Therapeutic significance and pharmacological activities of antidiarrheal medicinal plants mention in Ayurveda: A review

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ABSTRACT

Diarrhea is a serious problem affecting 3-5 billion people per year around the world, especially children of below 5 years. 70% of the world population uses traditional and indigenous medicine for their primary health care. The facts of these indigenous remedies are passed verbally and sometimes as documents. Since ancient time, Ayurveda is the main system of healing in South East Asian countries. Indian literature from ayurvedic texts and other books claim the potency of several plants in the treatment of diarrhea. As the global prospective of ayurvedic medicine is increasing, interest regarding the scientific basis of their action is parallely increasing. Researchers are doing experiments to establish the relation between the claimed action and observed pharmacological activities. In the present article, an attempt was made to compile the scientific basis of medicinal plants used to cure diarrhea in Ayurveda. Literature was collected via electronic search (PubMed, ScienceDirect, Medline, and Google Scholar) from published articles that reports antidiarrheal activity of plants that were mentioned in Ayurveda classics. A total of 109 plant species belonging to 58 families were reported for their antidiarrheal activity. Several Indian medicinal plants have demonstrated promising antidiarrheal effects, but the studies on the antidiarrheal potentials of these plants are not taken beyond proof of concept stage. It is hoped that the article would stimulate future clinical studies because of the paucity of knowledge in this area.

KEY WORDS: Ayurveda, diarrhea, medicinal plant, traditional medicine

INTRODUCTION

Gastroenteritis is a clinico-pathological term that refers to inflammation and oxidative stress of the intestines which leads to disturbance in the balance of secretory and absorptive function of the intestines resulting in diarrhea [1,2]. Hence, diarrhea can be defined as a gastrointestinal disorder in which there is a rapid transit of gastric contents through the intestine, which is characterized by abnormal fluidity and high frequency of fecal evacuation, usually semisolid or watery fecal matter, three or more times/day [1-3]. There is an increase in flow rate of feces with or without the presence of blood and mucus, accompanied by increased secretion and decreased absorption of fluid, leading to loss of water and electrolytes [2,4]. The major causative agents of diarrhea in human beings include a variety of enteric pathogenic bacteria such as Salmonella typhi, Shigella flexneri, Escherichia coli, Staphylococcus aureus, Vibrio cholerae, and Candida albicans [4,5]. Viruses, protozoans, helminths, intestinal disorders, immunological factor, and medications can also cause diarrhea in human being [6-8]. Etiological factors for diarrhea include the food intolerances, contaminated drinking water, undercooked meat and eggs, inadequate kitchen hygiene, poor sanitation [9], bile salts, hormones, irritable bowel syndrome, and intoxication [10].

According to the World Health Organization (WHO), diarrhea affects 3-5 billion people/year worldwide and causes 5 million deaths per annum [11]. Children, however, are more susceptible to the disease, which is the one of the leading causes of death in infants and children below 5 years of age [12].

Due to high mortality and morbidity, especially in children, the WHO together with the United Nations Children’s Fund has initiated Diarrhea Disease Control Program to control diarrhea in developing countries. Oral rehydration solution [13], zinc solution [14], probiotics [15], and specific antibiotics have reduced mortality rate in diarrheal disease. However, chronic diarrhea is still a life challenging problem in some regions of the world. Unfortunately, the program does not reach to the needy, and the disease is still a major challenge in front of primary health practitioner as well as researcher. Therefore, the different traditional systems of medicines such as Chinese medicine [16], Japanese medicine [17], acupuncture therapy [18], and ayurvedic medicine [19] are included in this program.
Since ancient times, medicinal plants have been used to treat different ailments due to their accessibility, availability, inherited practice, economic feasibility, and perceived efficacy [20]. Nowadays, the use of medicines from plant source increases significantly with conventional therapies. Hence, the plants are gaining more attention by the researchers to find out new and effective agents for different diseases. Several medicinal plants in the different regions of the world have been used to cure diarrhea [19,21].

The knowledge of indigenous medicines is passing from generation to generation orally worldwide [22]. It is, therefore, documentation of such knowledge as well as reported the scientific basis of their pharmacological potential is necessary since they are usually considered as free from adverse effects. A range of medicinal plants were reported for their effectiveness in diarrhea [23-27]. The protective role of these plants is probably due to their anti-inflammatory, antioxidant, and astringent properties [28]. India has a rich plant resources providing valuable medicine, which are conveniently used in Ayurveda, Unani, and other system of medicines for the treatment of various diseases [29]. Keeping this in view, the present article was initiated, with an aim to compile the scientific basis of medicinal plants used to cure diarrhea. A variety of curative agents from these indigenous plants has been isolated. These isolated compounds are belonging to different phytochemical classes such as flavonoids, saponins, terpenoids, steroids, phenolic compounds, and alkaloids [30-32]. Flavonoids and saponins inhibit the release of prostaglandins, autacoids, and contractions caused by spasms, as well as motility and hydroelectrolytic secretions [33,34] while saponins may prevent release of histamine [35]. Polyphenols and tannins provide strength to intestinal mucosa, decrease intestinal secretion, intestinal transit and promotes balance in water transport across the mucosal cells [36].

Previously, we enumerated a large number of plants, which are used in the ayurvedic system as antidiarrheal [19]. A majority of these plants have been investigated pharmacologically with respect to the potential antidiarrheal activity. In this review, we present ethnopharmacological data of 109 plant species belonging to 58 families mentioned in ayurvedic texts for controlling diarrhea with their possible mechanism of action [Table 1 and Figure 1]. Mostly, leaf (23%), root (14%), barks (11%), fruit (9%), and seed (8%) of the plants are used for antidiarrheal activity [Figure 2].

