

BAIRWA RANJAN et. al.

Online Available at www.thepharmaresearch.info

THE PHARMA RESEARCH, A JOURNAL

The Pharma Research (T. Ph. Res.), (2011), 5(2); 247-258.

Copyright © 2011 by Sudarshan Publication

Published on- 15 Sep 2011

Original Article

ISSN 0975-8216

Medicinal Uses of *Trachyspermum Ammi*: A Review

BAIRWA RANJAN*, SINGHAL MANMOHAN, SODHA RAVINDRA SINGH, RAJAWAT BALWANT SINGH

Affiliated to:

School of Pharmaceutical Sciences, Jaipur National University, Jaipur, Rajasthan-302025 India.



For Email Click Here

ABSTRACT

Trachyspermum ammi commonly known as 'Ajwain' is distributed throughout India and it is mostly cultivated in Gujarat and Rajasthan. The plant is used traditionally as a stimulant, carminative, flatulence, atonic dyspepsia, diarrhoea, abdominal tumours, abdominal pains, piles, and bronchial problems, lack of appetite, galactagogue, asthma and amenorrhoea. Medicinally, it has been proven to possess various pharmacological activities like antifungal, antioxidant, antimicrobial, antinociceptive, cytotoxic activity, Hypolipidaemic, Antihypertensive, antispasmodic, broncho-dilating actions, Antilithiasis, diuretic, Abortifacient, Antitussive, Nematicidal, Anthelmintic and Antifilarial Activity. Further, studies reveal the presence of various phytochemical constituents mainly carbohydrates, glycosides, saponins, phenolic compounds, volatile oil (thymol, γ -terpinene, para-cymene, and α - and β -pinene), protein, fat, fibre and mineral matter containing calcium, phosphorous, iron and nicotinic acid. These studies reveal that *T. ammi* is a source of medicinally active compounds and have various pharmacological effects; hence, this drug encourage finding its new therapeutic uses.

Keywords: *Trachyspermum ammi*, Apiaceae, fruit, antimicrobial, Ajwain.

INTRODUCTION

It is native of Egypt and is cultivated in Iraq, Iran, Afghanistan, Pakistan, and India. In India, it is cultivated in Madhyapardesh, Uttarpardesh, Gujarat, Rajasthan, Maharashtra, Bihar and West Bengal.^[1]

Trachyspermum ammi L. belonging to family Apiaceae a highly valued medicinally important seed spice. The roots are diuretic in nature and the seeds possess excellent aphrodisiac properties. The seeds contain 2–4.4% brown coloured oil known as ajwain oil. The main component of this oil is thymol, which is used as gastro-intestinal ailments, lack of appetite and bronchial problems. The oil exhibits fungicidal,^[2] antimicrobial^[3] and anti-aggregatory effects on humans.^[4]

Ajwain is traditional potential herbs, is widely used for curing various diseases in humans and animals. The fruit possesses stimulant, antispasmodic and carminative properties. It is an important remedial agent for flatulence, atonic dyspepsia and diarrhoea.^[5] The seed of ajwain is bitter, pungent and it acts as anthelmintic, carminative, laxative, and stomachic. It also cures abdominal tumours, abdominal pains and piles.^[6]

Seeds contain an essential oil containing about 50% thymol which is a strong germicide, anti-spasmodic and fungicide. Thymol is also used in toothpaste and perfumery.^[7]

Vernacular names^[1]

Sanskrit: Yamini, Yaminiki, Yaviniki; Assamese: Jain; English: Bishop's weed; Hindi: Ajwain, Jevain; Bengali: Yamani, Yauvan, Yavan, Javan, Yavani, Yoyana; Gujrati: Ajma, Ajmo, Yavan, Javain; Kannada: Oma, Yom, Omu; Malayalam: Oman, Ayanodakan; Marathi: Onva; Oriya: Juani; Tamil: Omam; Telugu: Vamu

Taxonomical classification^[8]

Kingdom: Plantae, Plant;
Subkingdom : Tracheobionta, Vascular plants
Superdivision: Spermatophyta, Seed plants;
Division : Magnoliophyta, Flowering plants
Class : Magnoliopsida, Dicotyledons;
Order : Apiales
Family : Apiaceae
Genus : *Trachyspermum*
Species : *ammi*

