EVALUATION OF MEDICINAL PLANT-BASED FORMULATIONS FOR GROWTH, YIELD AND PEST MANAGEMENT IN CHILLI

(*Capsicum annuum* Linn.)

By

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(2019-12-019)

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THESIS

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DEPARTMENT OF PLANTATION CROPS AND SPICES

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2021

DECLARATION

I, Shafreena Shirin P. (2019-12-019) hereby declare that the thesis entitled **"Evaluation of medicinal plant-based formulations for growth, yield and pest management in chilli (*Capsicum annuum* Linn.)"** is a bonafide record of research done by me during the course of research and that it has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Evaluation of medicinal plant-based formulations for growth, yield and pest management in chilli (*Capsicum annuum* Linn.)"** is a bonafide record of research work done independently by **Ms. Shafreena Shirin P. (2019-12-019)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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SHAFREENA SHIRIN P.

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ABBREVIATIONS

%:	Per cent
/:	Per
a.i:	active ingredient
AMPRS:	Aromatic and Medicinal Plant Research Station
ANOCOVA:	Analysis of Covariance
ANOVA:	Analysis of Variance
ATP:	Adenosine triphosphate
AVP:	Anti-Viral Protein
BPF:	Biopesticide Formulation
CBR:	Cost Benefit Ratio
Cm:	Centimeter
CV:	Critical Varience
DAT:	Days After Treatment
DMRT:	Duncan's Multiple Range Test
EC:	Emulsifiable concentration
et al.,.:	*et alia* (and associates)
etc.:	Et cetera
FAO:	Food and Agricultural Organization
FrE:	Fruit extract
g:	Gram
GC:	Gas chromatography
GC-MS:	Gas chromatography–mass spectrometry
GRAPES:	General Rshiny Based Analysis Platform Empowered by Statistics

HAE:	Hours After Exposure
IGR:	Insect Growth Regulators
J:	Journal
KAU:	Kerala Agricultural University
LC50:	Lethal Concentration 50
Lit.:	Litre
MFC:	Minimum Fungicidal Concentration
mg $100g^{-1}$:	milligram per 100 gram
MIC:	Minimal inhibitory concentration
NAU:	Navsari Agricultural University
NSKE:	Neem Seed Kernel Extract
PDA:	Potato Dextrose Agar
POP:	Package of Practices
RI:	Reproductive Index
Sl. No:	Serial Number
SEm:	Standard error of mean
Viz.:	Namely
WHO:	World Health Organization
Wpe:	Whole plant extract
EI-mass:	Electron Ionization mass spectra
NMR:	NMR nuclear magnetic resonance spectroscopy
UV:	Ultra Violet spectral data
ZTO:	Zedoary Turmeric Oil

Introduction

1. INTRODUCTION

Pest management is one of the important components of crop management to mitigate economic losses of agricultural crops and commodities. Around 40 per cent of the crops accounting to $ 220 billion are lost globally each year due to pest and diseases leading to major impact on economy of every country (FAO, 2021). This major threat to financial losses and quality deterioration of crops led to the major insights in the field of research for new and ecofriendly pest management strategies.

In order to abate and eradicate pests from the crop plants, various pest management strategies are followed. Chemical pesticides are in use as a quick and an effective remedy as pest management strategy. In recent times, the harmful effects of chemical pesticides on environment and health concern have caused a shift to adapt various ecofriendly ways of pest management that follows nontoxic mechanisms. Use of synthetic pesticides has negatively affected export trade especially of horticultural produce (Nashwa, 2012). Detection of banned pesticides or having traces above the regulatory residue limits has led to loss of market and income to both the growers and the exporters (Geraldin, 2020). Therefore, botanical pesticides are gaining popularity as they are safe to use on crops produced for human consumption. Recently there is a lucrative market among consumers willing to pay more for organically produced food.

This positive trend has encouraged the research field on ecofriendly and effective pest management strategies. Many phytochemical pesticides exhibiting broad spectrum activity against pest and diseases have long been considered as an attractive alternative to synthetic chemical pesticides as they are biodegradable, target specific and pose no or less hazard to environment and to human health (Walia *et al.,* 2014). Medicinal plants are resources to medicinally important bioactive molecules most of which probably evolved as chemical defenses against predation or infection (Anitha *et al.*, 2016).

There are many studies in progress involving the known and yet to be exploited plant species with pesticidal properties. Botanical pesticides are derivatives of plants that repel, inhibit growth or kill pests (Hernandez-Moreno, 2013). The common bioactive compounds in botanical pesticides are secondary metabolites such as steroids, alkaloids, tannins, terpenes, phenols, flavonoids and resins that possess antifungal, antibacterial, antioxidant or insecticidal properties (Misra, 2014).

The mode of action of botanicals include repellence, inhibition, morphological and physiological interference, growth regulation, denaturation of proteins and other effects depending on type of botanical compound and pest. For instance, pesticides from pyrethrum target the nerve cells of insects leading to paralysis and death while neem-based pesticides have anti-feedant and repellence properties, induce moulting abnormalities, hinder oviposition and disrupt the endocrine system (Grdisa, 2013).

Understanding the mode of action including the physical, biological and chemical interactions between the pest and pesticide is vital in pest management as it dictates the management strategy to be adopted. The testing of the efficacy of such potential plant-based sources for antimicrobial and pest control activities could be an important step towards environmental safety and ultimately human health. Improvement in the understanding of the mechanisms of action can offer new prospects for using these substances in pest management. In this context a study was taken up for evaluation of medicinal plant-based formulations for growth, yield and pest management in chilli (*Capsicum annuum* Linn.).

Review of Literature

2. REVIEW OF LITERATURE

The research programme entitled "Evaluation of medicinal plant-based formulations for growth, yield and pest management in Chilli (*Capsicum annuum* Linn.)" was conducted at the Department of Plantation Crops and Spices, College of Agriculture, Vellanikkara during the period from October 2020 to May 2021. Literature pertaining to the research topic is reviewed in this chapter.

2.1 Botanicals in pest management

Botanicals are one of the alternatives in agricultural pest management. The desirable features of the botanical pesticides such as lack of persistence and bioaccumulation in the environment, selectivity towards beneficial insects and low toxicity to humans (Grdisa and Grsic, 2013) led to significant developments of botanical pesticides from different plant sources. Botanical pesticides are the naturally occurring secondary metabolites (phytochemicals) extracted from the plant sources which can control and kill the pests thus helping in the agricultural pest management. They are generally safer to humans and the environment than conventional chemical pesticides. Thus, they are of great importance in the field of research on pest management.

