reliever and has potent anti-inflammatory properties against chemically produced inflammation (Salma *et al.*, 2017).

1.3Antimicrobial activity

Using fungal strains such Trichophyton rubrum, Candida tropicalis, Candida albicans, and Penicillium marneffei, the antifungal qualities of *Picrorhiza kurroa* root extract were evaluated. These clinical fungal isolates were successfully suppressed by a 10% alcoholic root extract solvent (Shubha *et al.*, 2016). Dried *P. kurroa* stolons also showed broad-spectrum antibacterial action against a number of pathogenic microorganisms, such as *Gloeocercospora sorghi, Erwinia chrysanthemi, Rhizoctonia solani, Fusarium oxysporum,* and *Sporisorium scitamineum*, in acetone and methanol extracts. Additionally, a 0.1% methanol stock solution, chloroform extract, and water extract all showed antibacterial activity (Salma *et al.*, 2017).

1.4 Antioxidant activity

Because they scavenge free radicals, antioxidants are essential for defending the body against a variety of illnesses. After receiving treatment with *Picrorhiza kurroa* extract, patients with liver cirrhosis showed decreased hepatic enzyme activity (Kalaivani and Mathew, 2010) (Salma *et al.,* 2017). By scavenging free radicals in vivo, the ethanol extract of *P. kurroa* rhizome, when given at a dose of 20 mg per kilogram of body weight, successfully restored the stomach walls in rats with gastric ulcers caused by indomethacin (Ray et al., 2002). Using a variety of testing techniques, Kant *et al.* (2013) verified the antioxidant effectiveness of *P. kurroa* leaf fractions. With IC50 values of 75.16±3.2 and 55.5±4.8 µg/mL for DPPH radical scavenging and metal chelation, respectively, the extract showed substantial reducing power and antioxidant qualities. These attributes demonstrate the possibilities *P. kurroa* extract as a natural antioxidant and dietary supplement to treat oxidative stress-related illnesses (Salma *et al.*, 2017).

2. *Andrographis paniculata*

Swertia chirayita (Gentianaceae) and *Andrographis paniculata* (Acanthaceae) are well-known medicinal herbs that are frequently used interchangeably due to their comparable therapeutic qualities. They are referred to as Kiriyattu in Malayalam, and their Sanskrit name, Kiratatikta, which translates to "black-colored with a bitter taste," reflects their similar traits. Bioactive substances such as diterpenes, flavonoids, and stigmasterols are abundant in these plants. Compounds such as amarogentin, swerchirin, and swertiamarin are responsible for their remarkable bitterness and medicinal effects, which include antihelminthic, hypoglycemic, and antipyretic qualities. Numerous pharmacological actions, such as anti-inflammatory, hepatoprotective, antidiarrheal, antiviral, and antimalarial effects, are exhibited by the plants. The food, cosmetic, pharmaceutical, and agricultural sectors all make extensive use of them (Nagalekshmi et al., 2011).

Phytochemistry

The active elements of *Andrographis paniculata* are frequently extracted from its aerial parts and roots, which are abundant in a variety of chemicals. Its chemical makeup varies depending on a number of factors, including harvest time, location, and processing techniques. Many plant metabolites have been isolated as a result of phytochemical investigations on *A. paniculata*. Terpenoids—more especially, ent-labdane diterpene lactones—are important among them because of their prevalence and therapeutic uses. Polyphenols, noriridoids, xanthones, flavonoids (flavones), and both trace and macro elements are further isolated chemicals (Okhuarobo *et al.,* 2014).

Pharmacological properties

2.1 Hepatoprotective activity

According to a study looking at *Andrographis paniculata's* liver-protective qualities, oral treatment of *Andrographis paniculata* extract (100–200 mg/kg) dramatically decreased the acute hepatotoxicity that paracetamol (150 mg/kg) caused in albino mice. Histological and biochemical tests demonstrated this dose-dependent protection. Studies have shown that extract from *Andrographis paniculata* provides protection against hepatotoxicity caused by paracetamol (Nagalekshmi *et al.,* 2011). Additionally, rats who had liver damage from ethanol were used to test the extract's effects. It was discovered that administering *Andrographis paniculata* aqueous extract (at different body weight dosages) shielded the rats

from the ethanol's hepatotoxic effects and markedly decreased increased serum transaminase levels (Vetriselvan *et al.*, 2010).