Botanical description

It is widely grown in arid and semi-arid regions^[9] where soils contain high levels of salts^[10-11] Ajwain is a profusely branched annual herb, 60-90 cm tall. Stem is striated; inflorescence compound umbel with 16 umbellets, each containing up to 16 flowers; flowers actinomorphic, white, male and bisexual; corolla 5, petals bilobed; stamens 5, alternating with the petals; ovary inferior; stigma knob-like; fruit aromatic, ovoid, cordate, cremocarp with a persistent

stylopodium; Leaves pinnate, with a terminal and 7 pairs of lateral leaflets.^[12] Fruit, consists of two mericarps, grayish brown, ovoid, compressed, about 2 mm long and 1.7 mm wide, 5 ridges and 6 vittae in each mericarp, usually separate, 5 primary ridges.^[1]

Microscopic description^[1]

Transverse section of fruit shows two hexagonal structures attached with each other by a carpophores, epicarps consists of a single layer of tangentially elongated tabular cells, mesocarp consists of moderately thick-walled, rectangular to polygonal tangentially elongated cells having some vittae, carpophores and vascular bundles present as groups of thick-walled radially elongated cells, integument, barrel shaped of tangentially elongated cells, endosperm consists of thin walled cells filled with embryo, oil globules, small and circular, composed of polygonal thin walled cells. The powder microscopic shows the presence of oil globules and groups of endosperm cells.

Phytochemical studies

Ajwain seed analysis has revealed it to contain fibre (11.9%), carbohydrates (38.6%), tannins, glycosides, moisture (8.9%), protein (15.4%), fat (18.1%), saponins, flavone and mineral matter (7.1%) containing calcium, phosphorous, iron and nicotinic acid.^[13] The Ajwain fruits yields 2%

to 4% brownish essential oil, with thymol as the major constituent (35% to 60%).^[14] The nonthymol fraction (thymene) contains para-cymene, γ -terpinene, α - and β -pinenes, dipentene, α -terpinene, and carvacrol.^[15] Minute amounts of caphene, myrcene, and α -3-carene also have been found in the plant. Alcoholic extracts contain a highly hygroscopic saponin. From the fruits, a yellow, crystalline flavone and a steroid-like substance have been isolated and also contain 6-O- β -glucopyranosyloxythymol^[16], a glucoside and a yield of 25% oleoresin containing 12% volatile oil (thymol, γ -terpinene, para-cymene, and α - and β -pinene).^[17] The principal oil constituents of *T. ammi* are carvone (46%), limonene (38%), and dillapiole (9%).^[18]

Pharmacological activities

Ajwain with its characteristic aromatic smell and pungent taste is widely used as a spice in curries. Its seeds are used in small quantities for flavouring numerous foods, as preservatives, in medicine and for the manufacture of essential oil in perfumery.^[13] In Indian system of medicine, *ajwain* is administered as a stomach disorders, a paste of crushed fruits is applied externally for relieving colic pains; and a hot and dry fomentation of the fruits applied on chest for asthma.^[19,40] *T. ammi* has been shown to possess Antimicrobial,^[20] Hypolipidaemic,^[21]

Digestive stimulant,^[22] Antihypertensive, Hepatoprotective, Antispasmodic, Broncho-dilating,^[23] Antilithiasis, diuretic,^[24] Abortifacient,^[25] galactogogic,^[26] Antiplatelet-Aggregatory,^[27] Antiinflammatory,^[28] Antitussive Effects,^[29] Antifilarial,^[30] Gestroprotective,^[31] Nematicidal,^[32] Anthelmintic,^[33] Detoxification of aflatoxins,^[34] Ameliorative effect.^[35] Therapeutic uses of *T. ammi* fruits include; stomachic, carminative^[36] and expectorant, antiseptic^[37] and amoebiasis, antimicrobial^[38] seeds soaked in lemon juice with *Prunus amygdalus* (Badam) given in amenorrhoea^[39] it is also used as Antipyretic, febrifugal and in the treatment of typhoid fever.^[41,42]

Antihypertensive, antispasmodic and broncho-dilating activity

The antihypertensive effect of *T. ammi* administered intravenously *in vivo*, and the antispasmodic and broncho-dilating actions *in vitro*. The studied of calcium channel blockade that has been found to mediate the spasmolytic effects of plant materials and considered that this mechanism contributed to their observed result and supported the traditional use of *T. ammi* in hyperactive disease states of the gut such as colic and diarrhoea as well as in hypertension.^[23]