Plants contain thousands of constituents and are valuable sources of new and biologically active molecules (phenols and polyphenols, terpenoids, quinones, flavones, flavonoids, flavanols, tannins, coumarins and alkaloids) possessing a wide range of physical and chemical defences against a variety of insects and provide them resistance to pathogenic organism (Gurjar, 2012). The major commercially used botanical pesticides in the agricultural pest management are neem based pesticides, rotenone and pyrethrum and plant essential oils. During course of evolution, the selection pressure caused by pathogens and herbivores has probably been highly acute and intense and resulted in a vast chemical diversity in higher plants. Unlike compounds synthesized in the laboratory, secondary compounds from plants are virtually guaranteed to have biological activity, protecting the plant from pathogen, herbivore or competitor.

Botanical insecticides, which contain plant extracts as active components, are safer as well as environmentally friendlier than chemicals. Use of these chemicals of plant origin, commonly called “botanicals or phytochemicals” has attracted particular attention because of their specificity to insect pests, biodegradability and the potential for commercial application (Bishop and Thronton, 1997; Shukla *et al.*, 2000). The efficient use of such renewable natural resources is becoming increasingly important worldwide. There is no doubt that many plant secondary metabolites affect insect behaviour, development and reproduction. The botanicals offer better compatibility with other biological pest control agents than that of the synthetics and this has brought them to sudden prominence in pest management programme.

Aromatic secondary metabolites with phenolic structures, like carvacrol, eugenol, and thymol, show antimicrobial effects and serves as plant defence mechanisms against pathogenic microorganisms (Das, 2010). The volatile antimicrobial substance allicin (Diallyl thiosulfinate) is synthesized in garlic when the tissues are damaged and the substrate alliin (S-allyl cysteine sulfoxide) mixes with the enzyme alliin-lyase. Allicin is readily membrane-permeable and undergoes thiol-disulphide exchange reactions with free thiol groups in proteins. Allicin effectively controlled seed-borne *Alternaria* spp. in carrot, Phytophthora leaf blight of tomato and tuber blight of potato as well as Magnaporthe on rice and downy mildew of *Arabidopsis thaliana* (Slusarenko, 2008). Application of plant products especially essential oils is a very attractive method for controlling post-harvest diseases.

Essential oil extracted from lemon grass (*Cymbopogon* spp.) is effective against post-harvest anthracnose of mango fruit (Salomone, 2008). The anti-viral protein (AVP) extracts from *Bougainvillea spectabilis* and *Prosopis chilensis* were found to be effective in reducing the sunflower necrosis virus (SFNV) infection both in cowpea and sunflower plants (Lavanya, 2009).

2.1. a Mode of action against insects

Most plant extracts act on insects by repelling, deterring feeding and oviposition, toxicity, lethal activity and interfering with physiological activities (Laxmishree, 2017). The multi-active role of botanical insecticides on insect pests makes them more popular. Commercialised products from plants such as pyrethrum have been reported to possess among others the neurotoxicant effects on insect pests causing paralysis and knock down and consequently mortality (Grdisa, 2013). Botanical pesticides also interfere with production of important enzymes such as those responsible for moulting thus inhibiting growth and development (Ntalli, 2011). Garlic (*Allium sativum*) and turmeric (*Curcuma longa*) extracts cause mortality, repellence, toxicity and inhibition of progeny emergence on the red flour beetle (*Tribolium castaneum*) (Ali, 2014). Extracts from these plants have been reported to interfere with oviposition, egg hatching and general development of the insect pests. Some botanical pesticides have been associated with paralysis and blockage of electron transportation in respiratory processes of insects, immobilization and toxicity (Moreira, 2007 and Singh, 2001).

2.1. b Mode of action against fungal pathogens

The terpenes, phenols, alcohols, alkaloids, tannins and other secondary metabolites found in botanical pesticides induce toxicity to fungal cell walls, cell membranes and cell organelles (Yoon, 2013). These metabolites also inhibit spore germination, mycelial development, germ tube elongation, delayed sporulation and also inhibit production of important enzymes, DNA and protein synthesis (Martinez, 2012). The plant compounds also induce structural modifications of the hypha and mycelia thus inhibiting production of substances such as aflatoxin and fumonisin from some fungi such as *Aspergillus* spp. and *Fusarium* spp. respectively. This results in reduced pathogenicity of mycotoxin producing fungal pathogens (Martinez, 2012). Exposure of *Fusarium verticillioides* to different plant extracts has been shown to cause disruption of cell walls, loss of cellular components and inhibiting production of essential compounds like fumonisin and ergosterol (Bomfim, 2014). For instance, ginger (*Zingiber officinale*) extracts reduce cytoplasmic content of *Fusarium* sp. in addition to inducing change in the morphology of microconidia (Yamamoto-Ribeiro, 2013). According to Perelló *et al.* (2013), allicin, the most active constituent of garlic (*Allium sativum*), causes morphological abnormalities such as collapsing, thinning and damaging of hyphal strands, inhibited germination of spores and hyphal growth. Allicin, like other secondary metabolites found in the plants, is target specific and always work in synergy with other compounds to inhibit sporangium formation and spore germination (Hadi, 2013 and Wink, 2015).

2.1. c Mode of action on bacterial pathogens

The chemical composition of botanical pesticides provides varied antibacterial properties including growth inhibition (Aljamali, 2013). Gram-negative bacteria are more susceptible than gram-positive bacteria due to absence of a peptidoglycan cell wall (Djeussi, 2013). Some of the effects of the botanical pesticides on bacteria include inhibition of cellular processes such as protein synthesis, increasing permeability of plasma membrane leading to leakage of cell contents and finally death (Khan, 2009). The antimicrobial activity of *Aloe vera* is attributed to presence of phytochemicals which denature microbe proteins hence disrupting their functionality. *Aloe vera* contains cinnamic acid which inhibits glucose uptake and production of ATP (Djeussi, 2013). Ascorbic and coumaric acids are also present in *Aloe vera* which inhibits enzymatic activities which in turn affects the functionality of the microorganisms (Karpagam, 2011).