**DISCUSSION**

Since ages, human beings have relied on plants as a resource of the therapeutic arsenal in the fight against certain human diseases. Plant-based drugs have formed the basis of traditional medicine systems, i.e., Ayurveda, Siddha, Unani, Homeopathy, and Chinese. Herbal-based therapy is one of the popular and effective practices to overcome the illness. The WHO also promotes utilization of local knowledge of plant-based medicines in health care. It has been reported by the WHO that about 70-80% of the population in developing countries relies on traditional/ethno medicines for their primary health care. Since ancient time ayurvedic system of medicine is indigenous to and widely practiced in India. Nature has bestowed India with an enormous wealth of medicinal plants. Therefore, their rational uses for combating diseases are described traditionally.

Acharya charaka has mentioned a group of antidiarrheal plants named as Parish-Samagrabhishay Mahakshayasa, which includes priyangu (Callicarpa macrophylla), ananta (Hemidesmus indicus R.B.), seed of amra (Mangifera indica), katvanga (Ailanthus excelsa Roxb.), lodhra (Syringococcus racemosus), mocharasa (Salacia malabarica Schott and Endl.), samanga – Rubia cordifolia, flower of dhakati – Woodfordia fruticosa, padma – lotus (Nelumbo nucifera), and filaments of padma – lotus (N. nucifera). Moreover, he also listed some most useful antidiarrheal plants such as katavanga (A. excelsa Roxb.), mustaka (Cyperus rotundus Linn.), amrita (Tinospora cordifolia [Willd.] Miers ex Hook. f. & Thoms.), atishiva (Aconitum heterophyllum Wall. ex. Royle.), bila (Aegle marmelos Correa), cumuda (N. nucifera Gaertn.), utpala, padma, kutaja bark (Holarhena antidysenterica [Linn.] Wall.), gambhari fruit (Gmelina arborea Roxb.), prishnapuri (Uraria picta [Jacq.] Dev. ex DC.), and bala (Sida cordifolia) [187]. In addition, Acharya Susurata mentioned that the vacha (Acorus calamus Linn.) and harida (Curcuma longa Linn.), etc., are best for amatisara (diarrhea where undigested food matter pass in stool) while ambastha (Cissampelos pareira Linn.) and priyangu (C. macrophylla) are best for pakwatsara (diarrhea where only digested food matter pass in stool) [188].

The ayurvedic Pharmacopoeia mentioned more than 1200 species of plants, nearly 100 minerals and over 100 animal products officially. Although there is no record of pharmacological testing during the period when ayurvedic texts were written. However, nowadays, extensive researches are carried out concerning the phytopharmacological basis of their therapeutic principles. Public, academic as well as government organizations are showing interest in the scientific mechanism of action exerted by these plants. Similar to modern and other traditional medicines, ayurvedic medicines have been also evaluated for their phytopharmacology with the help of advances in science and technology. Scientific screening on laboratory animal and in vitro evaluations supports traditional uses of medicinal plants.