2.2 Antioxidant activity

By preserving healthy heart function, the hydroalcoholic extract of *Andrographis paniculata* is well-known for its strong antioxidant and cardioprotective properties (Ojha *et al.*, 2009). Ethanol extracts outperformed water extracts in the DPPH experiment for their capacity to eliminate free radicals (Wasman *et al.*, 2011). A higher total polyphenol content in methanol extracts is associated with stronger antioxidant activity. Research employing assays for DNA breakage, lipid peroxidation, and DPPH has demonstrated that methanol extracts possess a greater capacity for antioxidant activity. *A. paniculata* demonstrated strong antioxidant effects in diabetic rats by raising SOD and catalase activity and lowering blood glucose levels. In a variety of tests, leaf extracts demonstrated the most promise, with the highest antioxidant activity (91.01%) recorded at 1000 µg/ml of ethanolic extract (Sivananthan *et al.*, 2013).

2.3Antimicrobial activity

Gram-positive and Gram-negative bacteria were both significantly inhibited by the ethanol extract of *Andrographis paniculata* (Mishra *et al.*, 2009). Strong antibacterial qualities were demonstrated by acetone and ethanol extracts, especially against Bacillus subtilis and Staphylococcus aureus (Hosamani *et al.*, 2011). The stem and root's chloroform extracts demonstrated antifungal and antibacterial qualities. Aqueous extracts and compounds like andrographolides also demonstrated antibacterial properties. Methanol extracts shown notable efficacy against Staphylococcus aureus and Escherichia coli. Furthermore, the plant inhibited DENV1 and HSV-1, exhibiting antifungal activity and perhaps antiviral qualities (Sivananthan *et al.*, 2013).

3. *Glycyrrhiza glabra*

Licorice grows best in areas with sandy, clay, or fertile soils that are easily accessible to water, such as those near rivers or streams. Its most significant medicinal components are the rhizomes and roots, which are traditionally used either by itself or in combination with other plants to treat a variety of illnesses. These include respiratory disorders like coughs, asthma, tonsillitis, and sore throats, as well as digestive disorders including stomach ulcers, excessive thirst, flatulence, and colic. Other conditions for which licorice has been used include epilepsy, fever, paralysis, rheumatism, leucorrhea, psoriasis, prostate cancer, malaria,

bleeding disorders, jaundice, and sexual weakness. According to Sawant B.S. *et al.* (2016), it is also utilized as a flavoring agent in foods, drinks, and tobacco products.

Phytochemistry

Because of its complex chemical makeup, licorice (*Glycyrrhiza glabra)* has attracted a lot of study. A variety of minerals, including calcium, potassium, and magnesium, as well as proteins, polysaccharides, amino acids, and simple sugars are present. It also contains vitamins including B-complex, E, and C, as well as starches, pectins, gums, resins, sterols, tannins, and phytosterols (Wang *et al.,* 2015). Several bioactive substances, including as flavonoids, triterpenes, and saponins, have also been discovered (Rizzato *et al.,* 2017). About 10% of the dry weight of licorice root is made up of glycyrrhizin, a triterpenoid saponin that is roughly 50 times sweeter than sucrose (Yu *et al.,* 2015). Glycyrrhizin's therapeutic effects are enhanced when gut bacteria convert it to glycyrrhetic acid during ingestion (Albermann *et al.,* 2010). Glycyrrhizin, a tribasic acid, is naturally present in licorice root as calcium and potassium salts and can produce a variety of other salts. The Food Chemicals Codex has criteria for the ammonium salt of glycyrrhizin, which is obtained from licorice extracts and is frequently used as a food flavoring agent (Wang *et al.*, 2000).

