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Potential of Indian traditional medicinal plant turmeric as insecticide Antifeedant and insect repellent against household, museum and library insect pests

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Abstract
Indian traditional medicine system has a substantial knowledge of plants for all uses from medicine to spices. Many plants are being used as insect repellent and insecticides from long time traditionally, these plant based insecticides are safe for human health and livestock, available locally and easily, and are economical as well as environment friendly. Studies conducted on these plants have revealed that these can be an alternative for conventional chemical insecticides. However, due to toxic and harmful nature chemical insecticides are not advisable to use against nuisance insect pest of library museum and homes where there is a possibility that they can come in human contact directly. The objective of this study is to review the potential, of traditional medicinal plant turmeric to control and manage domestic, library and museum insect pests. Turmeric rhizome powder is used all over the world as essential spices, medicine and colouring agent; without any health issues. Turmeric fresh juice, rhizome powder and leaf essential oils are reported for its potential natural pesticides for crop and grain protection.
The study confirms the claim that turmeric is a cast effective, environmentally safe and health friendly household insecticide. Turmeric can also be used in library and museums to protect books and artifacts from insects effectively.

Keywords: *curcuma longa*, turmeric, plant based pesticides, herbal pesticides domestic insect pests

Introduction
Insect pests were always major problem of houses museums and libraries. They not only spread disease but also destroy valuable goods, books and artifacts made of cellulose fibers and proteins. Domestic insect pests are not advised to control by synthetic chemicals because of their toxicity and hazardous nature, normally used to control insect pests of agriculture. So we need an alternative method to control these insect pest. The method should be cast effective, easily available, environment friendly harmless to human health. Indian system of traditional medicine use plants from thousands of year's medicine and spices, they are not only healthy but also cost effective and easily available.
Apart from medicine and spices there are also certain plants which are being used for insect pest control from very long time as a part of traditional knowledge. Many of these claimed traditional plants have been studied through scientific methods and are found effective against insect pests. The study show that several plant products (powder oil and extracts) can be used as potential pesticide against household insect pest, book pests and museum pests, they show high toxicity against selective insect pest or inhibition of their reproduction [1].
Turmeric is one of the most distinguished essential spices all over the world, with a long history, of use in the eastern civilization [2]. Plants co-evolved with insects to protect themselves from potential insect pest's infections and diseases, they produce toxic substances and secondary metabolites as natural defenses against pests, such as insects and pathogens [3, 4]. Tens of thousands of secondary metabolites produced by plants as part of their defense mechanism against harmful insect pests. Traditionally used botanical insecticide products include nicotine, rotenone, ryania, sabadilla, and pyrethrum [5].
Natural products for household insect pest tend to be safer alternative for conventional insecticides owing to their rapid degradation, lack of persistence minimal adverse effects on human, livestock and environment [6].
Here we have selected and reviewed turmeric, well known for its use as medicine, spices, dye and a traditional pesticide against many insect pest of agriculture and stored grain pest.

Turmeric
Turmeric is rhizomatous perennial herb of Zingiberaceae (Ginger family) found mainly in South East Asia. It is used for its flavouring properties as a spice food preservative and food colouring agent. Turmeric has a well-known therapeutic history in home remedies and in Indian traditional medicine system due to variety of important beneficial properties. Natural products from turmeric have been reported for analgesic, antibacterial, antifungal, anti-inflammatory, antioxidant, and digestive properties [7]. However, turmeric is also well reported for its insecticidal properties against certain pests of agricultural and household insect pest. Its show potential repellent effect against noxious mosquito species. Study show turmeric products as natural environment friendly economical alternative to chemical pesticides.
Turmeric is derived from the rhizome a tuberous underground part with rough and segmented skin. The rhizome is yellowish brown with a dull orange interior, with smaller tubers branching off. The dried grinded rhizome is a yellow powder with a bitter, slightly acrid, yet sweet taste. Apart from multiple medicinal use of turmeric rhizome, several plant products like essential oil of leaves are credited with interesting pesticidal properties against insects and fungi of agricultural significance, including repellent properties against noxious mosquito

species. There are several studies regarding potential use of turmeric as pesticide against domestic insect pest and pest of grain products however less information available regarding its use against insect pest of libraries and museums.