In the present scenario, modern pharmaceuticals offer a number of medicines for diarrhea, but diarrhea still remains a major health threat to the people in tropical and subtropical countries. It is one of the leading causes of mortality in children especially under the age of 5 years [12]. Different factors such as infections, malnutrition, food intolerances, intestinal disorders, and some medications may trigger diarrhea [6-8]. Currently, available pharmacological treatments are seem to be insufficient in diarrhea control. It is because of lack of admittance, high cost, and adverse effects of modern pharmaceuticals as well as therapeutic approaches. Therefore, investigations on drugs from different alternative and complementary medicines along with traditional system of medicines were going on.
| Sanskrit name | Botanical name | Family       | Part used                      | Extract/dose                        | Standard drug and dose | Model                                                                 | Mechanism                                                                 | References |
|--------------|----------------|--------------|--------------------------------|-------------------------------------|------------------------|----------------------------------------------------------------------|---------------------------------------------------------------------------|------------|
| Atibala      | *Abutilon indicum* (Linn.) | Malvaceae    | Leaf                           | Methanolic and aqueous extract      | Loperamide (1 mg/kg)   | Gastrointestinal motility test, castor oil-induced diarrhea model, and PGE₂-induced enteropooling model | Prevented Na⁺ and K⁺ loss                                               | [37]       |
| Khadir       | *Acacia catechu* Willd. | Fabaceae     | Heartwood                      | Ethyl acetate extract (250 mg/kg)   | Diphenoxylate (10 mg/kg) and atropine (1 ml/200 g, p.o.) | Castor oil-induced diarrhea model                                        |                                                           | [38]       |
| Babool       | *Acacia nilotica* Dellie & Ssp. *indica* (Benth.) Brenan. | Caesalpiniaceae | Bark                           | Petroleum ether, methanolic and aqueous extract |                        |                                                                      |                                                           | [39]       |
| Ativisha     | *Aconitum heterophyllum* Wall. ex. *Royle.* | Ranunculaceae | Root                           | Ethanolic extract (50, 100, and 200 mg/kg) and isolatedaconitine | Loperamide (2 mg/kg, p.o.) and atropine (0.1 mg/kg, s.c.) | Castor oil-induced diarrhea model, small intestinal transit time, PGE₂-induced enteropooling, and gastric emptying test | Inhibition of spontaneous and high K⁺-induced contractions and antispasmodic activity | [40]       |
| Vacha        | *Acorus calamus* Linn. | Araceae      | Root and essential oil         | Methanolic extract and n-hexane fraction |                        | Castor oil-induced diarrhea model, spasmylytic activity               |                                                           | [41,42]   |
|              |                 |              | Rhizome                        | Aqueous and methanolic extract (3, 7.5, and 15 mg) |                        | Castor oil-induced diarrhea model                                          |                                                           |            |
| Bilva        | *Aegle marmelos* Correa. | Rutaceae     | Unripe fruit pulp              | Aqueous extract                     | -                      | Antimicrobial activity                                                | Through reduced bacterial adherence to intestinal wall and invasion of Hep-2 cells | [43-50]   |
|              |                 |              | Leaf                           | Aqueous extract (50, 100, and 200 mg/kg) | Loperamide (3 mg/kg orally) | Castor oil-induced diarrhea, magnesium sulfate-induced diarrhea, and gastric transit time | Inhibition of intestinal transit of food material and inhibition of intestinal secretion |            |
|              |                 |              | Fruit                          | Polyherbal formulation (25, 50, and 100 mg/kg) | Mebidid (10 ml/kg, p.o.) | Castor oil-induced diarrhea model, intestinal secretion model, and antispasmodic effect |                                                           |            |
|              |                 |              | Unripe fruit extract           | Aqueous and methanolic extract      |                        | Castor oil-induced diarrhea model                                        |                                                           |            |
|              |                 |              | Fruit                          | Aqueous extract                     | Diphenoxylate and yohimbine | Castor oil-induced diarrhea model                                        |                                                           |            |
|              |                 |              | Dried fruit pulp               | Ethanolic extract                   | -                      | In vitro antibacterial activity                                         |                                                           |            |
|              |                 |              | Root                           | Chloroform extract                  | -                      | Castor oil-induced diarrhea model                                        |                                                           |            |
| Sanskrit name | Botanical name | Family | Part used | Model and dose | Standard drug | Extract/dose | Mechanism | References |
|--------------|----------------|--------|-----------|----------------|---------------|---------------|-----------|------------|
| Gorakhgajra | Alchornea humboldtiana | Simaroubaceae | Stem and leaf | Alcoholic and aqueous extract (400 mg/kg, i.p.) | Loperamide | (3 mg/kg, i.p.) | Gastrointestinal motility test and castor oil-induced diarrhea model | [51] |
| Aralu | Aerva lanata | Amaranthaceae | Whole plant | Ethanolic and aqueous extract (400 and 800 mg/kg, i.p.) | Loperamide | (3 mg/kg, i.p.) | Gastrointestinal motility test and castor oil-induced diarrhea model | [52] |
| Saptaparna | Alstonia scholaris | Apocynaceae | Bark | Ethanolic and aqueous extract (250 mg/kg) | Loperamide | (50 mg/kg) | Gastrointestinal motility test and castor oil-induced diarrhea model | [54,55] |
| Sinduri | Bixa orellana | Bixaceae | Leaf | Methanolic extract (125, 250, and 500 mg/kg) | Loperamide | (3 mg/kg orally) | Castor oil-induced diarrhea model | [66] |
| Sanskrit name | Botanical name | Family          | Part used | Extract/dose                      | Standard drug and dose | Model                                                                 | Mechanism                                                                 | References |
|--------------|----------------|-----------------|-----------|-----------------------------------|------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------|------------|
| Sallaki      | *Boswellia serrata* Roxb. | Burseraceae    | Gum resin | Hydroalcoholic extract and 3–acetyl–11–keto–b–boswellic acid | Loperamide (5 mg/kg)   | Upper gastrointestinal transit in croton oil-treated animal, castor oil-induced diarrhea model | Inhibition of acetylcholine-induced contractions by the L-type Ca\(^{2+}\) channel blockers | [67]       |
| Parnabija    | *Bryophyllum pinnatum* (Lam.) Kurz. | Crassulaceae  | Leaf | Aqueous extract (100, 200, and 300 mg/kg) | Loperamide (1 mg/kg)   | Castor oil-induced diarrhea model, castor oil-induced enteropooling, small intestinal transit time | Inhibition Na\(^{+}\)-K\(^{-}\)ATPase activity | [68]       |
| Priyala      | *Buchanania lanzan* Spreng. | Fagaceae    | Leaf | (200 and 400 mg/kg)               | Loperamide (3 mg/kg orally) | Castor oil-induced diarrhea model and PGE\(_2\)-induced enteropooling | Castor oil-induced diarrhea model and PGE\(_2\)-induced enteropooling | [69]       |
| Palash       | *Butea monosperma* Lam. Kunze. | Fabaceae   | Stem bark | Ethanolic extract                | Loperamide (5 mg/kg, p.o.) | Castor oil-induced diarrhea model                                  | Antibacterial activity                                                   | [70]       |
| Latakaranja  | *Caesalpinia bonducella* Flem. | Caesalpiniaceae | Leaf | Methanolic extract and its ethyl acetate, chloroform, and petroleum ether fractions (200 and 400 mg/kg) | Loperamide (50 mg/kg)   | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model | [71]       |
| Gumohar      | *Caesalpinia pulcherrima* Linn. | Caesalpiniaceae | Bark | Ethanolic extract (500 mg/kg)       | Loperamide (5 mg/kg)   | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model | [72]       |
| Arka         | *Calotropis gigantea* R.Br. | Asclepiadaceae | Aerial part | Hydroalcoholic extract (200 and 400 mg/kg) | Atropine (3 mg/kg, i.p.) | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model | [73]       |
| Arka         | *Calotropis procera* (Ait.) R.Br. | Asclepiadaceae | Dry latex | Ethanol extract (500 mg/kg) | Loperamide (4 mg/kg) | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model | [74-77]   |
| Tea          | *Camellia sinensis* (Linn.) O. Kuntze. | Theaceae | Leaf | Aqueous and alcoholic extract (100, 200 mg/kg) | Loperamide (3 mg/kg orally) | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model and PGE\(_2\)-induced enteropooling | [78]       |
| Hinsra       | *Capparis zeylanica* Linn. | Capparidaceae  | Leaf | Methanolic extract (100, 150, 200 mg/kg) | Loperamide (3 mg/kg orally) | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model and small intestine transit method | [79]       |
| Erand karkati| *Carica papaya* Linn. | Caricaceae   | Fruit | Methanolic and aqueous extract (100, 200 and 400 mg/kg) | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model and magnesium sulfate-induced diarrhea | [80]       |
| Shitiwar     | *Celosia argentea* Linn. | Amaranthaceae | Leaf | Alcoholic extract (100, 200 mg/kg) | Atropine (0.1 mg/kg, i.p.) | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model | [81]       |
| Patra        | *Cinnamomum tamala* Buch.–Ham. | Lauraceae | Bark | Ethanolic extract (25, 50, and 100 mg/kg) | Loperamide (5 mg/kg)   | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model | [82]       |
| Twaka        | *Cinnamomum zeylanicum* Linn. | Lauraceae | Bark | Aqueous extract (100 and 200 mg/kg) | Loperamide (5 mg/kg)   | Castor oil-induced diarrhea model                                  | Castor oil-induced diarrhea model and magnesium sulfate-induced diarrhea | [83]       |
| Sanskrit name | Botanical name | Family | Part used | Extract/dose | Standard drug and dose | Model | Mechanism | References |
|--------------|----------------|--------|-----------|--------------|------------------------|-------|-----------|------------|
| Patha        | Cissampelos pareira Linn. | Menispermaceae | Root | Ethanolic extract (25-100 mg/kg) | | Castor oil-induced diarrhea model | Inhibitory effect on the concentration of Na⁺ and K⁺, reduction in the lipid peroxidation and Prevention from oxidative stress | [84] |
| Hulhul       | Cleome viscosa L. | Capparidaceae | Whole plant | Methanolic extract | Diphenoxylate (5 mg/kg orally) | Castor oil-induced diarrhea model and PG_E₂-induced enteropooling gastrointestinal motility | | [85] |
| Vaamana–haati | Clerodendrum indicum | Verbenaceae | Leaf | Methanolic extract and chloroform fraction | | Castor oil-induced diarrhea model | | [86] |
| Aparajita    | Clitoria ternatea L. | Fabaceae | Leaf | Methanolic extract (100, 200, and 300 mg/kg) | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model | | [87,88] |
| Vaamana–haati | Clerodendrum indicum | Verbenaceae | Root | Methanolic extract (100, 200, and 400 mg/kg) | Atropine (5 mg/kg, i.p.) | Castor oil-induced diarrhea model, intestinal transit and castor oil-induced enteropooling | | |
| Dhanyaka     | Coriandrum sativum Linn. | Apiaceae | Leaf | Aqueous extract (150 and 300 mg/kg) | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model | | [89] |
| Varuna       | Crataeva nurvala | Fabaceae | Stem bark | Ethanolic extract (500 mg/kg) | | Castor oil-induced diarrhea model, castor oil-induced enteropooling, and small intestine transit model | | [90] |
| Jiraka       | Cuminum cyminum Linn. | Apiaceae | Seed | Aqueous extract | Loperamide (3 mg/kg) | Castor oil induced diarrhea model, PG_E₂-induced enteropooling model, intestinal transit by charcoal | | [91] |
| Haridra      | Curcuma longa Linn. | Zingiberaceae | Rhizome | Aqueous extract (200 mg/kg) | | Castor oil-induced diarrhea model | | [92] |
| Durva        | Cynodon dactylon Pers. | Poaceae | Whole plant | Methanolic extract (200 and 300 mg/kg) | Atropine (5 mg/kg orally) | Castor oil-induced diarrhea model, gastrointestinal charcoal meal test, and enteropooling model | | [93] |
| Mustaka      | Cyperus rotundus Linn. | Cyperaceae | Rhizome | Methanolic extract (250-500 mg/kg) | | Castor oil-induced diarrhea model | | [94,95] |
| Goraksha     | Dalbergia lanceolaria Linn.f. | Fabaceae | Bark | Petroleum ether, ethanolic extract | Diphenoxylate (5 mg/kg, p.o.) | Castor oil and magnesium sulfate-induced diarrhea | | [96] |
| Shimsapa     | Dalbergia sissoo Roxb. ex DC. | Fabaceae | Leaf | Ethanol extract | | Castor oil-induced diarrhea model and magnesium sulfate-MgSO₄-induced diarrhea | | [97] |
| Kusha        | Desmostachya bipinnata L. | Poaceae | Leaf | Alcohol aqueous extract (200, 400 mg/kg) | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model, gastrointestinal motility test with charcoal meal test | | [98] |
| Virataru     | Dicrostachys cinerea W. & A. | Mimosaceae | Leaf bark and root | Ethanol extract (200 and 400 mg/kg) | Loperamide (5 mg/kg, p.o.) | Castor oil-induced diarrhea model and small intestinal transit model | | [99] |
| Tinduka      | Diospyros peregrina Hude. | Ebenaceae | Bark and seed | Ethanol extract (250 and 500 mg/kg) | | Castor oil-induced diarrhea model | | [100] |

