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RESEARCH ARTICLE

BOTANICAL ANTHELMINTICS

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ABSTRACT

Helminth parasitism especially gastrointestinal parasitism is one of the major health problems severely limiting the animal productivity in dairy animals. Chemotherapy is a major treatment modality used for the control of helminth infection in livestock. However, due to increasing development of anthelmintic resistance and the limited availability of commercial drugs to the rural people as well as the high cost of such synthetic medicines, a growing interest in the ethno-veterinary approach to examine the anthelmintic properties of plants traditionally used by local farmers in different parts of the globe is emerging. Medicinal plants are resources of new drugs and have served through ages, as a constant source of medicaments for the treatment of a variety of diseases and are known to provide a rich source of botanical anthelmintics. A large number of plant products are being used to combat gastro-intestinal parasites of livestock and also humans. Phytotherapeutic drugs are safe, non-toxic, biodegradable and do not leave residues in animals products. This review paper summarizes the anthelmintic activities of the medicinal plants and possible mode of action which could be further explored for the identification of lead compounds and development of potential anthelmintic drug.

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INTRODUCTION

Livestock, an adjunct to agriculture, plays an important role in the future growth and development of Indian economy. India has the largest livestock population which constitutes nearly 7% towards its national income where cattle and buffaloes generate 54% of energy for agricultural operations. The livestock provides regular employment to 18.4 million people. Helminth parasitism especially gastrointestinal parasitism is one of the major health problems severely limiting the animal productivity in dairy animals. Any effort to intensify livestock production has been seriously affected by various factors, of which the most serious losses are due to gastrointestinal (GI) helminths.

Paramphistomosis and haemonchosis are the major parasitic diseases reducing the production potential of livestock. Clinical paramphistomosis is associated with few species of flukes namely *Cotylophoron cotylophorum, Fischoederius elongatus, Gastrothylax crumenifer, Gigantocotyle explanatum, Paramphistomum cervi* and *Paramphistomum epilectum.* Clinical signs include anorexia, weight loss, foetid diarrohea, dehydration and death**.** Pathogenesis due to *Haemonchus contortus* is associated with the haematophagic activities of developing larvae and adult worms. The greatest losses associated with helminth infection are sub-clinical, and economic assessments show that financial costs of internal parasitism are enormous due to increase in mortality, and a reduction in growth rate and wool production. Chemotherapy is a major treatment modality used for the control of helminth infection in livestock. However, chemotherapeutic anthelmintic drugs for the control of helminth infection are far from satisfaction, probably due to the absence of broad-spectrum activity of these drugs. Resistance to chemotherapeutic anthelmintics is an increasing problem in many countries (Waller and Prichard, 1985)**.** Furthermore, side effects on the host are a serious problem with many chemotherapeutic anthelmintics currently available. It is imperative to decrease the reliance on these chemotherapeutic drugs for parasite control, not only because of resistance, but also because of growing concerns about the adverse consequences of these anti parasitic drugs on the ecosystem and biodiversity. This danger has given impetus to the search for new drugs, with attention focusing on the search for plant products and the application of plant products as alternative methods of control. Environmental aspects favouring plant anthelmintics include their biodegradability.

On the other hand, chemotherapeutic anthelmintics poses the problem of soil contamination and also residual amounts of these anthelmintics may be found in the faeces after treatment and these may have deleterious effects on the environment. Naturally produced plant anthelmintics offer an alternative that can overcome some of these problems and is both sustainable and environmentally acceptable. In response to the need to discover new anthelmintic drugs of natural origin with possibly low toxicity to host animals and also to raise them

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free from chemical inputs, there is a growing interest in ethno medical and ethno veterinary practices across the world (Guarrera, 1999). In this regard, several medicinal plants have been investigated for their anthelmintic properties. However, scientific evidence on the anthelmintic efficacy of most plant products is limited, regardless of their wide ethno veterinary usage. Scientific validation of anthelmintic effects and possible side-effects of plant products in ruminants is necessary prior to their adoption as a novel method for parasite control.

Validation of anthelmintic activities of plants

Pharmacodynamic interaction of drug or plant extracts can be better described using both *in vitro* and *in vivo* studies. *In vitro* studies offer rapid, sensitive and more economical methods for screening and evaluation of anthelmintic activity of plant extracts. Most of the effects recorded *in vitro* also occur *in vivo* (Rahman and Bryant, 1977) and contribute to the anthelmintic efficacy.