Origin, Nomenclature, History, Cultivation

The plant materials are traditionally being used as protectants of stored grain products is old practice [8]. Turmeric is the most essential spices all over the world, used as food colouring agent and as natural dye [9]. It originated from south eastern Asia, most probably in India. The plant is cultivated in all part of India [10], southern China, Taiwan Japan Myanmar Indonesia [11] and in Africa [12]. *Curcuma longa*, common turmeric is the most valuable and economically important member of the genus. The other important species of genus Curcuma is *C. aromatica* used in medicine.133 species of name and used for various preparations

Turmeric as Biopesticide

Studies reveals that turmeric have potential bioactive agent that interfere insect behaviour and growth, it has repellent antifeedant and insecticidal properties [13]. Turmer**ic** powder, essential oils and certain bioactive constituents of the plant are found to have insecticidal and repellent activity against many insect pests.

Insecticidal Activity of Turmeric

The insect control activity of most of the turmeric products were found comparable to or better than that of commercial neem formulation [14]. Turmeric powder, turmeric leaves and unutilized parts of the turmeric plant were reported for their insecticidal activity against many insect pests.

Turmeric oil reported for 50-60% nymphal mortality against *Schistocerca gregaria* and *Dysdercus koenigii* nymphs at a concentration of 20 and 50 µg per nymph respectively [14]. ar-turmerone, extracted and purified from *C. longa* rhizomes was found effective against cabbage looper [15]. Turmeric rhizome extracts were fond effective against *T. casteneum* [16]. Petroleum ether, acetone and ethanol extracts of turmeric were found effective against *T. castaneum* [17]. *Curcuma aromatica* ethanolic extract is reported for its insecticidal activity by Pitasawat [16].

Contect and Fumigant Actions

The turmeric powder demonstrated low toxicity in topical application against third star larvae of cabbage looper at a dose of (10 µ g/larva). However, addition of PBO as a synergist increased toxicity of turmeric powder and all of its derivatives [15].

Essential oil of turmeric leaf extracts have been explored for the contact and fumigant actions for toxicity and found effective in both [18]. The adult of *R.dominica* were found highly susceptible to contact action of the leaf oil with LD_{50} value of 36.71 µg/mg weight of insect [18]. Adults of *S. oryzae*. Essential oil of the turmeric leaves were also found highly susceptible in fumigant assay against Adult of *S. oryzae* with LC_{50} value of 11.36 mg/liter air. *T. castaneum* was reported to be repelled by contact and fumigant action of turmeric powder at concentrations ranging from 100–500 mg litre^{-1} [19].

Antifeedant Activity

Antifeedants are the substances that reduces consumption (feeding) by an insect. More precisely it is defined by Ismam "behaviour modifying substance that deters feeding through a direct action on peripheral sensilla (= taste organs) in insects" [20]. The essential oils and many other products of medicinal and aromatic plants have been known to exhibit antifeedant properties against number of insects. Antifeedant activity is demonstrated through either choice or non-choice test over a short duration. Plant based antifeedants are mostly secondary metabolites- alkaloids, phenolics and terpenoids [21]. The well documented antifeedants from plants are limonoids from the neem (*Azadirachta indica*) and chinaberry (*Melia azedarach*) trees and limonin from Citrus species. The terpenoids that show antifeedant activity are cardenolides, steroidal saponins and withanolides, several types of diterpenes (based on a 20-carbon skeleton) are well known as antifeedants, including the clerodanes and the abietanes. *Curcuma longa* leaf oil is reported to significantly reduce growth rate, food consumption and food utilization in adults of *R. dominica* and *S. oryzae* and adult and larvae of *T. casteneum* [13]. *T. castaneum* adult and larvae show 84.3 and 81.7% feeding deterrence at the concentration of 213.15 mg/g food respectively. Feeding deterrence by turmeric oil is also recorded against *R. dominica* [13].