2.1. d Mode of action on virus pathogens

Botanical pesticides inhibit viral pathogen development mainly through manipulation of the host by production of antiviral proteins which induce inhibition of any activity between plants and the virus (Montanha, 2004). Some compounds found in plants with antiviral properties induce systemic resistance of the host plants, inhibit transmission of viruses and have insecticidal properties against insect vectors (Waziri, 2015). General modes of action include inhibiting virus penetration into the host cell, inhibiting virus replication, enzymatic activity as well as haemagglutination, which is vital for virus attachment. Inhibiting virus attachment to the host cell as well as multiplication at the early stages is key in achieving antiviral action (Bhanuprakash, 2008). Prevention of adsorption of the virus to the host is also a major mechanism of plant extracts in managing viral infections (Kohn, 2015). *Thuja orientalis* inhibited multiplication of Watermelon Mosaic Virus isolated from water melon (*Citrus lanatus*). There was reduction in symptoms of virus infection on the hypocotyls of explants after treatment with the extracts. The reduction in disease symptoms was attributed to blockage of liberation of nucleic acids, thus inhibiting multiplication of the virus (Elbeshehy, 2015).

2.1.1 Insecticidal botanicals

The response of plant-based insecticides were analysed against potato-tuber moth, *Phthorimaea operculella*, (Lepidoptera: Gelechiidae) infesting solanaceous crops. Extract from the seeds of *Ocimum basilicum*, rhizomes of *Acorus calamus* and leaves of *Ageratum conyzoides* were tested in films in the laboratory conditions against 5^{th} instar larvae of *Phthorimaea operculella* (Zell.). The percentage mortalities caused in 24 h by 2 per cent extracts were 44.07, 41.54 and 40.74, respectively (Pandey *et al.,* 2012).

Palaniswamy and Ragini (2000) evaluated the leaf extracts of nine plant species (*Adathoda vasica*, *Vitex negundo*, *Azadirachta indica*, *Aristolochia bracteata*, *Lippia nodiflora*, *Argemone mexicana, Sansevieria* sp., *Cissus quadrangularis* and *Aloe* sp.) as five per cent aqueous extracts on chilli plants 30 days after transplanting. The *Polyphagotarsonemus latus* populations were reduced in all treatments, compared to the untreated control, at five and ten days after treatment with *Lippia nodiflora* and *Aloe* sp. leaf extracts resulting in the lowest populations at 0.67 mites $leaf^{-1}$.

Smitha and Giraddi (2002) studied the influence of organics, new acaricides, insect growth regulator, botanicals and bioagents. The synergistic effect of some plant oils with dicofol was also included in the study on yellow mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) infestation in chilli at University of Agricultural Sciences, Dharwad. Botanicals, *viz*., NSKE, *Clerodendrum inerme* and *Vitex negundo* leaf extracts at 5 per cent were moderate in their efficacy, whereas bioagents, *Verticillium lecanii* and *Paecilomyces fumosoroseus* and insect growth regulator, buprofezin were ineffective as indicated by poor population reduction and eventual yield reduction. Castor oil that recorded least mite population and leaf curl index emerged as the best synergist with dicofol in reducing yellow mite with highest dry chilli yield (3.04 q ha^{-1}). Honge oil and neem oil also synergized dicofol and were next only to castor oil. Botanicals and bioagents were found to be safe to the natural enemies, viz., coccinellids and *Amblyseius* spp. in chilli ecosystem. However, *Vitex negundo* was slightly toxic to *Amblyseius* spp. compared to other plant extracts.

Muthulakshmi *et al.* (2004) studied the efficacy of plant extracts against *Nilaparvata lugens* (Stal), *Cnaphalocrosis medinalis* (Guenee), *Spodoptera litura* Fab. and *Henosepilachna vigintioctopunctata* F. Aqueous plants extracts of roots of *Withania somnifera*, tubers of *Gloriosa superba*, shoots of *Ocimum basilicum*, leaves of *Nicotiana tabacum*, seeds of *Anamirta cocculus*, whole plant of *Tagetes erecta*, rhizomes of *Acorus calamus*, seeds of *Azadirachta indica*, whole plants and roots of *Tephrosia purpurea*, shoots of *Ruellia tuberose* at 10 per cent level were used. Screenhouse studies revealed that oviposition and hatchability was less in *Azadirachta indica*, *Acorus calamus* and *Gloriosa superba*. Only 42.86 per cent nymphs became adults in *Acorus calamus* 10 per cent treated plants.

Tewary *et al.* (2005) demonstrated the pesticidal properties in five medicinal plants (*Berberis lyceum* L., *Hedera nepalensis* L., *Acorus calamus* L., *Zanthoxylum armatum* L. and *Valeriana jatamansi* L.) against *Aphis craccivora* Koch. Activity against *Aphis craccivora* was found in all the test samples with varied toxic potential. Most promising results against *Aphis craccivora* were showed by the extract prepared from leaves of *Hedera nepalensis*, roots of *Berberis* lycium and essential oil from the rhizomes of *Acorus* calamus and whole plant of *Valeriana jatamansi*. These four samples produced mortality in the range 91 to 95 per cent at lower testing dose (5000 ppm).

Thonte *et al.* (2009) studied the insecticidal effect of six medicinal plants, *Azadirachta indica* Linn. (Meliaceae), *Embelia ribes* Burm. (Euphorbiaceae), *Acorus calamus* Linn. (Araceae), Solanum *nigrum* Linn. (Solanaceae), *Ocimum sanctum* Linn. (Labiatae), *Pongamia glabra* Vent. (Leguminosae), on insect pests, aphids, white grub and wireworm of the potato plant (*Solanum tuberosum* Linn. Family: Solanaceae). Aqueous decoction of each plant was sprayed on plants over a period of eight weeks. Aqueous decoction of all plants was found more effective against potato aphids as compared to sub-soil pest; wireworm and white grub. Out of six plants, decoction of *Azadirachta indica* and *Ocimum sanctum* showed significant insecticidal activity against potato pests.

Venkateshalu *et al.* (2009) evaluated the herbal pesticide Stanza from Universal Crop Science Ltd, against thrips and mites in chilli crop and found significant reduction in thrips (1.36 leaf^{-1}) and mite (3.75 leaf^{-1}) population at 2 ml L^{-1} with a highest crop yield of 32.64 q ha^{-1}.

Mamun and Ahmed (2011) reported pest control properties of botanicals like *Azadirachta indica*, *Melia azedarach*, *Swietenia mahagoni*, *Pongamia pinnata*, *Adathoda vasica*, *Acorus calamus*, *Nicotiana tabacum*, *Derris elliptica*, *Annona squamosa*, Smart weed (*Polygonum hydropiper*), Bur weed (*Xanthium strumarium*), *Datura metel*, *Calotropis gigantea*, Bidens (*Bidens pilosa*), *Lantana camara*, *Chrysanthemum cinerariifolium*, *Artemisia vulgaris*, *Tagetes erecta*, *Clerodendrum inerme*, Wild sunflower (*Helianthus* sp.) against the major pests of tea such as *Helopeltis*, red spider mite, aphids, thrips, jassid, flushworm, termites and nematodes.