Table 1. List of plants with anthelmintic activity

Plant	Part Used	Target parasite	Host	Reference
Acacia albida	Seeds	Worm infestation	Sheep, goat	Nwude and lbrahim(1980)
Acacia arabica willd.	Root, stem, bark	G.I nematodes	Sheep	Tariq and Tantry (2012)
Acacia Arabica	Bark	*Cotylophoron cotylophorum*	Sheep	Veerakumari *et al*. (2012a)
Acacia Arabica	Bark	*C. cotylophorum*	Sheep	Veerakumari *et al*. (2013)
Acacia concinna	Pods	*C. cotylophorum*	Sheep	Priya *et al*. (2013)
Acacia karoo	Ethanol extract	*H. contortus*	Goat	Kahiya *et al.*(2003)
Acacia mearnsii	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al*. (2007)
Acacia polyacantha	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
Acacia tortilis	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
Achillea millifolium Linn.	Whole herb	G.I nematodes	Sheep	Tariq and Tantry (2012)
Aconitum chasmanthum Stapf.	Root	G.I nematodes	Sheep	Tariq and Tantry (2012)
Aconitum heterophyllum Wall. ex. Royle.	Root	G.I nematodes	Sheep	Tariq and Tantry (2012)
Aconitum violaceum	Root	G.I nematodes	Sheep	Tariq and Tantry (2012)
Acorus calamus Linn.	Rhizome	G.I nematodes	Sheep	Tariq and Tantry (2012)
Adhatoda vasica	Roots	Mixed GI G.I nematodes	Sheep	Lateef *et al.* (2003)
Adhatoda vasica	Leaves	*C. cotylophorum*	Sheep	Jeya and Veerakumari (2015)
Ajuga bracteosa Wall.	Whole herb	G.I nematodes	Sheep	Tariq and Tantry (2012)
Albizia anthelmintica	Bark and root	*Haemonchus contortus* and *Trichuris ovis Fasciola,* Lungworms	Cattle, goat, sheep	Minja (1989); ITDG and IIRR (1996)
Albizia anthelmintica	Bark	Anthelmintic	Cattle, goat, sheep	Minja (1989); ITDG and IIRR, (1996)
Albizia anthelmintica	Bark	*Fasciola gigantica*	Goat	Koko *et al.* (2000)
Albizia coriavera	Bark	Fasciola spp., Lungworms	Cattle, goat, sheep	ITDG and IIRR (1996)
Albizia lebbek	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
Alstonia boonei	Bark	*Ascaris suum Onchocerus volvulus*	Cattle, goat, sheep	Fakae *et al.*(2000)
A. sativum	Bulb	Roundworms	Cattle, goat, sheep	ITDG and IIRR (1996)
A. sativum	Bulb	Round-worms	Cattle, goat, sheep	Iqbal *et al.* (2001)
A. sativum	Bulb/alcoholic extract	*Fasciola gigantica, Gigantocotyle explanatum*	Cattle, goat, sheep	Singh *et al*. (2007)
A. sativum	Bulbs	GI nematodes	Goat	Amin *et al*. (2009)
A. sativum	Bulb/aqueous extract	*Fasciola gigantica*	Cattle	Jeyathilakan *et al*. (2012)
A. sativum	Bulb/Aqueous extract	*Bunostomum trigonocephalum*	Cattle, goat, sheep	Khobragade *et al*. (1994)
A. sativum	Bulb/Oil extract	*Asaridia galli, Heterakis gallinarum*	Cattle, goat, sheep	Singh and Nagaich (1999)
A. sativum	Bulb/Methanol extract	*H. contortus*	Goat, sheep	Iqbal *et al*. (2001)
A. sativum	Bulbils/ Aqueous extract	*H. contortus*	Sheep	Veerakumari and Lakshmi (2006)
A. sativum	Bulbils/Aqueous extract	*C. cotylophorum*	Sheep	Veerakumari *et al.* (2012b)
A. sativum	Bulb	G.I nematodes	Sheep	Tariq and Tantry (2012)
Amaranthus spinosus	Ethanol extract	GI neamatodes	Goat	Sujon *et al*. (2008)
Ananas comosus	Leaves extract	*Toxocara vituloram*	Calves	Islam *et al.*(2005)
A. comosus	Ethanol extract	GI neamatodes	Goat	Sujon *et al*. (2008)
A. comosus	Leaves	*Trichuris ovis* and *Trichuris globosa*	Ruminants	Behnke *et al.* (2008)