Hepatoprotective activity

The Hepatoprotective Actions *in vivo* showed that *T. ammi* was 80% protective in mice

against a normally-lethal dose of paracetamol (1 g/kg), it prevented the CCl₄-induced prolongation of pentobarbital sleeping time in mice, and it tended to normalise the high serum levels of liver enzymes caused by CCl₄-induced liver damage in rats.^[23]

Antilithiasis and diuretic activity

Antilithiasis and diuretic actions *in vivo* of *T. ammi* on inhibiting oxalate urolithiasis induced in rats. In a further study of a possible diuretic effect the results found that *T. ammi* was not effective in increasing the 24 hour urine production. The results concluded that the traditional use of *T. ammi* in the treatment of kidney stones was not supported by their experimental evidence.^[24]

Abortifacient and galactogogic actions

Trachyspermum ammi was listed in 14 indigenous medicinal plants that were reported to have been used for abortion in some districts of Uttar Pradesh (India) in their survey conducted in 1987. Specifically, in the village of Kallipuschium, Lucknow district, 50 of the 75 pregnant women who were surveyed (of a total of 155 women in the fertile period) claimed to have used *T. ammi* seed for abortion. The herb was not 100% effective so the possibility of causing congenital defects was of concern. There was a high risk of potential human foetotoxicity of ten plants including *T. ammi*,

based on teratogenicity observed in rat foetuses.^[25]

The National Dairy Research Institute in India investigated the oestrogenic content of some herbs (including *T. ammi*) that are traditionally used to increase milk yield in dairy cattle. *T. ammi* has also been traditionally used as a galactagogue in humans. The total phytoestrogen content of dry *T. ammi* seed was 473 ppm, which was the second highest in the list of eight herbs tested (total phytoestrogen contents 131-593 ppm).^[26]

Antiplatelet-aggregatory

Antiplatelet-Aggregatory experiments *in vitro* with blood from human volunteers, it showed that a dried ethereal extract of *T. ammi* seeds, inhibited aggregation of platelets induced by arachidonic acid, collagen and epinephrine. Research study was intended to support the traditional use of *T. ammi* in women post parturition.^[27]

Anti-inflammatory potential

Anti-inflammatory principles of the total alcoholic extract (TAE) and total aqueous extract (TAQ) of the Ajwain seeds. TAE and TAQ exhibited significant ($P < 0.001$) antiinflammatory activity in both the animal models. The weights of the adrenal glands were found to be significantly increased in TAE and TAQ treated animals. TAE and TAQ extracts from the ajwain seeds exhibit significant antiinflammatory potential.^[28]

Antitussive effects

The antitussive effects of aerosols of two different concentrations of aqueous and macerated extracts and carvacrol, codeine, and saline were tested by counting the number of coughs produced. The results showed significant reduction of cough number obtained in the presence of both concentrations of aqueous and macerated extracts and codeine ($p < 0.001$ for extracts and $p < 0.01$ for codeine).^[29]

Antifilarial activity

In vitro activity of a methanolic extract of fruits of *Trachyspermum ammi* (Apiaceae) against *Setaria digitata* worms has been investigated. The crude extract and the active fraction showed significant activity against the adult *S. digitata* by both a worm motility and MTT [3-(4, 5-dimethylthiazol-2-yl)-2, 5- diphenyltetrazolium bromide] reduction assays. The isolated active principle phenolic monoterpene screened for *in vivo* antifilarial activity against the human filarial worm *B. malayi* in *Mastomys coucha*, showing macrofilaricidal activity and female worm sterility *in vivo* against *B. malayi*. *T. ammi* crude extract exhibited macrofilaricidal activity. The IC₅₀ values for the isolated active principle 2- isopropyl-5-methyl phenol at two incubation periods 24 and 48 hr were 0.024 and 0.002 mg/mL, respectively. The *in vivo* effect of the active principle 2-isopropyl-5-methyl phenol was

evaluated against the *B. malayi* parasite in a *Mastomys coucha* model. The mean percentage mortality of adults (58.93%) in the group treated with 50 mg/Kg was significantly ($P < 0.0001$) higher than that was obtained in the control group (19.05%).^[30]