Shanker and Uthamasamy (2010) studied the bioefficacy of plant extracts of *Cassia tora, Clerodendrum inerme, Calotropis gigantea, Aloe vera, Vitex negundo, Andrographis paniculata* and neem seed kernel extract (NSKE) against *Helicoverpa armigera* and *Aphis gossypii* and found that insecticidal activity was highest for NSKE (10%) followed by NSKE (5%), *Andrographis paniculata*, *Vitex negundo, Calotropis gigantea, Cassia tora, Clerodendrum inerme, and Aloe vera* extract. All botanicals showed greater ovipositional deterrence than insecticidal activity exhibiting 40–100 per cent inhibition compared to untreated control.

Field study on evaluation on the efficacy of different bio-pesticides (neem, tobacco and datura) against major sucking pests on brinjal at the experimental area of Entomology Section, Agriculture Research Institute, (ARI) Tando, during 2015 revealed that the first spray of neem extract showed the highest reduction per cent (82.60%) against white fly, followed by tobacco extract (75.95%), datura extract (73.93%), and lowest for untreated control (11.07%). In the second spray also neem extract showed highest effect against white fly (67.53%); followed by tobacco extract (56.43%), datura extract (42.25%), and least by untreated plot (5.49%). Neem extract showed highest effect (55.95%) against jassids also, followed by tobacco extract (53.38%), datura extract (63.11%) and untreated control (8.00%). In the second spray also, neem extract showed highest reduction per cent (68.73%) followed by tobacco extract (55.72%), datura extract (50.66%) and the lowest was resulted by untreated control (13.90%). Against mites' population on brinjal, the first spray results showed that neem extract showed highest effect (96.19%) followed by tobacco extract (95.75%), datura extract (86.86%) and least population was recorded in untreated control (9.96%). After second spray, neem extract showed highest reduction per cent (98.33%), followed by tobacco extract (92.85%), datura extract (88.93%) and the lowest reduction per cent was resulted by untreated control (9.14%) respectively. Neem extract thus found superior against sucking insect pests studied in brinjal, followed by, tobacco extract and datura extract (Ali *et al.*, 2014).

Evaluation of four different plant extracts *Acorus calamus, Vitex negundo*, *Adathoda vasica* and *Dioscorea deltoidea* against *Helioverpa armigera* revealed that LC_{50} values for methanol, ethyl acetate, hexane extract of *Acorus calamus*, methanol extract of *Vitex negundo* and ethyl acetate extract of *Adathoda vasica* were 2.0203, 2.2938, 2.8474, 3.4600 and 4.1709 per cent for 2nd instar larvae of *Plutella xylostella*, respectively. For *Helicoverpa armigera*, LC_{50} values were 1.7495, 2.3296, 3.0859, 3.7773 and 4.0296 per cent for methanol, ethyl acetate, hexane extract of *Acorus calamus*, methanol extract of *Adathoda vaisca* and ethyl acetate extract of *Vitex negundo* for 2^{nd} instar larvae of *Helicoverpa armigera*. Different plant extracts also exhibited ovicidal activity against *Plutella xylostella* and *Helicoverpa armigera* and resulted in 12.62 to 79.39 and 12.74 to 53.61 per cent reduction in egg hatching, respectively. Plant extracts from polar solvents were found to be more effective in reducing the hatchability as compared to non-polar. Maximum anti-feedant activity (74.63 and 80.95% feeding inhibition) was observed in hexane and methanol extract of *Acorus calamus* for *Plutella xylostella* and *Helicoverpa armigera*, respectively. Repellent effects showed that maximum repellency was observed in methanol extract of *Acorus calamus* (51.33%) and ethyl acetate extract of *Vitex negundo* (56.89%) for *Plutella xylostella* and *Helicoverpa armigera*, respectively (Singh, K. and Mehta, P. K. 2015).

Botanical oils *viz.* Neem oil, Mahogany oil and Karanja oil and the acaricide Ambush 1.8 EC were tested against jute yellow mite *(Polyphagotarsonemus latus)* in the field laboratory of Entomology, Bangladesh Agricultural University, on standing jute plants of the experimental plots and assessed for their effect on the basis of population of the pest at 24, 48 and 72 hours after treatment and the reduction of yellow mite infested plant after 7 and 10 days of spraying. The acaricide Ambush 1.8 EC was found effective with highest per cent of reduction *(*80.25*)* in mite infested plant. Among the botanicals, neem oil and mahogany oil showed better efficacy and caused 60.55 per cent and 55.89 per cent reduction of mite infestation respectively. Karanja oil was not found promising in controlling yellow mite of jute. Considering the effectiveness against the mite pest as well as the environmental safety, use of neem and mahogany oil and also the reduced risk acaricide, Ambush 1.8 EC (Rahman *et al.*, 2016).

Lab study using 42 methanol extracts and 12 aqueous extracts of 29 indigenous medicinal plant species for their acaricidal bioactivity against the two spotted spider mite, *Tetranychus urticae* adults showed that 14 methanol plant extracts caused significant mortality in mites. Methanol whole plant extracts (WPEs) of *Lotus carmeli*, *Alchemilladia demata, Eryngium deserlorum* and aqueous fruit extracts (FrEs) of *Melia azedarach* caused toxic effects against the adult mites in the range of 41-46 per cent mortality. The methanol WPE of *Lotus carmeli* and the aqueous FrE of *Melia azedarach* (1:5) caused the highest mite mortality of 43.55 per cent and 45.55 per cent, respectively and each was used as reference sample for potential acaricidal activity in the methanol and aqueous treatment groups. Methanol extracts of *Salvia rubifolia* flowers and *Calendula palestina* FrE were found to be more active against the adult mite than their extracts of other plant parts as leaves and flowers, respectively. The former two extracts, flower extracts of *Anthemis scariosa*, *Echinops gaillardoti, Nepeta curviflora,* and *Ranunculus cuneatus*, leaves and stems extract of *Anthemis scariosa* and WPEs of *Melissa inodora, Ranunuculus myosuroides, Origanum libanoticum* and *Achillea damascena* were found to be comparable in their acaricidal activity to that of the whole plant extract of *Lotus carmeli* (Abou-Fakhr Hammad *et al.,* 2017).