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A. comosus	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Andrographis paniculata	Leaves/Aqueous extract	*H. contortus*	Sheep and goat	Singh *et al*. (2011)
Areca catechu	Nut	Taenicidal	Cattle, goat, dog	Roepke (1996)
Areca caetcheu	Nut, Ethanol extract	*C. cotylophorum*	sheep	Manoj Dhanraj and Veerakumari (2015 a)
Artemesia absinthium	Root powder/aqueous extract	G.I nematodes	Sheep	Tariq *et al*. (2009)
A. maritime	Whole herb	*Neoascaris vitulorum*	Buffalo, calves	Akhtar *et al*. (1982); Farnsworth *et al*. (1985); Sherif *et al*. (1987)
A. maritime	Whole herb	G.I nematodes	Sheep	Tariq and Tantry (2012)
A. absinthium	-	G.I nematodes	Sheep	Tariq and Tantry (2012)
A. brevifolia	Crude methonolic and aqueous extract of whole plant	*H. contortus*	Sheep	Iqbal *et al.* (2004)
A. herbaalba	Powdered shoots	*H. contortus*	Sheep and goat	Idris *et al.* (1982)
A. maritime	Whole herb	*Neoascaris vitulorum*	Buffalo, calves	Akhtar *et al*. (1982); Farnsworth *et al*. (1985); Sherif *et al*. (1987)
A. maritime	Root powder	*H. contortus*	Sheep and goat	Jangde *et al*. (2001)
Artemisia mesatlantica	Flavonoids and sesquiterpene lactones	Anthelmintic	Sheep and goat	Holeman *et al.* (1991)
Asparagus filicinus Buch.	Root	G.I nematodes	Sheep	Tariq and Tantry (2012)
Azadirachta indica	Fruit seed and oil	G.I nematodes *(Trichostongylids)*	Small ruminants	Mostofa *et al.* (1996)
A. indica	Leaves/methanol extract	*H. contortus*	Goat	Arora *et al.* (2010)
A. indica	Cake and Leaves	Anthelmintic	Small ruminants	Gowda (1997); Mostofa *et al.*(1996)
A. indica	Leaves/Ethanol extract	*Trichuris globulosa*		Sarwal *et al*.(2000)
A. indica	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus* and *Cooperia*	Sheep and goat	Max *et al.* (2007)
A. indica	Bark/Alcoholic extract	*H. contortus*	Sheep	Swarnakar *et al.* (2008a)
A. indica	Leaves/aqueous extract	*H. contortus*	Sheep and goat	Singh *et al*. (2008)
A. indica	Metanol extract	*Fasciola gigantica*	Livestock	Kushwaha *et al.*(2004)
A. indica	Ethanol extract	*C. cotylophorum*	Sheep	Veerakumari and Priya (2006)
A. indica	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Balanites aegyptiaca		*Fasciola gigantica*	Goat	Koko *et al.* (2000)
Bauhinia tomentosa	Leaves/Aqueous and ethanol extracts	*H. contortus*	Sheep and goat	Vihan *et al*. (2007)
Bauhinia variegate	Leaves/Methanol extract	*H. contortus*	Sheep and goat	Bharadwaj *et al*. (2010)
Boswellia dalzelii	Bark	Anthelmintic	Sheep, goat	Nwude and Ibrahim (1980)
Brassica nigra Linn.	Seed	G.I nematodes	Sheep	Tariq and Tantry (2012)
Butea frondosa	Seeds	*Ascaridia galli*	*In vitro*	Lal *et al.*(1976)
B. frondosa	Seed/ether extract	*Ascaridia galli*		Sharma and Sisodia (1976)
B. frondosa	Seeds/Palasonin	*Ascaris lumbicoides*	Sheep	Rao *et al.* (1977)
B. frondosa	Seeds/Isolated a purified/Palasonin	*Ascaridia galli*	Livestock	Kumar *et al.* (1983)
B. frondosa	Seeds/Solution in ammonia (Palasonin)	*H. contortus*	Sheep	Sathianesan *et al.* (1984)
B. frondosa	Seeds/Ether and Alcoholic extracts	*Ascaridia galli*	Livestock	Shilaskar and Parashar (1989)
B. frondosa	Seeds/Aqueousextract (Palasonin)	*H. contortus*	Sheep	Jangde *et al.* (2001)
B. frondosa	Seeds/Aqueous, alcohol, ether and chloroform	*H. contortus*	Sheep	Swarnkar *et al.* (2008c)
B. frondosa	Seeds/Chloroform extract	*H. contortus*	Sheep	Vihan *et al.* (2007)
B. frondosa	Seeds/Palasonin	*Ascaris lumbicoides*	Sheep	Parker and Palmer (l991)