Table 1: (Contd...)
| Sanskrit name | Botanical name | Family | Part used | Extract/dose | Standard drug and dose | Model | Mechanism | References |
|--------------|---------------|--------|-----------|--------------|------------------------|-------|-----------|------------|
| Amalaki      | Emblica officinalis Gaertn. | Euphorbiaceae | Fruit | Ethanolic extract (500 mg/kg) | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model | Inhibition of intestinal motility, antimicrobial action, and antisecretory effects | [101-103] |
|              |               |        | Crude extract (500-700 mg/kg) | Loperamide (10 mg/kg) | Castor oil-induced diarrhea model and enteropooling model | Mediated possibly through dual blockade of muscarinic receptors and Ca\(^{2+}\) channels | |
|              |               |        | Methanolic extract | | | | |
| Paribhadra   | Erythrina indica Lam. | Fabaceae | Leaf | Ethanolic and aqueous extract (500 mg/kg) | Loperamide (5 mg/kg) | Castor oil-induced diarrhea model, PGE\(_2\)-induced intestinal fluid enteropooling, and gastrointestinal motility in both BaSO\(_4\) and charcoal meal tests | | [104] |
| Dugdhika Big | Euphorbia hirta Linn. | Euphorbiaceae | Whole plant | Ethanolic and water extract (2.0 mg/kg) | | Castor oil-induced diarrhea model, PGE\(_2\)-induced enteropooling, gastrointestinal motility in both BaSO\(_4\) and charcoal meal tests | | [105] |
| Kapittha     | Feronia limonia Linn. Swingle | Rutaceae | Leaf | Ethanolic extract (250, 500 mg/kg) | Loperamide (50 mg/kg) | Antibacterial activity, castor oil-induced diarrhea model | | [106,107] |
| Vata         | Ficus benghalensis | Moraceae | Leaf | Methanolic (3, 7.5 and 15 mg/kg) | Loperamide (25 mg/kg) | Castor oil-induced diarrhea model | | [108,109] |
|              |               |        | Root | Ethanolic extract (400 mg/kg) | Diphenoxylate (5 mg/kg, p.o.) | Gastrointestinal motility in charcoal meal test, castor oil-induced diarrhea model, and PGE\(_2\)-induced enteropooling | | |
| Kakudumbara  | Ficus hispida Linn. | Moraceae | Leaf | Methanolic extract | Diphenoxylate (5 mg/kg, p.o.) | Castor oil-induced and PGE\(_2\)-induced enteropooling model | | [110] |
| Udumbara     | Ficus racemosa Linn. | Moraceae | Bark | Ethanolic extract 400 mg/kg | Diphenoxylate (5 mg/kg, p.o.) | Castor oil-induced diarrhea model and PGE\(_2\)-induced enteropooling model | | [109] |
| Ashvattha    | Ficus religiosa Linn. | Moraceae | Stem bark | Hydroalcoholic, acetone extract | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model | | [111] |
| Udumber      | Ficus glomerata L. | Moraceae | Leaf | Methanolic extract (100 and 200 mg/kg) | Atropine (3 mg/kg) | Castor oil-induced diarrhea model, castor oil-induced enteropooling, and intestinal transit | | [112] |
| Parpata      | Fumaria parviflora | Papaveraceae | Aerial part | Aqueous and methanolic extract | Dicyclomine, (50 and 100 mg/kg) and Loperamide (10 mg/kg, p.o.) | Castor oil-induced diarrhea model | CCB blockade of muscarinic receptors | [113] |
| Sanskrit name | Botanical name | Family | Part used | Extract/dose | Standard drug and dose | Model | Mechanism | References |
|--------------|---------------|--------|-----------|--------------|------------------------|-------|-----------|------------|
| Kasmari      | Gmelina arborea Roxb. | Verbenaceae | Root      | Ethanolic and N–butanol (200, 400 mg/kg) | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model | Inhibition of intestinal motility and bactericidal activity | [114,115] |
| Sariva       | Hemidesmus indicus R.Br. | Apocynaceae | Root      | Methanolic extract (500-1500 mg/kg) | Loperamide (5 mg/kg) | Castor oil-induced diarrhea model | Charcoal meal test and enteropooling model | [116,117] |
| Kutaja       | Holarrhena antidysenterica (Linn.) Wall. | Asclepiadaceae | Seed     | Ethanolic extract (100 and 200 mg/kg) | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model, antibacterial activity against EPEC *in vitro* | | [118] |
| Cirabilva    | Holoptelea integrifolia Planch. | Urticaceae | Leaf      | Ethanolic extract (250 and 500 mg/kg), isolated alkaloid | Loperamide (5 mg/kg) | Castor oil and magnesium sulfate-induced diarrhea model | | [119] |
| Bandhuka     | Ixora coccinea Linn. | Rubiaceae | Flower    | Aqueous extract (400 mg/kg) | Loperamide (5 mg/kg) | Castor oil-induced diarrhea model | | [120,121] |
| Bandhuka     | Ixora coccinea Linn. | Rubiaceae | Leaf      | Aqueous extract (400 mg/kg) | Loperamide (5 mg/kg) | Castor oil-induced diarrhea model | | |
| Vyaghra errand | Jatropha curcas Linn. | Euphorbiaceae | Root      | Methanolic extract (50 and 100 mg/kg) | Chlormepazine (30 mg/kg, i.p.) | Castor oil or magnesium sulfate-induced diarrhea | Inhibition of prostaglandin biosynthesis and reduction of osmotic pressure, decreases in peristaltic activity, Castor oil-induced permeability changes in intestinal mucosal membrane to water and electrolyte Inhibition of prostaglandin biosynthesis and reduction propulsive movement of small intestine | [122,123] |
| Madhuca      | Madhuca indica J. F. Gmel. | Sapotaceae | Dried bark | Ethanolic extract (250 and 500 mg/kg) | Loperamide (50 mg/kg) | Castor oil-induced diarrhea model | | [124] |
| Amra         | Mangifera indica Linn. | Anacardiaceae | Stem bark and root bark | Methanolic extract (3, 7.5, and 15 mg/kg) | Loperamide (50 mg/kg) | Castor oil-induced diarrhea model | | [108,125-127] |
|              |                |          | Seed      | Alcoholic and aqueous extract | Loperamide | Castor oil-induced diarrhea model | By increasing colonic water and electrolyte reabsorption or by inhibiting intestinal motility | |
|              |                |          | Leaf      | Aqueous extract (25 and 50 mg/kg) | Loperamide (2 mg/kg) | Castor oil-induced diarrhea model | Enhancement of Na⁺-K⁺ ATPase activity | |
|              |                |          | Seed      | Methanolic and aqueous extract (250 mg/kg) | Loperamide (3 mg/kg, p.o.) | Castor oil- and magnesium sulfate-induced diarrhea model | | |
| Sanskrit name | Botanical name | Family | Part used | Extract/dose | Standard drug and dose | Model | Mechanism | References |
|--------------|---------------|--------|-----------|--------------|------------------------|-------|-----------|------------|
| Pudina | Mentha longifolia (Linn.) Huds. | Lamiaceae | Whole plant | Crude extract, petroleum spirit fraction, aqueous fraction (100-1000 mg/kg) | Loperamide | Castor oil-induced diarrhea model | Inhibition of spontaneous and high K⁺-induced contractions, spasmolytic activity, mediated possibly through CCB | [128,129] |
| Lajjalu | Mimosa pudica Linn. | Mimosaceae | Leaf | Essential oil (20-80 mg/kg) | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model | | [130,131] |
| Lajjalu | Mimosa pudica Linn. | Mimosaceae | Root | Ethanolic and aqueous extract (150 and 250 mg/kg) | Castor oil-induced diarrhea model, gastrointestinal motility in charcoal meal test | | [132] |
| Karvellaka | Monordica charantia | Cucurbitaceae | Leaf | Aqueous extract | Castor oil-induced diarrhea model, gastrointestinal transit, intestinal fluid accumulation and gastric emptying | | [133,134] |
| Shobhanjana | Moringa oleifera Lam. | Moringaceae | Leaf | Hydroalcoholic extract (2500 mg/kg) | Diphenoxylate (5 mg/kg orally) | Castor oil- and magnesium sulfate-induced gastro-intestinal motility, castor oil, and PGE₂-induced enteropooling, charcoal meal test | [135,136] |
| Surabhi-nimba | Murraya koenigii (Linn.) Spreng. | Rutaceae | Leaf | Ethanolic extract (150 and 300 mg/kg) and alcoholic extract (400 mg/kg) | Atropine (0.1 mg/kg, i.p. and 0.5 mg/kg) | Castor oil-induced diarrhea model, charcoal meal test, and PGE₂-induced diarrhea | | [137] |
| Kamini | Murraya paniculata (L.) Jack. | Rutaceae | Leaf | Ethanolic extract (300 and 600 mg/kg) | Diphenoxylate (5 mg/kg orally) | Castor oil-induced diarrhea model, gastro-intestinal motility in the charcoal meal test | | [138] |
| Kadali | Musa paradisiaca Linn. | Musaceae | Sap | 0.25, 0.50, and 1.00 mL | Diphenoxylate (5 mg/kg orally) | Castor oil-induced diarrhea model, castor oil-induced enteropooling, and gastro-intestinal motility | Inhibition Na⁺-K⁺ ATPase activity | [139] |
| Jatiphala | Myristica fragrans Houtt. | Myristicaceae | Flower bud | Aqueous extract and petroleum ether extract | Atropine | Antispasmodic | Inhibited the contraction produced by acetylcholine, histamine, and prostaglandin | [140-142] |
| Kamala | Nelumbo nucifera Gaertn. | Nymphaeaceae | Rhizome | (100, 200, 400, and 600 mg/kg) | Castor oil-induced diarrhea model and PGE₂-induced enteropooling and charcoal meal test | | |
| Sanskrit name | Botanical name | Family | Part used | Extract/dose | Standard drug and dose | Model | Mechanism | References |
|--------------|----------------|--------|-----------|--------------|------------------------|-------|-----------|------------|
| Root bark    | *Castor officinalis* | **Euphorbiaceae** | Root bark  | Methanolic extract (100, 200, 400, and 600 mg/kg) | Loperamide (10 mg/kg, p.o.) | Castor oil-induced diarrhea model | Possibly through the presence of Ca²⁺ antagonist | [143] |
| Rhizome      | *Oroxylum indicum* | **Bignoniaceae** | Rhizome   | Methanolic extract (400 mg/kg) | Loperamide (66.67 μg/kg, p.o.) | Castor oil-induced diarrhea model | - | [144, 145] |
| Seed oil     | *Oxalis corniculata* | **Gerniaceae** | Seed oil  | Crude hexane extract | - | Castor oil-induced diarrhea model | - | [146] |
| Root         | *Paederia foetida* | **Rubiaceae** | Root      | Aqueous, ethanolic extract (300-1000 mg/kg) | Atropine (5 mg/kg) | Castor oil-induced diarrhea model | - | [147] |
| Stem bark    | *Phoenix dactylifera* | **Palmaceae** | Stem bark | Methanolic extract (400 mg/kg) | Loperamide (5 mg/kg) | Castor oil-induced diarrhea model | - | [148] |
| Bark         | *Piper nigrum* | **Piperaceae** | Bark      | Flavonoids rich fraction | - | Castor oil-induced diarrhea model | - | [149-153] |