Gastro protective Activity

Trachyspermum ammi fruit showed antiulcer activity by using different ulcer models. Animals pre-treated with ethanolic extract showed significant decrease in ulcer index and percentage ulcer protection in all models. The results suggests that the extract showed significant protection ($p < 0.001$) by reducing ulcerative lesions when compared with control group of animals.^[31]

Detoxification of aflatoxins

The seed extract of Ajowan showed the maximum degradation of aflatoxin G1 (AFG1). The aflatoxin detoxifying activity of the seeds extract was significantly reduced upon boiling. Significant levels of degradation of other aflatoxin viz., AFB1, AFB2 and AFG2 by the dialyzed seeds extract was also observed. Time course study of AFG1 detoxification by dialyzed *T. ammi* extract showed that more than 91% degradation occurred 24 h and 78% degradation occurred within 6 h after incubation.^[34]

Ameliorative effect

Effect of ajwain extract on hexachlorocyclohexane(HCH)-induced

oxidative stress and toxicity in rats were investigated. Pre-feeding of ajwain extract resulted in increased GSH, GSH-peroxidase, G-6-PDH, SOD, catalase, glutathione S-transferase (GST) activities and decreased hepatic levels of lipid peroxides. It was concluded that HCH administration resulted in hepatic free radical stress, causing toxicity, which could be reduced by the dietary ajwain extract.^[35]

Antimicrobial actions in vitro

The antimicrobial action of *T. ammi*, in the protection of foodstuffs against microbial spoilage, conducting laboratory assays of antimicrobial efficacy *in vitro* was studied. The active principles thought to be responsible for the antimicrobial activity of ajwain were reported to be carvacol and thymol.^[43] 'Thymol' kill the bacteria resistant to even prevalent third generation antibiotics and multi-drug resistant microbial pathogens and thus work as a plant based 4th generation herbal antibiotic formulation.^[44] Antifungal action of volatile constituents of *T. ammi* seeds on ten fungi (*Acrophialophora fusispora*, *Curvularia lunata*, *Fusarium chlamydosporum*, *F. poae*, *Myrothecium roridum*, *Papulaspora sp.*, *Alternaria grisea*, *A. tenuissima*, *Drechslera tetramera*, and *Rhizoctonia solani*). *T. ammi* seeds were found to inhibit the growth of all test fungi by 72-90%.^[45] Phenolic compounds, such as thymol and carvacol,

are known to be either bactericidal or bacteriostatic agents depending on the concentration used.^[46]

Hypolipidaemic action in vivo

Antihyperlipidaemic effect of *T. ammi* seed has been obtained in albino rabbits. It was assessed that *T. ammi* powder at dose rate of 2 g/kg body weight and its equivalent methanol extract were extensively effective lipid lowering action by decreased total cholesterol, LDL-cholesterol, triglycerides, total lipids.^[47]

Digestive stimulant actions in vivo and in vitro

T. ammi would increase the secretion of gastric acid; the addition of *T. ammi* to the infusion increased the amount of gastric acid. The gastric acid secretion was increased nearly four-fold by *T. ammi*.^[22] *T. ammi* on the food transit time in experimental rats *in vivo*, the addition of *T. ammi* to the diet reduced food transit time and also enhanced the activity of digestive enzymes and/or caused a higher secretion of bile acids.^[48]

Nematicidal Activity

Pine wilt disease, caused by the pinewood nematode (PWN), *Bursaphelenchus xylophilus*. Nematicidal activity of Ajwain oil constituents (camphene, pinene, myrcene, limonene, terpinene, terpinen- 4-ol, thymol and carvacrol) against PWN.^[32] PWN bodies treated with the muscle activity blockers

levamisole hydrochloride and morantal ttrate.^[49] Amino and hydroxyl groups have been hypothesized as target sites of methyl isothiocyanate in nematodes.^[50] Some essential oils have been reported to interfere with the neuromodulator octopamine^[51] or GABA-gated chloride channels of insect pests.^[52] Thymol and carvacrol were very effective against PWN. These studies confirm that the nematicidal activity of Ajwain oil was mainly attributed to the activity of thymol and carvacrol.^[53] Nematicidal activity of ajwain essential oils LC₅₀ values was 0.431mg/ml.^[54]