Pharmacological properties

3.1 Hepatoprotective activity

Several research have demonstrated the hepatoprotective benefits of glycyrrhizin and 18β-glycyrrhetic acid, especially in lowering lipid peroxidation and free radicals (Huo *et al.*, 2011). Glycyrrhizin and glycyrrhetinic acids stop drug-induced liver damage by interfering with the human bile acid processing system. While glycyrrhizin has been shown to decrease liver histology and raise serum aminotransferases, glycyrrhetinic acid is well-known for its hepatoprotective and anti-inflammatory qualities. In patients with chronic hepatitis, long-term usage of glycyrrhizin has been shown to slow the development of hepatocellular carcinoma (Pastorino *et al.,* 2018). *Glycyrrhiza* has been used to treat chronic hepatitis for more than 50 years. In comparison to a placebo, laboratory tests have demonstrated that it can decrease serum aminotransferase levels and improve liver histology. In one study, Swiss albino mice's liver tissues exhibited hepatoprotective qualities against oxidative stress brought on by CCl4 when given hydromethanolic root extract of Glycyrrhiza at doses of 300 and 600 mg/kg for seven days (Sharma *et al.,* 2014).

3.2 Antimicrobial activity

Given the serious threat posed by multidrug-resistant bacteria, research into novel antimicrobial medications is essential. Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, and Candida albicans are among the Gram-positive and Gram-negative bacteria that have been demonstrated to be susceptible to the herb licorice, *Glycyrrhiza glabra*. Secondary metabolites, including flavonoids, alkaloids, and saponins—specifically, glabridin, glabrol, and glycyrrhetinic acid—are responsible for its antibacterial qualities (Pastorino *et al.,* 2018). *Glycyrrhiza* has been shown in vitro to influence Pseudomonas aeruginosa biofilm formation, efflux mechanisms, and membrane permeability. Additionally, α-haemolysin, an exotoxin produced by Staphylococcus aureus, is linked to a number of illnesses, including severe pneumonia and skin infections. A substance called ligurigenin, which comes from *Glycyrrhiza*, prevents the synthesis of α-haemolysin, shielding human lung cells (A549) from the harm that this toxin can do (Rodino *et al.,* 2015).

3.3 Antioxidant activity

Studies conducted both in vitro and in vivo have validated *Glycyrrhiza*'s antioxidant qualities. When DPPH (1,1-diphenyl-2-picrylhydrazyl) and *Glycyrrhiza* root extract were mixed in an in vitro scavenging study, the methanolic extract demonstrated potent antioxidant activity, reaching a maximum scavenging rate of 67.22% at a dosage of 500 µg/ml (Hasan *et al.,* 2021). The dihydrostilbene compounds from *G. glabra* leaves showed notable antioxidant activity, according to Biondi, Rocco, and Ruberto (2003). Licochalcones B and D, which are also present in *G. glabra*, have strong DPPH radical neutralizing properties and can stop microsomal lipid peroxidation. These phenolic compounds can postpone the beginning of skin damage and are advantageous for shielding biological systems from oxidative stress. Because licorice extract has a high antioxidant content and helps prevent oxidative stress damage, its topical application may be beneficial in the development of new dermal and cosmetic products (Pastorino *et al.,* 2018).

4. *Boerhaavia diffusa*

Boerhavia diffusa is a member of the Nyctaginaceae family, also referred to as spreading hogweed or punarnava. The term "diffusa" refers to its diffuse branching, and it is named after the Dutch physician Hermann Boerhaave (Mishra *et al.,* 2014). Due to its worldwide distribution, *glycyrrhiza* is used extensively in ethnopharmacology to treat a wide range of illnesses, such as liver protection, cardiovascular problems, diuretic demands, skin

conditions, and eye problems. Its significant use in ethnomedicinal and traditional medicine over the last 35 years has sparked a number of research that have confirmed its pharmacological advantages, including hepatoprotective, nephroprotective, antidiabetic, anti-inflammatory, and anti-edematous qualities (Gaur *et al.*, 2022).