Plant extracts from Neem, *Azadiracta indica* L. Thulasi, *Ocimum sanctum* L., Notchi, *Vitex negundo* L. and Garlic, *Allium sativum* L. were tested against Tobacco caterpillar, *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) at 10 per cent and 15 per cent concentration and *Azadiracta indica* at 15 per cent showed antifeedant index and larval mortality as 79.39 and 82.10 per cent respectively. The least pupal transformation (20.20%) and least adult transformation (10.20%) were also recorded in *Azadiracta indica* 15 per cent (Murugasridevi, 2017).

Acaricidal efficacy of certain neem based pesticides against the red spider mite (*Tetranychus urticae* Koch) infesting okra during 2008 and 2009 revealed that out of nine neem based treatments, neem seed kernel extract (NSKE) five per cent applied as six rounds of foliar sprays proved to be the most effective with 88.80 per cent mite reduction. All other neem based formulated products (Neem Ban, Rakshak Gold) almost remained at par, with a reduction ranging from 81.00 to 83.60 per cent). The highest fruit yield (172.80 q ha^{-1}) of okra was obtained also in case of NSKE- five per cent and other neem based formulations of pesticides viz. Neembicidine, Achook, Neemark, Neemguard, Rakshak Gold and Uttam Neem remained statistically at par in this regard. Neem Ban and Neemazal appeared to be little inferior to the neem products in terms of yield realization, inspite of their equivalent acaricidal efficacy against *Tetranychus urticae*. The present findings suggest that NSKE (neem seed kernel extract) 5 per cent found to be the most effective eco-friendly management of *Tetranychus* urticae for sustainable cultivation of okra during summer season (Prasad *et al.,* 2017).

Devi et al. (2018) screened the botanicals for insecticidal property against pink mealybug, (*Maconellicoccus hirsutus* (Green) Hemiptera: Pseudococcidaea). The insecticidal activity of 10 per cent aquous extract of 46 plant species were evaluated and the per cent mortality ranged between 0.0 to 96.7 at 24 Hours After Exposure (HAE) and 0.0 to 98.3 at 48 and 72 HAE. *Calotropis gigantea* showed the highest mortality 96.7, 98.3 and 98.3 per cent at 24, 48 and 72 HAE. It was followed by *Ricinus communis, Helictere sisora, Centella asiatica, Spathodea campanulata, Colocasia esculenta*, *Ocimum tenuiflorum*, *Curcuma longa* and *Piper nigrum* which also showed potential in managing pink mealybugs.

Akter *et al.* (2019) evaluated the effectiveness of plant materials against yellow mite (*Polyphagotarsonemus latus*) on jute (*Corchorus olitorius*) cv. 0–9897 in both greenhouse and field condition during the period from March to October 2016. In greenhouse premises, the mortality per cent of 69.39, 67.77, 63.86, 62.43 and 61.47 were recorded with extract of neem seed kernel @ 1:20, mahogony seed, pithraj seed, turmeric powder and green neem leaf, respectively. In field condition, the highest reduction (70.20%) of infestation over control, lowest nodes plant^{-1} (52.50), tallest plant (3.10 m) and highest yield increase (38.60%) over control were observed in neem seed kernel extract @ 1:20. In conclusion, neem seed kernel extract, mahogany seed extracts, pithraj seed extract, neem leaf extract and turmeric powder extract @ 1:20 can be safely used for the management of yellow mite of Jute.

The effect of *Calotropis gigantea* based botanical (500 gm Calotropis leaf + 2 whole lemon extract + 1 litre cow urine + 1 litre raw buttermilk) at ten days interval starting at 15 days after transplanting, followed by once in 15 days was observed with minimum thrips population 1.8-7.8/apical shoot (four top leaves) during 10 to 100 days after transplanting of chilli (Chakroborty, *et al.,* 2019).

Elango *et al.* (2019) evaluated the acute toxicity of Spinosad, NSKE, horticultural mineral oil and entomopathogens at the recommended concentration against pomegranate sucking pests like thrips (*Scirtothrips dorsalis*), whitefly (*Siphoninus phillyreae*) and two tailed mealy bug (*Ferrisia virgata*). The study revealed that among all treatments, spinosad 45 per cent SC (0.0125%) exhibited mortality in thrips (53.33%), whitefly (55.55%) and mealy bugs (48.88%) followed by NSKE (5%) and azadirachtin 10000 ppm.

2.1.2 Antifungal botanicals

Dichloromethane extract of dry and powdered rhizomes of *Acorus calamus* L. were tested at various concentrations (0.01-0.15 %) against plant pathogenic molds for antifungal activity on Potato Dextrose Agar against *Alternaria* spp. isolated from leaf spot, *Fusarium* spp., isolated from wilt diseases of cruciferous vegetable, *Botrytis* spp., isolated from gray mold rot of roses and *Septoria* spp. isolated from leaf spot of chrysanthemum. The results indicated that all of the molds examined were sensitive to *Acorus calamus* extract. The growth of all tested fungi was completely inhibited at the concentration of 0.10 per cent upward. Separation by preparative-TLC and guidance by TLC-bioassay using *Cladosporium cladosporioides* as a diagnostic fungus revealed an active compound that was identified as β-asarone (cis-1, 2, 4-trimethoxy-5-(1-propenyl)- benzene) by GC-MS (Mungkornasawakul *et al.*, 2002).

Aqueous, saline buffer and acid extracts of 10 plant species used in traditional Uruguayan medicine were screened *in vitro* for their antifungal activity against the phytopathogenic fungus, *Alternaria spp.* Minimal inhibitory concentration (MIC) and minimum fungicidal concentration (MFC) of the extracts were determined. Three solvents were assayed on different tissues of the plants and among the 29 evaluated extracts, 31 per cent of the extracts inhibited growth, similar to the effects of a chemical fungicide. Acid extracts of the plants were more effective than the aqueous or saline buffer extracts against *Alternaria spp.* The MIC values of the extracts were determined ranging between 1.25 and 25 µg mL^{-1}. The MFC values of the extracts ranged between

1.25 µg mL^{-1} (*Rosmarinus officinalis* L.) and 10 µg mL^{-1} (*Cynara scolymus* L.). MICs and MFCs values obtained from leaves (*Salvia officinalis* L. and *Rosmarinus officinalis*) and seeds extracts (*Salvia* sclarea L.) were quite comparable to values obtained with the conventional fungicide Captan (2.5 µg mL^{-1}). The extracts of *Salvia sclarea, Salvia officinalis and Rosmarinus officinalis* could be considered as potential sources of antifungal compounds for treating diseases in plants (Dellavella *et al.,* 2011).