Anthelmintic Activity

Anthelmintic activity of *T. ammi*, shows its effect against specific helminths, e.g. *Ascaris lumbricoides* in humans and *Haemonchus contortus* in sheep.^[54] Anthelmintic Activity *T. ammi* exert by interference with the energy metabolism of parasites through potentiation of ATPase activity and thus loss of energy reserves.^[55] The plant has also been reported to possess cholinergic activity with peristaltic movements of the gut, thus helping in expulsion of intestinal parasites which might also be a contributory factor to its anthelmintic activity^[56-57]

References

1. The Ayurvedic Pharmacopoeia of India, Government of India, Ministry of Health and Family Welfare, Department of Ayush; Part-01, Volume-01, pp. 170-71.

2. Singh I, Singh VP: Antifungal properties of aqueous and organic extracts of seed plants against *Aspergillus flavus* and *A. niger*, *Phytomorphology*, 2000; 20, 151-157.
3. Sivropoulou A, Papanikolaou E, Nilolaou C, Kokkini S, Lanaras T, Arsenakis M: Antimicrobial and cytotoxic activities of *origanum* essential oils, *J Agric Food Chem*, 1996; 44, 1202-5.
4. Srivastava KC: Extract of a spice *Omum (Trachyspermum ammi)* shows antiaggregatory effects and alters arachidonic acid metabolism in human platelets, *Prostaglandins Leukot Essent Fatty Acids*, 1988; 33, 1-6.
5. Bentely R, Trimen H. *Medicinal Plants*, 1st ed. Delhi (INDIA): Asiatic Publisher; 1983.
6. Krishnamoorthy V, Madalageri MB: Bishop weeds (*Trachyspermum ammi*): an essential crop for north Karnataka, *Journal of Medicinal and Aromatic Plant Sciences*, 1999; 21:04, 996-998.
7. Joshi SG. *Medicinal Plants*, 1st ed. Delhi (INDIA): Oxford and IBH Publisher; 2000.
8. USDA- Natural Resources Conservation Service, Plant Profile: *Trachyspermum ammi* L. Sprague ex Turill- Ajowan caraway. Available from: <http://plants.usda.gov/java/profile?symbol=TRAM13>
9. Joshi SG. *Medicinal Plants*, 1st ed. Delhi (INDIA): Oxford and IBH Publisher; 2000.
10. Ashraf M: Salt tolerance of cotton some new advances, *Critical Reviews in Plant Sciences*, 2002; 02:01, 01-30.
11. Munns R: Comparative physiology of salt and water stress, *Plant Cell and Environment*, 2002; 25, 239-250.
12. Joy PP, Thomas J, Mathew S, Jose G, Joseph J. *Aromatic plants In Tropical Horticulture*, Vol 2. Calcutta (INDIA): Naya Prokash Publisher; 2001.
13. Pruthi JS. *Spices and Condiments*, 4th ed. Delhi (INDIA): National Book Trust Publisher; 1992.
14. Ishikawah T, Sega Y, Kitajima J: Water-soluble constituents of ajowan, *Chem Pharm Bull*, 2001; 49, 840-844.
15. Chopra RN. *Chopra's Indigenous Drug of India*, 2nd ed. Calcutta (INDIA): Academic Publishers; 1982.
16. Garg S: A new glucoside from *Trachyspermum ammi*, *Fitoterapia*, 1998; 06, 511-512.
17. Nagalakshmi S: Studies on chemical and technological aspects of ajowan (*Trachyspermum ammi* syn. *Carum copticum*), *J Food Sci Technol*, 2000; 37, 277-281.
18. Choudhury S: Composition of the seed oil of *Trachyspermum ammi* (L.) Sprague from northeast India, *J Essent Oil Res*, 1998; 10, 588-590.