Repellent Activity

Insect repellents are substances that act locally or at a distance, deterring an insect from flying to, landing on or biting a surface on human or animal skin [22, 23]. Insect repellents work by providing a vapor barrier deterring the insect from coming into contact with the surface [24]. Essential oil mixture of volatile compounds isolated from a large number of plants, have been found to possesses these properties against various insect, some of them being basis of commercial repellent formulation [25]. The insect repellent components in turmeric are repellency against adults of three insect pests of stored products, *Tribolium castaneum*, *Sitophilus granarius*, and *Rhyjopertha dominica* and turmeric powder were found effective against *S. grannarius* and *R. dominica* [27]. Petroleum ether ethanol and acetone extracts of turmeric rhizome were tested against *T. casteneum*, and petroleum ether was found more effective than ethanol and acetone extracts [27]. Compound extracted from turmeric powder show strong repellency against *T. casteneum* [28]. Turmeric power in combination with mustard oil was found to protect milled rice against *Sitophilus oryzae* [29]. The turmeric (*Curcuma longa*) extract has been reported for its repellent activity against *T. castaneum*, *Oryzaephilus surinamensis*, *Cryptolestes ferrugineus*, *Sitophilus oryzae*, and C*orcyra cephalonica* even after 3 months under laboratory conditions. Chander [30]. Rrhizome dust was found effective against store grain pests like *Rhizopertha dominica* [31].

Combination of mustard oil and turmeric powder were found suppressing progeny emergence of *S. oryzae* pest of milled rice. Combination of fly ash and turmeric dust were found effective against some pest of rice (*Cnaphalocrosis medinalis, Oxya nitidula*), some pests of eggplant (*Epilachna vigintioctopunctata, Aphis gossypii*, *Urentius hystricellus, coccidohystix insolitus*), and several pests of okra [32]. Rhizome of Turmeric has been reported to use as ant repellent in India, Maharashtra [33] earlier.

Growth Modulator and Larvicidal

Essential oils activity from plant leaves of turmeric *Curcuma longa* have been reported for growth inhibitory activity against stored grain pests. It affects the progeny production by reducing oviposition and egg hatching in stored grain insect pests [34, 18]. The turmeric *(Curcuma longa*), on hydro distillation yields oil rich in α-phellandrene (70%), reported to induce growth inhibition and larval mortality against *Spilosoma obliqua* [35].

Turmeric powder, its derivative *ar*-turmerone and turmeric crude essential oil exhibit pronounced insect growth regulator by properties. When cabbage loopers were reared on artificial diets incorporating turmeric powder or its derivatives and their binary mixtures with PBO for seven days in the laboratory significant effect was seen. Larval weight was significantly lower, on ar-turmerone (119.1 mg), ar-turmerone + PBO (81.8 mg) and ar-turmerone + sesamol (116.7 mg) treatments, compared to all other treatments including the negative control (297.8 mg) and the positive control (200.0 mg) [16].

Red flour beetle, *Tribolium castaneum* adults, fed on wheat flour (*Triticum aestivum* L., Poales: Poaceae), treated with turmeric oil (200 ppm) produced fewer and underweight larvae, pupae, and adults compared to those fed on untreated flour [36].

The major colouring chemical constituent of turmeric powder of rhizome are Curcuminoids comprising three closely related curcumins (I II and III). Curcuminoids were also screened for their growth inhibitory activity against the desert locust, *Schitoccerca gregaria* (Forsskal, 1775) (Orthoptera: Acrididae) and the red cotton bug, *Dysdercus koenigii* (Fabricius, 1775) (Hemiptera: Pyrrhocoridae) nymphs.

2-phellandrene(70%) rich oil obtained after hydro-distillation of turmeric leaves and unutilized parts of turmeric plant, was reported for its growth inhibition activity of *S. oblique* and diamond back moth, *Plutella xylostella* (Linnaeus) at 1.0 concentration [37, 38].

Curcumin a major component of turmeric rhizome is reported for its growth inhibition activity when injected into the hymolymph of *S. gregaria* fifth instar nymph, it produced 40-50% growth inhibition and 10-15% mortality at a dose of 20 µ g per nymph, the turmaric oil reported to produce 10% growth inhibition and 60% nymphal mortality at the same dosage [14]. Curcuminoids (I, II, and III) were reported to produced 45% growth inhibition during tropical application on *D. koenigii* nymph at a dose of 50 µ g [14].

Anti-Oviposition and Ovicidal Activity

The turmeric essential oil is reported to reduce oviposition by 72% and egg hatching by 80% in *T. castaneum* [18].

The turmeric leaves essential oil was investigated for progeny, oviposition and ovicidal effect on *Rhyzopertha dominica Sitophilus oryzae* and *T.castaneum.* The oil reported to reduce oviposition and egg hatching by 72 and 80%, respectively in *T. castaneum*. Turmeric extracts was found to cause increased egg mortality in the Angoumois grain moth, *Sitotroga cerealella* (Lepidoptera: Gelechiidae) when treated with 1,000 ppm of turmeric extracts prepared in acetone, ethanol or petroleum ether [39].