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B. monosperma	Seeds	Anthelmintic, GI G.I nematodes	Sheep and others	Kalesaraj and Kurup(1968); Chandra and Sabir(1978); Lal *et al.*(1978); Prashanth *et al.* (2001) Iqbal *et al.* (2006)
B. monosperma	Seeds	*Paramphistomum cervi*	Goat	Chopra *et al.*(1991)
Caesalpinia crista	Seed powder	*Fasciola gigantica*	Buffalo	Kailani *et al.* (1995)
Caesalpina crista	Seeds	*Toxocara vitulorum Ascaridia galli*	Buffalo, calves, chicken	Akhtar *et al*. (1985); Javed *et al*. (1994)
Calliandra portoricensis	Roots, leaves, flowers	*Toxocaracanis*, Gastrointestinal G.I nematodes, *H. contortus*	Dog, Sheep	Adewunmi and Akubue (1981); Jain *et al.*(1996); A1-Qarawi *et al.* (2001); Iqbal *et al.*(2005)
Calotropis procera	Latex	Gastrointestinal nematodes, *H. contortus*	Sheep	Iqbal *et al*. (2005)
Calatropis gigantean	Leaves/Extract (Methanol)	*H. contortus*	Sheep and goat	Yadav *et al.* (2010)
Cannabis sativa Linn.	Leaf	G.I nematodes	Sheep	Tariq and Tantry (2012)
Capillipedium foetidum	Oil, grass	*Taenia solium* and *Ascaris lumbricoides*	*In vitro*	Siddiqui and Garg (1990)
Carica papaya	Seeds/Alcoholic extract	*Ascaridia galli*	Small ruminants	Lal *et al.* (1976)
C. papaya	Seeds/Aqueous extract	*A.galli* and *Heterakis gallinae*	Small ruminants	Singh and Nagaich (1999)
C. papaya	Leaves	*Trichuris ovis* and *Trichuris globosa*	Ruminants	Behnke *et al.* (2008)
C. papaya	Seeds	GI nematodes	Goat	Amin *et al*. (2009)
C. papaya	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Carissa edulis	Root	Roundworms	Cattle, goat, sheep	ITDG and IIRR (1996)
Casia tora	Seeds/Alcohol and aqueous extracts	*Ascaridia galli*	Small ruminants	Deore *et al.* (2009)
Cassia spectalis	Roots	Round-worms	Cattle, goat,	ITDG and IIRR (1996)
Chenopodium album	Leaves	G.I nematodes	Sheep	Akhtar *et al.* (1999)
Chenopodium album	Seeds/Methanol extract	*H. contortus*	Sheep	Yadav *et al.* (2010)
Chenopodium ambrosoides Linn.	Whole herb	G.I nematodes	Sheep	Tariq and Tantry (2012)
Chrysophyllum cainito	Stem	*H. contortus*	Cattle	Fernandez (1991)
Chrysothamnus viscidiflorus	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Cissampelos mucromata	Root	Helminths	Goat, sheep	Minja (1989)
Cimum basilicum	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Citrus aurantifolia	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Corchorus spp.	Ethanol extract	GI nematodes	Goat	Sujon *et al*. (2008)
Corchorus capsularis	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Croton macrostachys	Leaves	Anthelmintic		Minja (1989)
Curcuma longa	Rhizome	GI nematodes	Goat	Amin *et al*. (2009)
Cucurbita Mexicana	Methanol extract	*H. contortus*	Sheep and goat	Iqbal *et al.* (2001)
Cucurbita sp.	Methanol extract	G.I nematodes	Sheep	Tariq and Tantry (2012)
Cuscuta reflexa	Whole plant	GI nematodes	Goat	Amin *et al*. (2009)
Cyathocline lyrata	Essential oil	Tape-worms, hookworms	*In vitro*	Shrivastava (1979)
Cymbopogon flexuosus	Leaves/Essential Oil	Strongyles	Goat	Sahoo and Tripathy (2007)
Cynodon dactylon	Ethanol extract	G.I nematodes	Goat, sheep	Sujon *et al*. (2008)
Datura quercifolia	Fruit	*Ascaridia galli*	*In vitro*	Kaushik *et al.,*1981
Datura stramonium Linn.	Seeds	G.I nematodes	Sheep	Tariq and Tantry (2012)
Daucus carrota Linn.	Roots	G.I nematodes	Sheep	Tariq and Tantry (2012)
Delphinium denodatum Wall.	Seeds	G.I nematodes	Sheep	Tariq and Tantry (2012)
Diospyros mespilliformis	Bark	Anthelmintic	Sheep, goat	Minja (1989)
Diospyros scabra	Seeds	*Fasciola*	Cattle, goat, sheep	ITDG and IIRR (1996)
Dodonea viscosa	Leaves	Intestinal worms	Cattle	Sharma and Singh (1989)
Embelia kilimandschiraca	Root	Helminthosis	Cattle	Minja (1989)
Embelia ribes	Seeds/Aqueous extract	*H. contortus*	Sheep and goat	Swarankar *et al.* (2009)
E. ribes	Aqueous extract	*H. contortus*	Goat	Arora *et al.* (2010)
E. ribes	Seed/Aqueous and Alcoholic extracts	*Paramphistomum cervi*	Goat, sheep	Chopra *et al*.(1991)
E. ribes	Seed/Aqueous and Alcoholic extracts	*H. contortus*	Sheep	Swarnkar *et al.* (2009)
Ericameria nauseosa	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Erythrina senegalensis	Bark	*Fasciola* spp.	Ruminants	Nwude and Ibrahim (1980)
Eugeniu spp.	Ethanol extract	GI nematodes	Goat	Sujon *et al*. (2008)
Ferula asafetida	Extract	*Ascaridia galli and Heterakis gallinae*	Livestock	Nagaich and Singh (2001)