19. Anonymous. The wealth of India, A dictionary of Indian Raw Materials and Industrial Products Publications and Information Directorate. New Delhi (INDIA): CSIR; Vol. XXI.
20. Bonjar GHS: Anti yeast activity of some plants used in traditional herbal-medicine of Iran, *Journal of Biological Sciences*, 2004; 04:02, 212-215.
21. Kumari KS, Prameela M: Effect of incorporating *Carum copticum* seeds in a high fat diet for albino rats, *Medical Science Research*, 1992; 20:06, 219-220.
22. Vasudevan K, Vembar S, Veeraraghavan K, Haranath PSRK: Influence of intragastric perfusion of aqueous spice extracts on acid secretion in anesthetized albino rats, *Indian Journal of Gastroenterology*, 2000; 19:02, 53-56.
23. Gilani AH, Jabeen Q, Ghayur MN, Janbaz KH, Akhtar MS: Studies on the antihypertensive, antispasmodic, bronchodilator and hepatoprotective activities of the *Carum copticum* seed extract, *Journal of Ethnopharmacology*, 2005; 98:12, 127-135.
24. Ahsan SK, Shah AH, Tanira MOM, Ahmad MS, Tariq M, Ageel AM: Studies on some herbal drugs used against kidney stones in Saudi folk medicine, *Fitoterapia*, 1990; 61:05, 435-458.
25. Nath D, Sethi N, Srivastav S, Jain AK, Srivastava R: Survey on indigenous medicinal plants used for abortion in some districts of Uttar Pradesh, *Fitoterapia*, 1997; 68:03, 223-225.
26. Kaur H: Estrogenic activity of some herbal galactagogue constituents, *Indian Journal of Animal Nutrition*, 1998; 15:03, 232-234.
27. Srivastava KC. Extract of a spice-omum (*Trachyspermum ammi*)-shows antiaggregatory effects and alters arachidonic acid metabolism in human platelets. *Prostaglandins Leukotrienes & Essential Fatty Acids*, 1988; 33:01, 16.
28. Thangam C, Dhananjayan R: Antiinflammatory Potential of the Seeds of *Carum Copticum* Linn, *Indian Journal of Pharmacology*, 2003; 35, 388-391.
29. Boskabady MH, Jandaghi P, Kiani S, Hasanzadeh L: Antitussive effect of *Carum copticum* in guinea pigs, *Journal of Ethnopharmacology*, 2005; 97, 79-82.
30. Mathew N, Bhattacharya SM, Perumal V, Muthuswamy K: Antifilarial Lead Molecules Isolated from *Trachyspermum ammi*, *Molecules*, 2008; 13, 2156-2168.
31. Ramaswamy S, Sengottuvelu S, Haja Sherief S, Jaikumar S, Saravanan R, Prasadkumar C, Sivakumar T: Gastroprotective Activity of Ethanolic Extract of *Trachyspermum Ammi* Fruit,

- International Journal of Pharma and Bio Sciences, 2010; 01:01, 01-15.
32. Pelczar MJ, Chan ECS, Krieg NR. Microbiology, 5th ed. New York (USA): Tata Mcgraw Hill Publisher; 1998.
 33. Priestley CM, Williamson EM, Wafford KA, Sattelle DB: Thymol, a constituent of thyme essential oil, is a positive allosteric modulator of human GABAA receptors and a homooligomeric GABA receptor from *Drosophila melanogaster*, British Journal of Pharmacology, 2003; 40, 1363-1372.
 34. Velazhahan R, Vijayanandraj S, Vijayasamundeeswari A, Paranidharan V, Samiyappan R, Iwamoto T: Detoxification of aflatoxins by seed extracts of the medicinal plant, *Trachyspermum ammi* (L.) Sprague ex Turrill Structural analysis and biological toxicity of degradation product of aflatoxin G1, Food Control, 2010; 21, 719–725.
 35. Anilakumar KR, Saritha V, Khanum F, Bawa AS: Ameliorative effect of ajwain extract on hexachlorocyclohexane-induced lipid peroxidation in rat liver, Food and Chemical Toxicology, 2009; 47, 279-282.
 36. Chialva F, Monguzzi F, Manitto P, Akgül A: Essential oil constituents of *Trachyspermum copticum* (L.) Link fruits, Journal of Essential Oil Research, 1993; 05:01, 105-106.
 37. Choudhury S, Riyazuddin A, Kanjilal PB, Leclercq PA: Composition of the seed oil of *Trachyspermum ammi* (L.) Sprague from Northeast India, Journal of Essential Oil Research, 1998; 10:05, 588-590.
 38. Himalaya Herbal Health Care, Herbal Monograph: *Trachyspermum ammi*, Available from: http://www.himalayahealthcare.com/herbfinder/h_trachy.htm
 39. Shome U, Rawat AKS, Mehrotra S. Time-tested household herbal remedies, Ethnobiology in human welfare, 1st ed. Delhi (INDIA): Jain & Deep Publisher; 1996.
 40. Singh VK, Govil JN, Arunachalam C. Recent Progress in Medicinal Plants. Vol 17. Houston Texas (USA): Studium Press LLC; 2007.
 41. Umadevi I, Daniel M: Phenolics of some fruit spices of the Apiaceae, National Academy Science Letters, 1990; 13:12, 439-441.
 42. Vedavathy S, Rao DN: Herbal folk medicine of Tirumala and Tirupati region of Chittoor district, Andhra Pradesh, Fitoterapia, 1995 ; 66:02, 167-171.
 43. Saxena AP, Vyas KM: Antimicrobial activity of seeds of some ethnomedicinal plants, Journal of