Contd...
| Sanskrit name | Botanical name | Family         | Part used | Extract/dose            | Standard drug and dose | Model                                           | Mechanism                                                                                      | References |
|--------------|----------------|----------------|-----------|-------------------------|------------------------|------------------------------------------------|------------------------------------------------------------------------------------------------|------------|
| Karkatasringi | *Pistacia integerrima* (J. L. Stewart ex Brandis) | Anacardiaceae | Gall      | Methanolic extract (700 and 900 mg kg) | Loperamide (10 mg/kg) | Castor oil-induced diarrhea model, spontaneous contractions in isolated rabbit jejunum | Inhibitory effect on prostaglandins                                                                 | [154]      |
| Karanja      | *Pongamia pinnata* (Linn.) Pierre. | Fabaceae       | Leaf      | Aqueous extract         | -                      | Antibacterial, antiangiudial and antirotaviral activity | Inhibits adherence of EPEC and invasion of EIEC and *Shigella flexneri* to epithelial cells | [155]      |
| Peruka       | *Psidium guajava* Linn. | Myrtaceae      | Leaf      | Aqueous extract (50-400 mg/kg) | Loperamide (10 mg/kg, p.o.) | Castor oil-induced diarrhea model | | [156-158] |
|              |                |                | Bark      | Methanolic and aqueous extract (100 mg/kg) | Loperamide (1 mg/kg, i.p.) | Gastrointestinal Motility, castor oil-induced diarrhea model, and PGE₂-induced enteropooling | | |
| Bijaka       | *Pterocarpus marsupium* | Fabaceae       | Heartwood | Ethanolic extract (250 and 500 mg/kg,) | Loperamide (5 mg/kg, p.o.) | Castor oil and charcoal-induced gastrointestinal motility test, intestinal transit of charcoal meal | Castor oil-induced diarrhea and PGE₂-induced enteropooling model, spontaneous movement of the isolated rat ileum, acetylcholine-induced contractions test | [159]      |
| Dadima       | *Punica granatum* Linn. | Punicaceae     | Seed      | Methanolic extract      |                        | Antimotility and antisecretory activity | | [160-162] |
|              |                |                | Peels     | Aqueous extract (100, 200, 300, and 400 mg/kg) |                        | | | |
|              |                |                | Rinds of fruit | Polyherbal formulation Aqueous extract | Mebarid (10 ml/kg, po) | Castor oil-induced diarrhea model, intestinal secretion, and charcoal meal test | | [163] |
| Mayaphala    | *Quercus infectoria* | Fagaceae       | Gall      | Ethanolic extract (250 and 500 mg/kg,) | Loperamide (3 mg/kg, p.o.) | Castor oil and magnesium sulfate-induced diarrhea models | | [164] |
| Sarpagandha  | *Rauvolfia serpentina* Benth. ex Kurz. | Apocynaceae | Root | Methanolic extract (100, 200, and 400 mg/kg) | Diphenoxylate (5 mg/kg, p.o.) | Castor oil-induced diarrhea model | | [165] |
| Manjistha    | *Rubia cordifolia* L. | Rubiaceae      | Root | Ethanolic extract (50, 100 mg/kg) |                        | Castor oil-induced diarrhea model, gastrointestinal transit time | | |
Table 1: (Contd...)