Chemical Composition of Turmeric as Biopesticie

Various part of turmeric plant contain different types of bioactive materials which have insecticidal, pesticidal or insect repellent activity. The major insect repellent and antifeedant constituents in *C. longa* are turmerone, ar-turmerone and curcuminoids [40, 14]. There are more than 100 component isolated from turmeric. Turmeric contains protein (6.3%), fat (5.1%), minerals (3.5%), carbohydrates (69.4%) and moisture (13.1%).The main component of its root is a volatile oil. Insecticidal substances at different concentration can be obtained from *C. longa* and other plant species, depending on location and local environment. For example, 0.32% and 0.50% (dwt) ar-turmerone was extracted from *C. longa* rhizomes in Brazil [41], and essential oil of the rhizomes of C. longa produced 44.4% and 38.6% (dwt) ar-turmerone in Nigeria [42] and Pakistan [43] respectively.

The major components (60%) extracted from turmeric extracted oil are identified as turmeron and ar-Temerone [44, 45]

The compounds found in rhizomes are 1,8Cineole, alpha-Terpineol, ar-Termerone, Ascorbic acid, Azulene, beta-Carotene, beta-sesquiphellandrene, barneol, caffeic acid, caprylic acid, cinnamic acid, Curcumin, guaiacol, Isoborneol, p-Coumaric acid, p-Cymene and p-methoxy cinnamic acid [46].

The major chemical constituents of turmeric powder are curcuminoids, including bisdemethoxycurcumin, curcumin (3.14%) and demethoxycurcumin.

Turmeric derivative sesquiterpene ar-turmerone, has potential insecticidal activity against cabbage looper larvae [15]. The major component responsible for repellent activity extracted from turmeric rhizome, rhizome powder and oil are turmerone and dehydroturmerone, which has been reported as strong repellent against red flour beetle *Tribolium castaneum* [47]. 2-phellandrene yields from turmeric leaves reported for growth inhibitor against *Spilarctia oblique* and *Plutella xylostella* at 1% concentration [37, 38]. The bioactive compound responsible for insecticidal or pesticidal activity are mainly found in essential oils identified as alpha-Penene, beta-Pinene, caryophyllene, eugenol and limonene [46]. Most active chemical of turmeric which act as a natural pesticide is Curcumin (Diferuloylmethane), which is also responsible for the yellow colour.

Safety, Efficacy, and Contradication

Turmeric is used as a spice and as a household remedy from centuries. Even at high dose no toxic effect of turmeric in humans or animals have been reported till date [48]. Curcumin which is most active substance in turmeric has poor bioavailability and not toxic to human [49] and animals [50], even at high dose. Bioavailability of Curcumin was found poor in tissues remote from the gastrointestinal tract including liver when measured in human tissue [51].

In an independent dose-escalation study on 15 patients with advanced colorectal cancer was conducted in the United Kingdom [52], there was no dose limiting toxicity reported and treatment was well tolerated. A similar result reported was by Lao *et al*. where studies were conducted on healthy human volunteers consuming a single dose of Curcumin ranging from 500 to 12,000 mg [48]. Clinical trial conducted by U.S. Food and Drug Administration (FDA), published a 300 page monograph, where the active component of Curcumin was declared as GRAS, generally regarded as safe for used in many products [53]. In phase one clinical study, no side effects of turmeric oil intake were observed during 3 months of volunteer oral dministration. No side effects on body weight, blood pressure, and hematological, renal, or hepatic toxicity [53]

was reported. Curcumin is a lipophilic molecule which rapidly permeates cell membranes, by affecting the structure and function of cellular membranes it mimics typical events during apoptosis. However, curcumin contrasted typical apoptotic cell death response due to membrane integrity loss was immediate, partly reversible, and cells could recover in a short time [54].

Conclusion

Natural products based insecticides are nontoxic and specific in there action so there is possibility of replacing synthetic insecticides with natural products. In recent studies we found *Curcuma longa* extracts of ethanol and petroleum ether are strong repellent against household, museum and library insect pest *Acrotelsa collaris* [55]. This study show that turmeric can play an important role as potential bio pesticide. Turmeric can be used directly and effectively in pest management of houses, library and museums without any adverse effect on human health. It is nontoxic, environment friendly and used from long time traditionally as medicine spices and colouring agent, originated from local natural resources economical and easily available target specific and biodegradable so the sustainable healthy environment can be kept.