Phytochemistry

Numerous bioactive substances, such as flavonoids, alkaloids, steroids, triterpenoids, lipids, lignins, carbohydrates, proteins, and glycoproteins, are found in *Boerhavia diffusa*, sometimes referred to as spreading hogweed or punarnava. Punarnavine (C17H22N2O), which has a melting point of 236–237°C, boeravinones A–F, hypoxanthine 9-L-arabinofuranoside, ursolic acid, punarnavoside, lirodendrin, and a glycoprotein with a molecular weight of 16–20 kDa are among the notable substances found in the plant (Mahesh *et al.*, 2012). A quick technique for measuring boeravinones in *Boerhavia diffusa* (BD) has just been created. Rotenone is one of the rotenoids, which are isoflavonoids that are known to block the electron transport chain at complex I in the mitochondria. The "toxophore" of rotenone is associated with its dimethoxy and prenyl-derived ring substitutions on ring A. However, because ring D lacks the isoprenoid residue or ring A is either mono-substituted or unsubstituted, the rotenoids in BD are not cytotoxic. According to Misra *et al.* (2014), genuine samples must have at least 0.005% boeravinone B, a rotenoid that acts as a chemical marker for BD.

Pharmacological properties

4.1 hepatoprotective activity

In rats, Madagundi *et al.* (2016) investigated the hepatoprotective effects of microorganisms. Following tests of the extracts of ethyl acetate and chloroform for their ability to neutralize free radicals, the ethyl acetate extract—which demonstrated a high IC50 value—was employed in in vivo investigations. Rats with liver injury from CCl4 showed higher levels of liver enzymes and bilirubin. These biochemical alterations were reversed and antioxidant enzyme activity was raised upon treatment with the extracts, suggesting hepatoprotective and antioxidant qualities. The ability of *B. diffusa* methanolic leaf extracts to lessen rifampicin-induced hepatotoxicity in rats was investigated by Muthulingam (2014). Rifampicin, a medication used to treat tuberculosis, raised liver enzyme levels while lowering blood protein levels. These readings returned to normal after taking 200 mg/kg of *B. diffusa* extract orally, indicating that the herb may have hepatoprotective properties because of its flavonoids. The

effectiveness of *B. diffusa* in reducing liver damage is demonstrated by these two investigations (Madagundi *et al.*, 2016; Muthulingam, 2014).

4.2 Antimicrobial activity

Aqueous and ethanolic extracts of the whole plant *Boerhaavia diffusa* (BD) have been shown in vitro to have antibacterial action against a variety of infections. Salmonella typhimurium (greater than 20 mm), Shigella dysenteriae (greater than 20 mm), Streptococcus species (inhibition zone: 10–19 mm), Neisseria gonorrhoeae (5–9 mm), Corynebacterium diphtheriae (aqueous extract: greater than 20 mm), and Clostridium tetani (ethanolic extract: 10–19 mm) were all successfully inhibited by these extracts. Additionally, both ethanolic and aqueous extracts demonstrated efficacy against Escherichia coli and Bacillus subtilis. The aqueous extract exhibited a minimum inhibitory concentration (MIC) of 250 µg/mL for both bacteria, but the ethanolic extract had a MIC of 125 µg/mL for B. subtilis and 250 µg/mL for E. coli (Mishra *et al.*, 2014).

Due to bioactive substances including flavonoids and alkaloids, Umamaheshwari discovered that *B. diffusa* extracts made in a variety of solvents exhibited antibacterial qualities against both gram-positive and gram-negative bacteria (Umamaheshwari *et al.*, 2010). Bacillus cereus, Bacillus subtilis, Escherichia coli, Klebsiella species, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhi, Shigella species, Staphylococcus aureus, and Yersinia enterocolitica were among the human pathogenic bacteria that the bioactive phytochemicals in *B. diffusa* leaves demonstrated antibacterial activity against at a concentration of 50 µL. Furthermore, gram-positive bacteria such *S. aureus, B. subtilis, S. faecalis, M. luteus*, and other gram-negative bacteria were inhibited by ethanol extracts of *B. diffusa* leaves. Methanol extracts demonstrated antibacterial activity against gram-negative bacteria such as K. pneumoniae, P. vulgaris, S. marcescens, and S. flexneri, as well as against all tested gram-positive bacteria with the exception of M. luteus(Kumar *et al.*, 2018).