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Ferula costata	Crude methanol and aqueous extract	*H. contortus*	Sheep	Kakar *et al.* (2013)
Ficus religiosa	Leaves/Methanol extract	*H. contortus*	Goat, sheep	Iqbal *et al.* (2001)
Ficus spp	Leaves	*Trichuris ovis* and *Trichuris globosa*	Ruminants	Behnke *et al*. (2008)
Flemingia vestita	Tuber/Extract (genistein)	*Ascaris suum*	Small ruminants	Yadav *et al.* (1992)
Flemingia macrophylla	Leaves	*H. contortus*	Sheep	Nyguyen *et al.* (2005)
Fritillaria royeli Hook.	Bulb	G.I nematodes	Sheep	Tariq and Tantry (2012)
Fumaria parviflora	Plant Powder	*Tricho strongylus*, *Haemonchus, Trichuris, Fasciola* spp.	Sheep, buffalo	Akhtar and Javed, (1985); Kailani *et al.* (1995)
Gardenia gummifera		Round worm	Goats	Jangde and Bansod (2004)
Geranium viscosissimum	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Gliricidia sepium	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
Gmelina arborea	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Hagenia abyssainicia	Fruit	Round-worms	Cattle, goat, sheep	ITDG and IIRR, 1996
Holarrhena antidysenterica	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Hyoscyamus niger	Seeds	Mixed nematode Infection	*In vivo*	Akhtar and Ahmad, 1990
Inula racemesa Hook.	Root	G.I nematodes	Sheep	Tariq and Tantry (2012)
lstonia scholaris	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Juglans regia Linn.	Bark and Leaf	G.I nematodes	Sheep	Tariq and Tantry (2012)
Juniperus macropoda Boiss.	Leaf	G.I nematodes	Sheep	Tariq and Tantry (2012)
Juniperus communis Linn.	Fruit	G.I nematodes	Sheep	Tariq and Tantry (2012)
Khaya senegalensis	Bark	*H. contortus* *Trichostrongylus* Sp. *Oesophagostomum* Sp. *Strongyloides* Sp. *Trichuris* Sp.	Sheep	Ademola *et al.*(2004)
Lagen siceraria	Seeds	Cestodes, *moniezia, avitelina* spp.	Sheep	Akhtar and Riffat, 1987
Lansium domesticum	Seeds	*Ascaridia galli* *Ascaris suum* *H. contortus*	Goat	Fernandez (1991)
Lantana trifolia	Fruit	*Fasciola* spp., lungworms	Cattle, goat, sheep	ITDG and IIRR, 1996
Lawsonia inermis	Leaves	*Fasciola* spp.	Sheep, goat	Nwude and Ibrahim, 1980
Lawsonia inermis	Leaves	*Setaria digitata*	-	Banu *et al.*(1992)
Leucas aspera	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Leucena leucocephala *and* Leucena diversifolia	Leaves	Mixed GI infection	Small ruminants	Semenye, 1990; Adejumo and Ademosun, 1991).
Leucaena leucocephala	Seeds	*Ascaridia galli* *Ascaris suum* *H. contortus*	Chicken Pig, Goat	Fernandez (1991)
Lespedeza cuneata	fresh forage or hay	*H. contortus*	Sheep	(Min *et al*., 2004; Lange *et al*., 2006; and Shaik *et al*., 2006)
Liatris punctate	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
L. corniculatus	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Lotus pedunculatus		*Teladorsagia circumcincta*	Sheep	Niezen *et al.*(1998)
Luvunga scandena	Ethanol extract	*H. contortus*		Sujon *et al.* (2008)
Mallotus philippinensis	Leaves/Chloroform extract	*H. contortus*	Sheep and goat	Vihan *et al.* (2007)
M. philippinensis	Fruit	*Moniezia* and *Avitellina*	Beetal Goat	Akhtar and Ahmad (1992)
M. philippinensi	Essential oil	*Fasciola gigantica*	Sheep and goat	Kushwaha *et al.*(2004)
Momordica charantias				