Study on Antifungal activity of zedoary turmeric oil (ZTO) against *Phytophthora capsici* at Jiangsu Province and Chinese Academy of Sciences, China revealed that the ZTO could inhibit *Phytophthora Capsici* growth and development *in vitro* and in detached cucumber and *Nicotiana benthamiana* leaves. Besides, ZTO treatment resulted in severe damage to the cell membrane of *Phytophthora capsici*, leading to the leakage of intracellular contents. They identified 50 volatile organic compounds from ZTO, and uncovered Curcumol, β-elemene, curdione and curcumenol with strong inhibitory activities against mycelial growth of *Phytophthora capsici (*Bi *et al.,* 2019).

2. 1. 3 Antibacterial botanicals

Satish *et al.* (1999) screened aqueous extracts from leaves of 30 higher plants, as *in vitro* for antibacterial activity against different pathovars of the phytopathogenic bacterium, *Xanthomonas campestris*. Eight plant species showed antibacterial activity based on the zone of inhibition in a diffusion assay. Significant antibacterial activity was observed in the aqueous extracts of *Prosopis juliflora*, *Oxalis corniculata* and *Lawsonia inermis*. The susceptibility of different pathovars of *Xanthomonas campestris* to these plant extracts varied. The antibacterial activity of extracts of a few plants was comparable with that of the synthetic antibiotics, Bacterimycin and Streptocycline.

Examination on the ethanobotanical efficacy of *Achyranthes aspera, Artemisia parviflora, Azadirachta indica, Calotropis gigantea, Lawsonia inermis, Mimosa pudica, Ixora coccinea, Parthenium hysterophorus* and *Chromolaena odorata* using agar disc diffusion method against phytopathogenic bacteria (*Xanthomonas vesicatoria* and *Ralstonia solanacearum*) showed maximum *in vitro* inhibition in methanol extracts of

Chromolaena odorata which offered inhibition zone of 12 mm against both bacteria, followed by chloroform extract of the same plant leaf with inhibition zone of 4 mm. The minimum inhibitory concentration (MIC) value for the phytopathogenic bacteria ranged between 0.25 to 4.0 mg ml^{-1} when tested with all four solvents extracts of *Chromolaena odorata*. Whereas, extracts of *Achyranthes aspera, Artemisia parviflora, Calotropis gigantea, Lawsonia inermis, Mimosa pudica* and *Ixora coccinea* were found to be ineffective or showed poor inhibition on tested phytopathogenic bacteria (Sukanya *et al.*, 2009).

Medicinal plants such as *Amaranthus spinosus, Barbeya oleoides, Clutia lanceolata, Lavandula pubescens, Maerua oblongifolia* and *Withania somnifera* collected from different locations in the south western parts of Saudi Arabia were screened against five plant pathogenic fungi causing serious diseases of vegetable crops, *viz*. *Alternaria brassicae*, *Alternaria solani*, *Botrytis fabae*, *Fusarium solani* and *Phytophthora infestans*. The aqueous extract of *Lavandula pubescens* leaves was found best for controlling all phytopathogenic fungi (Zakaria, 2010).

Kumar *et al.* (2017) evaluated the various botanicals like *Calotropis gigantea*, *Ocimum gratissimum*, *Ocimum sanctum, Tylophora asthmatica, Nigella sativa* and *Ruta graveolens* against *Ralstonia solanacearum*. *Ocimum grattissimum* extract showed highest inhibition zone of 28.66 mm. at 1:0 dilution. Alcohol extract of *Ocimum grattissimum* was the most the effective in inhibiting the growth of *Ralstonia solanacearum* followed by *Calotropis gigantea*, *Ocimum sanctum, Tylophora asthmatica, Nigella sativa* and *Ruta graveolens* extracts. Alcohol extract of *Ocimum gratissimum* was found more efficacious than that from *Ocimum sanctum* in delaying the onset of wilt disease where in 100 per cent wilt incidence was observed at 56 days after inoculation.

Amini *et al.* (2012) studied the effectiveness, minimum inhibitory concentration (MIC) and minimum fungicide concentration (MFC) of three medicinal plant essential oils of *Zataria multiflora*, *Thymus vulgaris* and *Thymus kotschyanus* on the mycelial growth of four pathogenic fungi including *Pythium aphanidermatum*, *Rhizoctonia solani* (AG4), *Fusarium graminearum* and *Sclerotinia sclerotiorum*. The results showed the effectiveness of these essential oils on the four studied plant pathogenic fungi with growth inhibition average of 100 per cent at 200 µl l^{-1} concentration. *Pythium aphanidermatum* and *Sclerotinia sclerotiorum* were the most sensitive and most resistant to the studied essential oils with average growth inhibition 89.54 per cent and 75.35 per cent, respectively.

Mutimawurugo *et al.* (2020) conducted an *in vitro* screening of the antibacterial activity of methanol, water and chloroform extracts of ten local plant materials against potato bacterial wilt (*Ralstonia solanacearum* Smith) in Rwanda. The results showed higher inhibition zone of methanol extracts (16.85 mm) against bacteria followed by water (14.42 mm) and chloroform (14.19 mm) extracts. All ten plant extracts inhibited the growth of the pathogen. Higher antibacterial activity was found in tobacco, wild marigold and garlic extracts (19.61, 18.56, and 18.3 mm inhibition zones, respectively). Minimal inhibitory concentration (MIC) of methanol extracts from tobacco and wild marigold was 6.25 mg mL^{-1}whereas, garlic methanol extract was 12.5 mg mL^{-1}. Water extract was showed MIC of 12.5 mg mL^{-1} in all three plant species. The findings revealed that tobacco, garlic and wild marigold extracts are the best and the methanol extracts are the most efficient in management of potato bacterial wilt in comparison to water and chloroform extracts.

2.2 **Pesticidal effects and phytochemicals in *Acorus calamus***

Study on insecticidal and juvenile hormone activity of plant extracts revealed that an essential oil of *Acorus calamus* L. inhibits interstitial cell activity; this would represent a new concept in insect chemosterilisation (Saxena *et al.*, 1977).

Essential oil of *Acorus calamus* was found toxic against late 3rd instar larvae of Dengue fever virus vector mosquito the *Aedes aegypti*. The LC_{50} was found to be 1250 ppm by WHO-method (Anon., 1970). When late 3^{rd} instar larvae were exposed to lower dose 150, 300, 450, 600 and 750 ppm, the abnormalities were produced. The abnormalities were increased with the increase of dose. These abnormalities are due to the effect of Insect Growth Regulators (IGR) by acorus oil, because in control no abnormalities were recorded (Verma *et al.,* 2006; Tariq *et al.,* 2009).