Reference

1. Emeasor KC, Ogbuji RO, Emosairue SO. Insecticidal activity of some seed powders against *Callosobruchus maculatus* (F.) (Coeoptera: Bruchidae) on stored cowpea. J Plant Dis Prot. 2005; 112:80-87.
2. Rvindran PN, Niraml babu K, Sivaraman K. (Eds). Turmeric: The golden spice of life. Turmeric the Genus *Curcuma*. CRC Press, Boka Ratan, FL, USA. 2007, 1-14.
3. Petacci F, Tavares WS, Freitas SS, TEles AM, Serrao JE, Zanuncio JC. Phytochemistry and quantification of polyphenols in extracts of the as teraceae weeds from Diamantina, Minas Gerais State, Brazil. Planta Daninh. 2012; 30:9-15.
4. Tavares WD, Grazziotti GH, de Souza Junior AA, de Sousa Freitas S, Consolaro HN, Ribeiro PE, *et al.* Screening of extracts of leaves and stems of Psychotria spp. (Rubiaceae) against *Sitophilus zeamais* (Coleoptera: Curculionidae) and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) for maize protection. J. Food Prot. 2013; 76(11):1892-1901.
5. Isman MB, Botanical insecticides, deterrents, and repellent in modern agriculture and an increasingly regulated world. Ann. Rev. Entomol. 2006; 51:45-66.
6. Ismam. Insect antifeedant, Pesticide Outlook – August 2002 The Royal Society of Chemistry. 2002; 152.
7. Chattopadhyay I, Biswas K, Bandyopadhyay U, Banerjee RK. Turmeric and curcumin: Biological actions and medicinal applications. Curr. Sci. 2004; 87:44-53.
8. Tripathi P, Dubey NK. Exploitation of natural products as an alternative strategy to control post-harvest fungal rotting of fruit and vegetables. Post-harvest Bio Technol. 2004; 32:235-245.
9. Green CL. Natural colourents and dyestuffs: A review of production markets and development potential. Non Wood Forest Product 4. Food and Agriculture organization of the United Nation, Rome, Italy.1995.
10. Kapoor LD. Handbook of Ayurvedic Medicinal Plants, CRC Press, Boca Raton, Florida. 2000; 185.
11. Yen K-Y. The illustrated Chinese materia medico: Crude and prepared. SMC Publishing, Taipei, Taiwan, 1992.
12. Iwu MM. Hand book of African medicinal plants. CRC press, Boka Raton, FL, USA, 1993.
13. Jilani G, Saxena RC. Repellent and feeding deterrent effect of turmeric oil, sweet flog oil, neem oil and neem-based insecticide against lesser grain borer (Coleoptera: Bostrychidae). Economic Entomology. 1990; 83: 629-634.
14. Chowdhury H, Walia S, Saxena VS. Isolation, characterization and insect growth inhibitory activity of major turmeric constituents and their derivatives against *Schistocerca gregaria* (Forsk) and *Dysdercus koenigii* (Walk). Pest Manag Sci. 2000; 56:1086-1092.
15. De Souza Tavares W, Akhtar Y, Gonçalves GL, Zanuncio JC, Isman MB. Turmeric powder and its derivatives from Curcuma longa rhizomes: Insecticidal effects on cabbage looper and the role of synergists. Scientific Reports. 2016 | 6:34093 | DOI: 10.1038/srep34093
16. Pitasawat B, Choochote W, Tuetun B, Tippawangkosol P, Kanjanapothi D, Jitpakdi A *et al.* Repellency of aromatic turmeric *Curcuma aromatica* under laboratory and field conditions. Journal of Vector Ecology. 2003, 234.
17. Iqbal J, Qayyum A, Mustafa SZ. Repellent effect of ethanol extracts of plant material on *Tribolium castaneum* (Herbst) (Tenebrionidae: Coleoptera). Pakistan J. Zool. 2010; 42(1):81-8.
18. Tripathi AK, Prajapati V, Verma N, Bahl JR, Bansal RP, Khanuja SPS *et al.* Bioactivities of the leaf essential oil of *Curcuma longa* (var. Ch-66) on three species of stored-product beetles (Coleoptera). J Econ Entomol. 2002; 95:183-189.
19. Parveen N, Mondal K, Behavioral response of *Tribolium castaneum* Herbst to turmeric (*Curcuma longa*) powder. J Zool Rajasthan-Univ. 1992; 41:10-11.
20. Isman MB, Matsuura H, MacKinnon S, Durst T, Towers G H N, Arnason JT *et al.* Phytochemistry of the Meliaceae: So many terpenoids, so few insecticides. Recent Advances in Phytochemistry. 1996; 30:155-178.
21. Frazier JL. The perception of plant allelochemicals that inhibit feeding, In Molecular Aspects of Insect-Plant Associations, L.B. Brattsten and S. Ahmad (Eds.), Plenum Press, New York. 1986, 1-42.
22. Blcakwell A, Stuart, Estambale BA. The repellant and antifeedant activity of oil of Myria gale against *Aedes Aegypti* mosquitoes and its enhancement by addtion of salicyluric acid. Proc. Royal Coll. Phytochem. 2003; 19:139-16.
23. Chochote W, Chaithong U, Kamsuk K, Jitpakdi A, Tippawangkosol P, Tuetum B *et al.* Repellent activity of selected essential oils against *Aedes aegypti*. Fitoterapia. 2007; 78:359-364.
24. Brown M, Hebert AA. Insect repellent: An overview. J. Am. Acad. Dermato. 1997; 36:243-249.
25. Curtis C, Lines J, Lu B, Renz A. Naural and synthetic repellents. Appropriate control in vector control. CRC Press, Florida. 1989, 4.
26. Tripathi AK, Prajapati V, Agarwal KK, Khanuja SPS, Kumar S. Bioactivities of the Leaf Essential Oil of *Curcuma longa* on three Species of Stored-Product Beetles (Coleoptera). J. Economic Entomology. 2002; 98: 1391-1398.
27. Jilani G, Su HCF, Laboratory studies on several plant