| Sanskrit name | Botanical name          | Family          | Part used | Extract/dose                                      | Standard drug and dose | Model                                                                 | Mechanism                                                                 | References |
|---------------|-------------------------|-----------------|-----------|--------------------------------------------------|------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------------|------------|
| Chandan       | Santalum album Linn.    | Santalaceae     | Heartwood | Methanolic extract (200, 400, and 800 mg/kg)     |                        | Castor oil-induced diarrhea model                                     | Spasmolytic role relaxed the acetylcholine-induced, 5-HT-induced and K⁺-induced contractions | [166]      |
| Asoka         | Saraca asoca (Roxb.) De Wilde | Caesalpiniaeae | Stem bark | Hydroalcoholic, acetone extract (200 mg/kg)      | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model                                     |                                                                          | [167]      |
| Kushtha       | Saussurea lappa Clarke  | Asteraceae      | Essential oil | 100, 300, and 500 mg/kg | Loperamide (5 mg/kg) |                                                                          |                                                                          | [168]      |
| Raj Bala      | Sida rhombifolia        | Malvaceae       | Root      | Methanolic extract (200 and 400 mg/kg)          | Diphenoxylate (5 mg/kg) | Castor oil-induced diarrhea model, intestinal transit, and castor oil-induced intestinal fluid accumulation (enteropooling) |                                                                          | [169]      |
| Kupilu        | Strychnos nux-vomica Linn. f. | Loganiaceae    | Root bark | Aqueous and Methanolic extract (3, 7.5, and 15 mg) Methanolic extract | Diphenoxylate (5 mg/kg) | Castor oil-induced diarrhea model                                     |                                                                          | [42]       |
| Kataka        | Strychnos potatorum Linn. | Loganiaceae    | Seed      | Methanolic extract (125, 250, and 500 mg/kg)    | Verapamil (50 mg/kg)   | Castor oil-induced diarrhea model, effects on gastrointestinal motility and PGE₂-induced gastric enteropooling |                                                                          | [170]      |
| Lodhra        | Symplocos racemosa Roxb. | Symplocaceae   | Bark      | Ethylacetate chloroform, n-butanol and aqueous fraction (300, 500 mg/kg) | Loperamide (2 mg/kg, p.o.) | Castor oil-induced diarrhea model, charcoal meal test, castor oil-induced intestinal secretions |                                                                          | [171]      |
| Jambu         | Syzygium cuminii Linn. Skeels | Myrtaceae      | Seed      | Aqueous extract (125, 250, and 500 mg/kg)       | Verapamil (50 mg/kg)   | Castor oil-induced diarrhea model, effects on gastrointestinal motility and PGE₂-induced gastric enteropooling |                                                                          | [172]      |
| Sharpunkha    | Tephrosia purpurea (Linn.) Pers. | Fabaceae      | Whole plant | Methanolic extract (300 mg/kg)                  | Verapamil (50 mg/kg) | Castor oil-induced diarrhea model, effects on gastrointestinal motility and PGE₂-induced gastric enteropooling |                                                                          | [173]      |
| Arjuna        | Terminalia arjuna (Roxb.) W. & A. | Combretaceae | Bark      | Methanolic extract (100, 200, and 400 mg/kg)    | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model, effects on gastrointestinal motility and PGE₂-induced gastric enteropooling |                                                                          | [174]      |
| Bibhitaki     | Terminalia bellirica Roxb. | Combretaceae   | Fruit     | Aqueous and ethanolic extract (143, 200, and 334 mg/kg) | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model, effects on gastrointestinal motility and PGE₂-induced gastric enteropooling |                                                                          | [175]      |
| Parisha       | Theespesia populnea Soland. Ex. Correa | Malvaceae | Stem bark | Methanolic fraction (100 mg/kg) and residue fraction (10, 25, and 50 mg/kg) of aqueous extract | Loperamide (3 mg/kg) | Castor oil-induced diarrhea model, PGE₂-induced diarrhea, charcoal meal test | Inhibition of elevated prostaglandin biosynthesis, reduced propulsive movement of the intestine | [176,177] |
|               |                         |                 |           | Aqueous extract (100, 200, and 400 mg/kg) and alcoholic extract (50, 100, and 200 mg/kg) | Atropine (3 mg/kg)     |                                                                 | Castor oil-induced diarrhea model; PGE₂-induced enteropooling, charcoal meal test |                       |