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Mangifera indica	Seeds	*Ascaridia galli*	Chicken	Fernandez (1991)
Magnifera indica	Ethanol extract	G.I nematodes	Goat	Sujon *et al*. (2008)
Manihot esculenta	Leaves	*H. contortus*	Sheep	Nyguyen *et al.* (2005)
Matricaria chammomila Linn.	Aerial parts	G.I nematodes	Sheep	Tariq and Tantry (2012)
Melia azedarach	Fruit (Powdered)	G.I. nematodes	Goat	Akhtar and Riffat (1984)
M. azederach	Fruit	*Ascaridia galli* *Haemonchus, Trichostrongylus, Trichuris, Chabertia spp*.	Goat	Akhtar and Riffat (1985);
M. azedarach	Seed/Alcoholic extract	*H. contortus*	Goat	Misri *et al.* (2002)
M. azedarach	Bark	GI nematodes	Goat	Amin *et al*. (2009)
M. azedarach	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Melilotus alba	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Melilotus officinalis	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Mentha sylvestris Linn.	Whole herb	G.I nematodes	Sheep	Tariq and Tantry (2012)
Mimisa isp	Leaves	*H. contortus*	Sheep	Nyguyen *et al*., 2005
Mimosa pudica	Stem	*H. contortus*	Sheep and goat	Fernandez (1991)
M. pudica	Leaves	*H. contortus*	Sheep	Nyguyen *et al.* (2005)
Momordica charantia	Ethanol extract	GI nematodes	Goat	Sujon *et al*. (2008)
M. charantia	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
M. charantia	Stem	*Ascaris suum* *Ascaridia galli* *H. contortus*	Pig, Chicken, Goat	Fernandez (1991); Farnsworth *et al*. (1985)
Moringa oleifera	Seeds	*Ascaridia galli* *Ascaris suum* *H. contortus*	Chicken, Pig, Goat	Fernandez (1991)
Morus alba	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.,* 2007
Morus alba Linn.	Bark and Leaf	Nematodes	Sheep	Tariq and Tantry (2012)
Mixture of *Azadirachta indica* *Butea frondosa* *Nigella sativa* *Piper longum*	Ethanol extract	*H. contortus* *Paramphistomum cervi* *Oesophagostomum*	Cow claves	Raje *et al.*(2003)
Myrisine africana Linn.	Whole plant	Nematodes	Sheep	Tariq and Tantry (2012)
Myrsine africana	Leaf	Roundworms	Cattle, goat, sheep,	ITDG and IIRR (1996)
Nauclea latifolia	Roots	*Ascaris suum* *Onchocerus volvulus*	*In vitro*	Fakae *et al.*(2000)
Nelumbo nucifera Gaertn.	Whole plant	Nematodes	Sheep	Tariq and Tantry (2012)
Nepeta cataria Linn.	Leaf/whole plants	Nematodes	Sheep	Tariq and Tantry (2012)
Nicotiana tabacum	Dried leaves/ Decoction	*H. contortus*	Sheep and goat	Raje and Jangde (2003)
Nicotiana tobacum	Dried leaves/ Aqueous and methanol extracts	*H. contortus*	Sheep and goat	Iqbal *et al.* (2006)
Nicotiana tobacum	Ethanol extract	GI nematodes	Goat	Sujon *et al*. (2008)
N. tabacum	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Nigella sativa	Seed powder	*F. gigantica*	Buffalo	Kailani *et al.* (1995)
Nymphea alba Linn.	Whole plant	Nematodes	Sheep	Tariq and Tantry (2012)
Ocimum basilicum Linn.	Seeds	Nematodes	Sheep	Tariq and Tantry (2012)
O. gratissimum	Leaves	*Ascaris suum* *Onchocerus volvulus*	*In vitro*	Fakae *et al.*(2000)
O. sanctum	Leaves	*H. contortus*	Sheep and goat	Garg (1997)
O. sanctum	Leaves	*Setaria digitata*	Livestock	Banu *et al.*(1992)
Onobrychis viciifolia	Hay	GI infections	Goats	Paolini *et al*. (2004, 2005).
Peganum harmala	Seeds	Mixed GI infection, cestode infection	Goats	Akhtar and Ahmed (1991)
P. harmala	Seeds	Nematodes	Sheep	Tariq and Tantry (2012)
P. harmala	Seeds	Mixed gastrointestinal Cestode infection	Goat Sheep	Akhtar and Ahmad (1991); Akhtar and Riffat (1986)
Perideridia gairdneri	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Persea americana	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
Pinus wallichiana	Needles	Nematodes	Sheep	Tariq and Tantry (2012)
Piper betle	Leaves/Essential oil	*Ascaridia galli*		Shilaskar and Parashar (1989)
P. betle	Ethanol extract	GI nematodes	Goat	Sujon *et al*. (2008)
P. betle	Leaves	GI nematodes	Goat	Amin *et al*. (2009)

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Piliostigma thonningii *Ocimum gratissimum* *Nauclea latifolia* *Alstonia boonei*	Bark, leaves, Roots and bark extract	*Ascaris suum* *Onchocerus volvulus*	Ruminants	Fakae *et al.*(2000)
Platanus orientalis	Bark, Seed	Nematodes	Sheep	Tariq and Tantry (2012)
Pongamia glabra	Seeds/Ether extract	*H. contortus*	Sheep and goat	Arora *et al.* (2010)
Populus alba Linn.	Bark	Nematodes	Sheep	Tariq and Tantry (2012)
Populus nigra Linn.	Bark	Nematodes	Sheep	Tariq and Tantry (2012)
Prosopis cineraria	Bark	*H. contortus*	Sheep and goat	Swarnker *et al*., 2008(b)
P. cineraria	Bark, etanol extract	*C. cotylophorum*	Sheep	Manigandan and Veerakumari (2015)
Prunella vulgaris	Root and stem bark	Nematodes	Sheep	Tariq and Tantry (2012)
Psidium guajava	Leaves	*H. contortus*	Sheep	Nyguyen *et al*. (2005)
P. guajava	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
Punica granatum	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
P. granatum	Rind	*C. cotylophorum*	Sheep	Veerakumari *et al*. (2012 b)
P. granatum Linn.	Flowers and leaves	G.I nematodes	Sheep	Tariq and Tantry (2012)
Quisqualis indica	Seeds	*H. contortus*	Goat	Xiao and Lin (1986)
Quisqualis indica	Stem	*Ascaris suum* *Ascaridia galli* *H. contortus*	Pig, Chicken, Goat	Fernandez (1991); Farnsworth *et al*. (1985)
Raphanus sativus	Root	Nematodes	Sheep	Tariq and Tantry (2012)
Rapanea melanoploeos	Seeds	Roundworms	Cattle, goat, sheep	ITDG and IIRR (1996)
Rhamnus principides	Leaves	Anthelmintic	Cattle, goat, sheep	Minja (1989)
Rhus vulgaris	Root	Roundworms	Cattle, goat, sheep,	ITDG and IIRR (1996)
Rhus vulgaris	Roots	Round-worms	Cattle, goats, sheep	ITDG and IIRR (1996)
Rhus aromatic	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Roltleria tinctoria		*Paramphistomum cervi*	Sheep and goat	Chopra *et al*.(1991)
Salvia plebeja	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Salix alba Linn.	Bark	Nematodes	Sheep	Tariq and Tantry (2012)
Sanguinaria canadensis	Methanol extract	*H. contortus*	Goat, sheep	Acharya *et al*. (2014)
Senecio lyratiparitus	Leaves	Anthelmintic	Goat, sheep	Minja (1989)
Schinopsis sp	Bark extract	*H. contortus*	Goat and sheep	Paolini *et al*. (2004)
Skimmia laureola	Essential oil from root, stem and leaves	*H. contortus*	Sheep	Mehmood *et al*. (2011)
Solanum nodiflorum	Fruit	Worm infestation	Sheep and goat	Nwude and Ibrahim (1980)
Spigelia anthelmia	Aerial parts	*H. contortus*	Sheep and goat	Assis *et al.*(2003)
Stephania glabra	Ethanol extract	*Fasciolopsis buski* *Raillietina echinobothrida*	Livestock	Tandon *et al.* (2004)
Syzygium aromaticum	Bud	*C. cotylophorum*	Sheep	Manoj Dhanraj and Veerakumari (2014;2015 a, b)
Tagetes patula	Flowers/Methanol extract	*H. contortus*	Sheep and goat	Bhardwaj *et al.* (2010)
T. patula	Flowers/Methanol extract	*H. contortus*	Sheep and goat	Singh *et al.*(2002)
Tamarindus indica	Leaves extract	*H. contortus, Oesophagostomum, Trichostrongylus and Cooperia*	Sheep and goat	Max *et al.* (2007)
T. indica	Root	Roundworms	Cattle, goat, sheep,	ITDG and IIRR (1996)
Terminalia arjuna	Bark/Crude methanolic extract	*H. contortus*	Sheep	Bachaya *et al.* (2009)
Terminalia chebula	Dry fruits	*Cotylophoron cotylophorum*	Sheep	Lokesh and Veerakumari(2015)
Thuja sinensis	Leaves/Ethanol extract	*H. contortus*	Sheep and goat	Vihan *et al.* (2007)
Tiinospora rumphii	Stem	*H. contortus*	Goat	Fernandez (1991)
Trachispermum ammi	Seeds/Extract with various solvents (Ethanol, methanol)	*Setaria cervi*	Sheep	Rizvi *et al.* (2012)
Trachyspermum ammi	Seed/Extract	*H. contortus*	Sheep	Lateef *et al.* (2006)
Trichilia emetic	Bark	*Fasciola* spp. lungworms	Cattle , goats,sheep	ITDG and IIRR (1996)