materials as insect repellants for protection of cereal grains. J. Econ Entomol. 1983; 76:154-157.
28. Su HCF, Horvat R, Jilani G. Isolation, purification and characterization of insect repellents from Curcuma longa L. J. Agr Food Chem. 1982; 30:290292.
29. Chander H, Kulkarni SG, Berry SK. Effectiveness of turmeric powder and mustard oil as protectants in stored milled rice against the rice weevil *Sitophilus oryzae*. Int Pest Control.1991; 33:94-97.
30. Chander H, Ahuja DK, Nagender A, Berry SK. Repellency of different plant extracts and commercial formulations used as prophylactic sprays to protect bagged grain against *Tribolium castaneum.* J Food Sci Technol Mys. 2000; 37:582585.
31. Chander H, Nagender A, Ahuja DK, Berry SK. Effect of various plant materials on the breeding of lesser grain borer (*Rhyzopertha dominica*) in milled rice in laboratory. J Food Sci Technol Mys, 2003; 40:482-485.
32. Sankari SA, Narayanasamy P. Bio-efficacy of flyash-based herbal pesticides against pests of rice and vegetables. Curr Sci India. 2007; 92:811-816.
33. Dhale DA. Plants Used for insect and pest control in North Maharashtra, India. The Journal of Ethanobiology and Traditional Medicine. 2013; 118:379-388.
34. Sharma SS, Gill k, Malik MS, Malik OP. Insecticidal, antifeedant and growth inhibitory activities of essential oils of some medicinal plants. J. Medicinal and Aromatic Plant Sci. 2000; 2(6).
35. Agarwal M, Walia S, Dhingra S. Pest control properties of turmeric leaf oil against Spilosoma obliqua, Dysdercus koenigii and Tribolium castaneum. Proceed. 2nd All India People's Congress, Calcutta. 1999, l-7.
36. Jilani G, Saxena RC, Rueda BP. Repellent and growth-inhibiting effects of turmeric oil, sweetflag oil, neem oil, and Margosano on red flour beetle (Coleoptera: Tenebrionidae). J. Econ. Entomol. 1998; 81:1226-1230.
37. Govindaraddi K. Antifeedant and insecticidal properties of essential oils of turmeric (*Curcuma longa* L.) and garlic (*Allium sativum* L.) against diamond back moth, *Plutella xylostella* (L). M.Sc thesis, CCS Haryana Agricultural University, Hisar; 2005.
38. Walia S. Allelochemicals as Biopesticide. Souvenir Conference on Biopesticides: Emerging Trends, Society of Biopesticide Sciences, India, and Jalandhar. 2005, 19-32.
39. Iqbal J, Jilani G, Aslam M. Growth inhibiting effects of plant extracts against the grain moth, *Sitotroga cerealella* (Oliv.) (Gelechiidae: Lepidoptera). Pak. J. Zool. 2010; 42: 597-601.
40. Lee HS, Shin WK, Song C, Cho KY, Ahn YJ. Insecticidal activities of ar-turmerone identified *Curcuma longa* L. rhizome against *Nilaparvata lugens* (Homoptera: Delphacidae) and *Plutella xyostella* (Lepidoptera: Yponomeutidae). Asia Pacific Entomology. 2001; 4:181-185.
41. de SouzaTavares W, de Sousa Freitas S. Grazziotti GH, Parente LML. ar-turmerone from Curcuma longa (Zingiberaceae) rhizomes and effects on *Sitophilus zeamais* (Coleoptera: Curculionidae) and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Ind. Crop Prod. 2013; 46:158-164.