4.3 Antioxidant activity

The antioxidant and possible anti-inflammatory qualities of a 50% ethanolic extract of the entire plant of *Boerhaavia diffusa* (BD) were assessed in a study by Gacche and Dhole. A DPPH radical scavenging activity with an IC_{50} value of 0.21 mg/mL indicated the extract's strong antioxidant capability. Its antioxidant potential was further enhanced by the presence of 42.5 mg/g of total polyphenols and 22.96 mg of vitamin C per 100 g (Gacche *et al.*, 2006). During the course of four weeks, thiobarbituric acid reactive compounds and hydroperoxides

were significantly reduced in rats with alloxan-induced diabetes when *Boerhaavia diffusa* leaf extract (200 mg/kg) was given orally. The leaf extract may improve antioxidant status in diabetic rats, as evidenced by the significant increases in antioxidant enzymes such as reduced glutathione, superoxide dismutase, catalase, glutathione peroxidase, and glutathione S-transferase in both liver and kidney tissues.

Another study used headspace solid-phase microextraction in conjunction with gas chromatography-mass spectrometry (HS-SPME-GC-MS) to investigate the volatile chemicals in *B. diffusa* leaves and roots. Numerous substances were found, such as norisoprenoids, terpenes, phenylpropanoids, and indole compounds. Furthermore, this species was the first to be described for organic acids, including fumaric, pyruvic, quinic, oxalic, and ketoglutaric acids. The existence of a phenolic acid and many flavonoids was also verified by the study (Nayak *et al.*, 2016).

CONCLUSION

In conclusion, the current review highlights the significant medicinal uses, phytochemistry, and pharmacological properties of *Picrorhiza kurrooa, Andrographis paniculata, Glycyrrhiza glabra, and Boerhavia diffusa*, focusing on their antioxidant, anti-inflammatory, antimicrobial, and hepatoprotective activities. There exists a variety of bioactive substances in *Picrorhiza kurrooa*, such as alkaloids, polyphenols, terpenoids, and flavonoids, which contribute to its anticarcinogenic, antioxidant, and neuroprotective properties. For its efficacy to be maximized for therapeutic use, it needs to be enhanced in terms of bioavailability. Further research is necessary to confirm its efficacy through clinical trials.

Traditionally, *A. paniculata* has been utilized in India, China, and Southeast Asia to treat a wide range of ailments. Its bioactive compounds, primarily diterpenoid lactones like andrographolide, Showcase significant pharmacological effects, such as antimicrobial, anti-inflammatory, antioxidant, and hepatoprotective properties. For modern medicinal applications, Additional studies are necessary to fully comprehend the phytochemistry of its pure compounds as well as their mechanisms of action.

Traditionally used in medicine, *G. glabra* contains flavonoids, glycyrrhizin, and other bioactive compounds which act as antioxidants, antivirals, antimicrobials, and anti-inflammatory compounds. Its therapeutic potential is widely acknowledged, but more Clinical trials are required to fully explore its safety profile and medicinal potential.

Lastly, *B. diffusa* is highly respected in traditional medicine, it is yet to gain a strong foothold in the herbal market despite its hepatoprotective, immunomodulatory, and anticancer properties. *B. diffusa* is highly promising for developing new therapeutic agents due to its diverse chemical profile, which includes novel rotenoid compounds.

The plants in this group have a broad spectrum of pharmacological actions, including protecting the liver, combating oxidative stress, reducing inflammation, and fighting microbial infections. Validating their safety and efficacy requires further clinical and laboratory studies, which may pave the way for their use in modern medicine more widely

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