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Trichosanthes multiloba		*Fasciolopsis buski R. echinobothrida*	Livestock	Tandon *et al.* (2004)
Trigonella foenum-graecum	Seeds	*Gastrothylax crumenifer*	Buffaloes	Swarnakar *et al*. (2014)
Urtica dioica Linn.	Leaf	Nematodes	Sheep	Tariq and Tantry (2012)
Uvaria hookeri	Root-bark	*H. contortus*	Sheep and goat	Padmaja *et al*. (1993)
Vernonia amygdalina	Stem, bark	*H. contortus*	*In vitro*	Alawa *et al.* (2003)
V. anthelmintica	Seeds/Ether and alcoholic extracts	*Ascaridia galli*	Livestock	Shilaskar and Parashar (1989)
Vitex negundo	Leaves	GI nematodes	Goat	Amin *et al*. (2009)
Xanthium flexuosus	Leaves/Fresh Juice	*H. contortus*	Sheep and goat	Sharma *et al.* (2003)
Xanthium strumarium		*H. contortus*	Sheep and goat	Sharma *et al.*(2003)
Zingiberus officinale	Rhizome/ Methanol extract	*H. contortus*	Sheep and goat	Iqbal *et al.* (2001)
Z. officinale	Rhizome/Extract	G.I. nematodes	Sheep	Iqbal *et al.* (2006)

However, concentrations of potentially active substances used *in vitro* do not always correspond to *in vivo* bioavailability. Hence, further *in vivo* study is required to enlighten the therapeutic potential of plant extracts in treating helminth infection. The *in vivo* assay such as faecal egg count reduction test is suitable for the evaluation of all types of anthelmintics (Verma *et al*., 2006). Further, *in vivo* observations on the haematobiochemical profile can offer more insights into the safety and protective efficacy of the plant extracts.

Many of the *in vitro* investigations on anthelmintic activity of plants, their oils, or extracts have been based on their toxic effects on the earthworm, *Pheritima posthuma* (Gaind and Budhiraja, 1967; Kokate and Varma, 1971; Dixit and Varma, 1975; Banerjee and Nigam, 1978; Girgune *et al.,* 1978; 1979; Garg and Kasera 1982a, b; Nanda *et al.,* 1987; Siddiqui and Garg, 1990; Garg and Siddiqui, 1992). However anthelmintic potential of plants should not be assessed based on their efficacy against earthworm. The anatomy and physiology of earthworm, which is an annelid and terrestrial in habitat differ from helminth parasites. Helminths are endo-parasites protect themselves by the production of anti-enzymes and derive energy through anaerobic metabolism. The plants which are effective against earthworm may not have anthelmintic efficacy. Even among the helminth parasites, the plants which are effective against trematodes are not effective against nematodes or cestodes. Hence using earthworm as a model for testing anthelmintic efficacy is inappropriate. Larval and adult Nematodes, cestodes and trematodes are used for the evaluation of anthelmintic activity of different plant material by various researchers (Aktar *et al.,* 2000; Veerakumari and Priya, 2006; Veerakumari and Lakshmi, 2006).