Contd...
| Sanskrit name | Botanical name | Family | Part used | Extract/dose | Standard drug and dose | Model | Mechanism | References |
|--------------|----------------|--------|-----------|--------------|------------------------|-------|-----------|------------|
| Guduchi | Tinospora cordifolia (Willd.) Miers ex Hook.f. & Thoms. | Menispermaceae | Stem | Ethanolic and aqueous extract | Loperamide (3 mg/kg, p.o.) | Castor oil and magnesium sulfate-induced diarrhea | [178] |
| Adhapushpi | Trichodesma indicum R.Br. | Boraginaceae | Root | Ethanolic extract | | | [179] |
| Methika | Trigonella foenum-graecum Linn. | Fabaceae | Whole plant | Aqueous extract (100, 200 mg/kg) | Loperamide (1 mg/kg, i.p.) | Castor oil-induced diarrhea model | [180] |
| Pind tagar | Valeriana hardwickii Wall. | Valerianaceae | Rhizome | Aqueous-Methanolic extract | Loperamide (10 mg/kg) | Castor oil-induced diarrhea model | [181] |
| Sampushpa | Vinca major L. | Apocynaceae | Aerial part | Ethanolic extract (250, 500, and 1000 mg/kg) | Loperamide (3 mg/kg, p.o.) | Castor oil-induced diarrhea model, castor oil and magnesium sulfate-induced enteropooling, gastrointestinal motility test using charcoal meal methods | [182] |
| Kutaja | Wrightia tinctoria Roxb. R.Br. | Apocynaceae | Bark | Ethanolic extract (500 and 1000-189 mg/kg) and isolated steroidal alkaloid fraction (50 and 100 mg/kg) | Loperamide (0.5 mg/kg), atropine (0.1 mg/kg, i.p.) | Castor oil-induced diarrhea model, charcoal meal, PGE2-induced enteropooling | [183] |
| Adaraka | Zingiber officinale Rosc. | Zingiberaceae | Rhizome | Zingerone | Loperamide (5 mg/kg, i.p.) | Intraluminal pressure changes and expelled fluid volume from the colon | [184] |
| Badara | Ziziphus jujuba Mill. | Rhamnaceae | Leaf | Aqueous extract | | Castor oil and magnesium sulfate-induced diarrhea models | [185] |
| Badara | Ziziphus mauritiana | Rhamnaceae | Root | Methanolic extract (25 and 50 mg/kg) | Diphenoxylate (2.5, 5 mg/kg) orally | Castor oil-induced diarrhea model and castor oil-induced fluid accumulation, spontaneous movement of the isolated rabbit jejunum, gastrointestinal transit time | [186] |