- Economic and Taxonomic Botany, 1986; 08:02, 291-300.
44. Khanuja SPS. Formulation Comprising Thymol useful in the Treatment of Drug Resistance Bacterial infection, CCIR, New Delhi (INDIA): United state patent 6824795 b2; 2004.
 45. Singh DB, Singh SP, Gupta RC: Anti fungal effect of volatiles from seeds of some Umbelliferae, Transactions of the British Mycological Society, 1979; 73:02, 349-350.
 46. Caccioni DLR, Guizzardi M, Biondi DM: Relationships between volatile components of citrus fruit essential oil and antimicrobial action on *Penicillium digitatum* and *Penicillium italicum*, Int J Food Microbiol, 2000; 88, 170-175.
 47. Javed IMS, Akhtar T, Khaliq MZ, Khan G, Muhammad M. Antihyperlipidaemic effect of *Trachyspermum ammi* (Ajwain) in rabbits, In: Proc 33rd All Pak Sci Conf Univ Agri Faisalabad, 2002.
 48. Platel K, Srinivasan K: Studies on the influence of dietary spices on food transit time in experimental rats, Nutrition Research, 2001; 21:09, 1309-1314.
 49. Murthy PS, Borse BB, Khanum H, Srinivas P: Inhibitory effects of Ajwain (*Trachyspermum ammi*) ethanolic extract on *A. ochraceus* growth and ochratoxin production, Turk J Biol, 2009; 33, 211-217.
 50. Singh G, Maurya S, Catalan C: Chemical, antifungal, antioxidative studies of Ajwain oil and its acetone extract, J Agric Food Chem, 2004; 52, 3292-3296.
 51. Choi IH, Shin SC, Park IK: Nematicidal activity of onion (*Allium cepa*) oil and its components against the pine wood nematode (*Bursaphelenchus xylophilus*), Nematology, 2007; 09, 231-5.
 52. Kong J, Lee SM, Moon YS, Lee SG, Ahn YJ: Nematicidal activity of plant essential oils against *Bursaphelenchus xylophilus*, Journal of Asia-Pacific Entomology, 2006; 09, 173-178.
 53. Wright DJ. Nematicides: Mode of action and new approaches to chemical control, Vol 3. New York (USA): Zukerman & Rhode Publisher; 1981.
 54. Kwon Park Il, Junheon K, Sang-Gil L: Nematicidal Activity of Plant Essential Oils and Components From Ajwain (*Trachyspermum ammi*), Allspice (*Pimenta dioica*) and Litsea (*Litsea cubeba*) Essential Oils Against Pine Wood Nematode (*Bursaphelenchus Xylophilus*), Journal of Nematology, 2007; 39:03, 275-279.
 55. Kostyukovsky M, Rafaeli A, Gileadi C, Demchenko N, Shaaya E: Activation of octopaminergic receptors by essential oil constituents isolated from aromatic

- plants: Possible mode of action against insect pests, *Pest Management Science*, 2002; 58, 1101-1106.
56. Tamurab T, Iwamoto H: Thymol - a classical smallmolecule compound that has a dual effect (potentiating and inhibitory) on myosin, *Biochemical and Biophysics Research Communications*, 2004; 18, 786-789.
57. Jabbar A, Iqbal Z, Khan MN: In vitro anthelmintic activity of *Trachyspermum ammi* seeds, *Pharmacognosy Magazine*, 2006; 2, 126-129.