Tariq & Qadri (2001) reported two hours repellency of acorus oil against dengue fever vector mosquitoes and 50 per cent biting after two hours. Whereas 2.5 hours repellency and 34 per cent biting in 2.5 hours was recorded by marketed repellents such as King & Mospel (Harish *et al.,* 1999; Ravikant *et al.,* 2007; Streloke *et al.,* 1989).

An antifungal substance was isolated from the extract of *Acorus gramineus* using various chromatographic procedures. The antibiotic was identified as beta-asarone, cis-2,4,5-trimethoxy-1-propenylbenzene, on the basis of the high-resolution EI-mass, NMR, and UV spectral data. Beta-asarone completely inhibited mycelial growth of some plant pathogenic fungi, *Cladosporium cucumerinum, Colletotrichum orbiculare, Magnaporthe grisea*, and *Pythium ultimum*, in a range of 0.5-30 microgram mL^{-1}. The growth of *Bacillus subtilis*, *Erwinia carotovora* subsp. *carotovora*, *Ralstonia solanacearum*, and *Xanthomonas campestris* pv. *vesicatoria* was slightly suppressed by beta-asarone. As the concentration of beta-asarone increased, *M. grisea* infection was drastically inhibited on rice leaves. Treatment with 500 microgram mL^{-1} of beta-asarone also greatly suppressed lesion formation of *Colletotrichum orbiculare* on cucumber leaves (Lee *et al.,* 2004).

Study on the effect of essential oil from rhizomes of *Acorus calamus* against grubs of *Trogaderma granarium* (Everts) showed 11.10, 22.59 and 44.70 per cent morality at exposure time of 3, 5 and 7 days, respectively. The mortality of 22.18, 24.44 and 27.77 per cent was observed with 30, 50 and 70 µL of oil respectively. Reduction in the population build up was observed both with increase in dose of *Acorus calamus* oil and exposure time. The exposure period found to be the most important factor affecting the toxic effect of the vapours of the Acorus oil rather than the dosage (Mansoor-ul-Hasan *et al.,* 2006).

Aqueous extract of sweet flag along with neem seed kernel extract reported minimum oviposition index of 0.22 and maximum ovicidal action of 62.60 per cent against *Leucinodes orbonalis* (Yasodha and Natarajan, 2007).

Ethanolic extract of *Acorus calamus* rhizome was evaluated on the insecticidal and genotoxic activity against *Drosophila melanogaster* and found that the Lethal concentrations (LC_{50}) values of ethanolic extract against larvae, adult males and females of *Drosophila melanogaster* were 109.54, 52.51, 41.11 mg L^{-1} respectively. Genotoxicity of adult flies were determined at 30 and 55 mg L^{-1} ethanolic extract of *Acorus calamus* (Kumar *et al.,* 2015).

Evaluation study of *Acorus calamus* L. against sucking pests of brinjal in agricultural college and research institute, killikulam during the year of 2014-2015 revealed that aqueous rhizome extract recorded the lowest mean population of aphids (9.28) followed by rhizome powder (14.14). Aqueous rhizome extract one per cent recorded a mean population of 70.29 per cent reduction over control on leaf hopper (Shinthiya and Razak, 2017).

An Emulsifiable Concentrate (EC) formulation of *Acorus calamus* imparted oviposition deterrence in the range of 48.85±2.86 to 56.79±1.50 per cent against *Leucinodes arbonalis.* The highest reduction in hatchability of 91.11 per cent was observed in 8.0 per cent concentration of *Acorus calamus* EC. The 8.0 per cent concentration of formulation resulted in a mortality of 79.98 per cent on neonate larvae. Per cent pupation and adult emergence was also low in 8.0 per cent concentration. The increase in concentration of *Acorus calamus* EC resulted in a decrease in per cent parasitisation as well as emergence rate of *Trichogramma pretiosum* and *Trichogramma chilonis* (Ranjith *et al.,* 2019).

2.3 **Pesticidal effects and phytochemicals in *Curcuma zedoaria***

Arora *et al.* (2014) evaluated the efficacy of an indigenous biopesticide formulation (BPF) comprising easily accessible botanicals (*Phyllanthus emblica* fruit, *Curcuma zedoaria,* Potassium aluminum sulfate dodecahydrate (naturally occurring mineral salt), alum, *Allium cepa* (onion) bulb, *Allium sativum* (garlic) bulb, *Calotropis procera* and fresh cow dung extract, *Lycopersicon esculentum* (tomato) leaf extract, *Ferula narthex, Azadirachta indica* leaves, *Ocimum canum* (tulsi) leaves and Cow urine) against insect pests of tomato crop under field. The BPF treatment showed control of 70–80 per cent of fruit borers compared to check plots, resulting in enhanced fruit yield of 35 tons ha^{-1} as compared to 15 tons ha^{-1} in the check plots. The fruit damage observed in 10 per cent BPF treated plots was only 3–4 per cent compared to 35–40 per cent in control plots and 16% in organically treated plots. It was slightly higher in five per cent BPF (5–7% damage) and 10 per cent BPF + organic (4–5% damage) treated plots. The damage observed was 8–11 per cent in five per cent BPF + organic plots. Because of least damage in BPF at 10 per cent treated plots, the highest yield was observed. It was 35–36 tons ha^{-1} compared to 15 tons ha^{-1} in check plots and 17 tons ha^{-1} in organically treated plots. Ten per cent BPF treatment was the best for controlling fruit borers of tomato crop.

The extracts of fifteen plants were evaluated for their antifungal activity against *Fusarium oxysporum* F. sp. *Udum* and rhizome extract of *Curcuma zedoaria* (Christm.) showed maximum inhibition (100%), followed by *Azadirachta indica* (81%) and *Allium cepa* Linn. (68%).The extract of more than 10 plants shows 50 per cent or above inhibition in mycelial growth (Gupta *et al.,* 2017).

Aungtikun and Soonwera (2019) screened the larvicidal property of essential oils from *Zingiber mekongense* Gagnep, *Myristica fragrans* Houtt and *Curcuma zedoaria* Roscoe and observed the strongest larvicidal activity against *Aedes albopictus by Curcuma zedoaria* at 10 per cent concentration and yielded the highest mortality rate of 100 per cent with LC_{50} value at 1.09 per cent and LT_{50} value of <0.01 h.