The most common effect of anthelmintic drugs against worm infections is paralysis of the parasite musculature either by inhibiting the neuromuscular transmission or enzymes involved in energy production; however, certain other drugs damage the tegument allowing partial digestion or rejection by the host immune system (Manger, 1991). The pharmacologic basis of the treatment for helminth infection generally involves interference with the integrity of parasite cells, neuromuscular coordination, energy metabolism or protective mechanisms against host immunity, which lead to starvation, paralysis, and expulsion or digestion of the parasite. A full understanding of the way in which drugs achieve their action helps to identify susceptible parasite systems and show the properties of drugs necessary to attack them.

Usage of plant anthelmintics to combat gastrointestinal helminths of small ruminants is well documented by several parasitologists (Hammond *et al.,* 1997; Schillhorn van Veen, 1997; Akhtar *et al.,* 2000; Tagboto and Towson, 2001; Githori *et al.,* 2006; Piyush *et al.,* 2013; Pathak and Chhabra, 2014). Aqueous and various solvent extracts viz. hexane, chloroform, ethylacetate, alcoholic extracts, pastes, essential oils, extracted from leaves, stem, fruits, flowers and roots or whole plants were used to test their anthelmintic efficacy *in vitro* or *in vivo.* Plants with anthelmintic activity are shown in Table 1.

An anthelmintic drug which could cause adverse changes to a parasite but not the host is said to be potential anthelmintics drug. Anthelmintic drugs impair the vital activities of the parasite and consequently result in the death of the parasites. The most common effect of anthelmintic drug is paralysis of parasite musculature either by inhibiting neuro-muscular transmission or enzymes involved in energy production (Manger, 1991: Veerakumari and Munuswamy, 2000). Drugs may also damage the tegument allowing partial digestion or rejection by host immune system. Anthelmintic drugs may induce pathological changes in various organ systems of the parasites affecting the vital physiological functions viz. excretion, osmoregulation and reproduction (Veerakumari and Munuswamy, 1999; Veerakumari and Paranthaman, 2004).

Mode of action of Phytoconstituents

Whole plant consumption has shown good anthelmintic effects against GI parasites of sheep. This could be either due to direct toxic effects on the parasites or it can be indirect due to changes in the gut environment that favour low fecundity and worm expulsion. The mechanisms whereby the consumption of certain plants and plant extracts can affect parasite viability, motility and fecundity both *in vitro* and *in vivo* are largely unknown. For some plants it has been suggested that the consumption could be associated with an enhanced immune response of host towards the parasites as a result of nutrient supplementation and thus improve nutrition (Athanasiadou and Kyriazakis, 2004). Curative property of the medicinal plants is attributed to the various chemical substances of different composition that arise as secondary metabolites and get localized in one or more parts of the plant. These complex phytochemicals could play a vital role in minimizing the development of drug resistance among parasites**.** A number of research works have elucidated the anthelmintic effect of tannin rich plants against GI helminth parasites (Athanasiadou,

et al., 2001; Paolini *et al*., 2003; Hoste *et al*., 2006; Alonso Díaz *et al*., 2008; Calderón-Quintal *et al.,* 2010; Martínez-Ortíz-de-Montellano *et al*., 2010). Apart from condensed tannins, catechins, flavonoids, steroids (Oliveira *et al*.,2009) and polyphenols (Lorimer *et al*., 1996) as well as bio-active enzymes such as cysteine proteinase and secondary metabolites such as alkaloids, and glycosides (Piyush Jain *et al*., 2013) possess anthelmintic property. Phytoconstituents, may act by inhibition of tubulin polymerization and blocking glucose uptake (Jain *et al.,* 2011). Any damage to the mucopolysaccharide membrance of parasites will expose the outer layer restricting their movment which finally may cause paralysis and ultimately death of parasite (Chandrashekhar *et al.,* 2008). The anthelmintic effects of tannins may be attributed to its capacity to bind free protein available for larval nutrition and thus reducing the nutrient availability resulting in larval starvation or decrease in gastrointestinal metabolism directly through inhibition of oxidative phosphorylation causing larval death (Scalbert., 1991; Athanasiadau *et al.,* 2001).

Conclusion

Discovery of new therapeutic substances of natural origin, with possibly least toxicity to animals will protect the animals from chemical inputs. The natural compounds derived from plants are more stable as these are mostly plant secondary metabolites synthesized over a long synthetic ones and therefore are a source of low molecular weight structures active against a wide range of target agents and this diversity can preclude the occurrence of resistance. The progress in the livestock sector will in turn result in more balanced development of rural economy and improvement in economic status of poor people associated with this sector.

A combinatorial approach would help us to formulate new anthelmintic phytomedicine to combat parasitic infections in livestock. Intensive effort on isolation, combined formulation and validation of the efficacy of these plant based anthelmintics and appropriate toxicological screening should be undertaken before the release of commercially viable product for use in livestock industry. Future research in this area seems promising, as there remain a lot of plants to be tested for their anthelmintic potential.

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