PGE2: Prostaglandin E2, CCB: Calcium channel blockade, EPEC: Enteropathogenic Escherichia coli, EIEC: Enteroinvasive Escherichia coli
Many phytoconstituents such as lupinifolin isolated from *Eriosema chinense*, omonoukanin B, dimethoxyflavone isolated from the stem bark of *Stereospermum kunthianum*, 6-(4-hydroxy-3-methoxyphenyl)-hexanonic acid, isovanillin, iso-acetovanillon from *Pycnocycla spinosa* Decne. Ex Boiss., have been evaluated for anti-diarrheal activity. However, in the mentioned list of ayurvedic plants limited isolation of the active constituents have been done which accounts for the numerous scope in this area for analytical, pharmacognostical as well as pharmacological screening of the active principles from these plants. Some of the constituents such as kurryram, koenimbine, koenine, piperine, and berberine are mentioned in the list with reported antidiarrheal activity [189-192].

Newer technologies such as in-silico, docking studies, interaction with enterotoxin from causative organism and nanotechnology were also employed in the antidiarrheal agent research works [193,194]. However, unfortunately, such advanced techniques were not used for the above listed ayurvedic plants. However, a few clinical trials reveal that the plants acts via a number of mechanisms, i.e., anti-inflammatory, antisecretory antimicrobial effect against *V. cholerae* and enterotoxigenic *E. coli*, rotavirus, detoxification of toxins and constipate, adsorbent, providing a rich source of calories; antimotility and antispasmodics effects [195].

**CONCLUSION**

The ethnomedicinal approach for diarrhea is a practical, cost-effective, and a logical for its treatment. Present data show that only a few isolated compounds from plants were investigated for antidiarrheal potential. Therefore, a significant research of chemical and biological properties of such less explored plants is still needed to determine their antidiarrheal efficacy which will possibly define their exact mechanism of actions.

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