42. Ajaiyeoba EO, Sama W, Essien EE, Olayemi JO, Ekundayo O, Walker TM *et al.* Larvicidal activity of turmerone-rich essential oils of Curcuma longa leaf and rhizome from Nigeria on Anopheles gambiae. Pharm. Biol. 2008; 46:279-282.
43. Naz S, Ilyas S, Jabeen S, Praveen Z. *et al*. Composition and antibacterial activity of the essential oil from the rhizome of turmeric (Curcuma longa L.). Asian J. Chem. 2011; 23:1639-1642.
44. Helen CFS, Horvat R, Jilani G. Isolation, purification and characterization of insect repellents from Curcuma longa L. Agri Food Chem. 1982; 30:290-292.
45. Gopalan B, Gota M, Kodama A, Hirose T. Supercritical carbon dioxide extraction of turmeric (Curcuma longa). Agri. Food. Chem. 2000; 48:2189-2192.
46. Duke JA, Dr. Duke's Essential Herbs. Emmaus, Pennsylvania: Rodale Press. 1999.
47. Chahal KK, Arora M, Joia BS, Chhabra BR. Bioefficacy of turmeric oil against Tribolium castaneum (Herbst) under laboratory conditions. Proc. 1st Congress onInsect Science:Contributed Papers, PAU Ludhiana. 2005; 147-148.
48. Lao CD, Ruffin MT, Normolle D, Heath DD, Murray SI, Bailey JM *et al.* Brenner DE. Dose escalation of a curcuminoid formulation. BMC complementary and alternative medicine. 2006; 6(1):10.
49. Soni K, Kuttan R. Effect of oral Curcumin administration on serum peroxides and cholesterol levels in human volunteers. I J Physiol Pharmacol 1992; 36(4):273-275.
50. Shankar TB, Shantha NV, Ramesh HP, Murthy IA, Murthy VS. Toxicity studies on turmeric (Curcuma longa): acute toxicity studies in rats, guineapigs and monkeys. Indian journal of experimental biology. 1980; 18(1):73-5.
51. Garcea G, Jones DJ, Singh R, Dennison AR, Farmer PB, Sharma RA *et al.* Steward WP, Gescher AJ, Berry DP. Detection of curcumin and its metabolites in hepatic tissue and portal blood of patients following oral administration. British journal of cancer. 2004; 8, 90(5):1011-5.
52. Joshi J, Ghaisas S, Vaidya A, Vaidya R, Kamat DV, Bhagwat AN *et al.* Early human safety study of turmeric oil (*Curcuma longa* oil) administered orally in healthy volunteers. JOURNAL-ASSOCIATION OF PHYSICIANS OF INDIA. 2003; 51:1055-60.
53. https://www.researchgate.net/publication/304643765_Botanicals_Its_Safe_Use_in_Pest_Control_and_Environmental_Management [accessed May 23, 2017]
54. Jaruga E, Salvioli S, Dobrucki J, Chrul S, Bandorowicz-Pikuła J, Sikora E *et al.* Apoptosis-like, reversible changes in plasma membrane asymmetry and permeability, and transient modifications in mitochondrial membrane potential induced by curcumin in rat thymocytes. FEBS letters. 1998; 433(3):287-93.
55. Kumar S, Singh K, Dwivedi KN. Repellent effect of three plants *Curcuma longa*, *Cymbopogon citratus, Adhatoda vasica* against insect pest silverfish, *Acrotelsa collaris* (fabr.) (thysanura: lepismatidae). World journal of pharmaceutical research. 2017; 6(5):1518-1527.