2.4 Pesticidal effects and phytochemicals in *Calotropis gigantea*

Evaluation study of *C. procera* extracts against *Henosepilachna elaterii* of cucumber revealed the strong repellency and deterrence from feeding. One per cent and **2.5** per cent extracts highly reduced the fecundity and longevity of the insect (Ahmed *et al.,* 2006).

Rai *et al.* (2009) proved that the effectiveness of the solvent extracts of *Calotropis tridax,* kochea against chilli mite in laboratory condition.

Calatropin and Calotoxin are the major active principles present in *C. gigantea*, which show anti feedancy, repellency, oviposition deterrence and insect growth regulator activity against insect pests (Sharma *et al.,* 2012).

Bharati *et al.* (2014) assessed the effects of herbal pesticides from *Calotropis procera* and *Allium sativum*, and a formulation containing azadirachtin on fecundity and fertility of the silverleaf whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) grown on greenhouse tomato plants. The effects were compared to that of pymetrozine, a synthetic insecticide. Results showed that there was a significant difference among treatments for all reproductive parameters. Gross fecundity rates for pesticides control, herbal extract control, *Calotropisprocera* extract, *Allium sativum* extract, azadirachtin and pymetrozine were 184.75, 146.72, 80.11, 82.18, 63.06 and 55.96 eggs, respectively.

Botanical extracts against thrips infesting garlic were screened at Organic Farm, NAU, Navsari during 2015, results indicated that of *Datura metel* (L.) leaves extract 10 per cent was the best in reducing thrips (*Thrips tabaci* Lindeman) population, recorded 14.79 thrips plant^{-1} with maximum bulb yield (75.24 q ha^{-1}). Highest Cost Benefit Ratio-CBR (1:13.47) was registered in the treatment *Datura metel* leaves extract 10 per cent followed by *C. gigantea* (L.) leaves extract 10 per cent (1:12.89) (Shah and Jigarkumar, 2016).

The flower extract of *C. gigantea* at 2000 ppm found to have insecticidal activity (90-95%) against papaya mealy bug infestation in *Ailanthus excelsa* within 24 hours of treatment (Sumathi *et al.*, 2017).

Dalei *et al.* (2018) assessed the acaricidal activity of ethanolic extracts of leaves of *Azadirachta indica*, whole plant of *Argemone Mexicana*, fruits of *Datura stramonium* and flowers of *C. gigantea* with reference to Deltamethrin and found that 100 mg ml^{-1} concentration of *Azadirachta indica* showed significant mortality of 86 per cent followed by 50mg, 25mg, and 12.5 mg ml^{-1} respectively. There was significant increase in Reproductive Index (RI) as the concentration of the extracts decreased ranging from 0.038-0.073. A significant percentage inhibition of oviposition (IO) was also reported. In case of *Argemone mexicana* mortality with significant variation ranged from 10 to 73.33 per cent. The RI increased significantly as the concentration of the extracts decreased from 100 mg $ml^{-1}$to 12.5 mg ml^{-1}. *Datura stramonium* showed significant mortality rate (66.67%) at the concentration of 100 mg ml^{-1}. There was increase in reproductive index (0.149 to 0.217) with decrease in concentration while inhibition of oviposition per cent increases with increase in concentration. Study indicated a mortality of 56.67 per cent, Reproductive Index (0.17-0.25), Inhibition of Oviposition of 66 per cent, larval mortality (60.33%) for flower of *C. gigantea*. The larval motility for *Azadirachta indica*, *Argemone mexicana*, *Datura stramonium* and *C. gigantea* at highest concentration was 75.67 per cent, 70.67 per cent, 65 per cent and 60.33 per cent respectively. From the regression equation, the LC_{50} values were found to be 29.21mg ml^{-1}, 46.77mg ml^{-1}, 61.66 mg ml^{-1} and 83.18 mg ml^{-1} for ethanolic extracts of leaves of *Azadirachta indica*, whole plant of *Argemone mexicana*, fruits of *Datura stramonium* and flowers of *C. gigantea* respectively. The plant extracts under consideration yielded varying degrees of acaricidal activity against *Rhipicephalus* (Boophilus) *microplus*. Among the four extracts, the leaves of *Azadirachta indica* revealed the highest activity followed by whole plant extract of *Argemone mexicana*, fruits of *Datura stramonium* and flowers of *C. gigantea*.

Devi *et al.* (2018) tried aqueous extracts of different parts of *C. gigantea* on female adult *Maconellicoccus hirsutus*. Maximum mortality was observed in leaf with 86.67, 91.67 and 93.33 per cent which was statistically on par with fruit pericarp showing mortality of 81.67, 88.33 and 90.00 per cent at 24, 48 and 72 HAE, respectively. LC_{50} values for fruit pericarp were 2.895 per cent followed by leaf (3.055%) and flower (3.560%).

Evaluation study on the effect of acetone, ethanol, hexane and methanol solvent's extracts of *Calotropis procera* against *Bemisia tabaci* (Hemiptera: Aleyrodidae) infesting tomato revealed that acetone extract showed the greatest effect on reducing the survival of cotton whiteflies. The effect of treatments on the intrinsic rate of population growth, finite rate of population growth, duration of each generation and gross and net rate of reproduction were significant at the level of five per cent. The intrinsic population growth rates for control treatments and acetone, ethanolic, hexane and methanolic extracts were 0.081, 0.03, 0.045, 0.054 and 0.043 per day, respectively. Regarding the parameters of the laying period and the total number of ova per insect, the control treatment was in the highest group with the values of 2.45 and 15.131, respectively, and the acetone extract treatment with the values of 0.59 and 3.093 were in the lowest group. All treatments were able to reduce the spawning period and the total number of ova per female compared to the control. Among the various solvents for extracting, acetone and methanol were better solvents for extracting the extract effective on cotton whitefly and the acetone extract can be considered as a suitable option in the integrated whitefly cotton management programme (Samih *et al.*, 2019).

Prabhu *et al.* (2020) investigated the effect of dried powder of *Calotropis gigantea* plant parts on different developmental stages of *Helicoverpa armigera*. The per cent mortality of second instar larvae of *H. armigera* was directly proportional to the concentration of the plant part dust. The leaf dust proved it's superiority over other plant part dusts by giving 86.66 per cent of mortality at 10 per cent concentration followed by 8 per cent (60.00%), 6 per cent (53.33%), 4 per cent (43.33%) mortality respectively. Flower dust treatment recorded the maximum mortality of 66.66 per cent at 6 per cent. Leaf dust at 10 per cent recorded maximum mortality rate of 83.33 per cent against third instar larvae whereas 8, 6, 4, and 2 per cent recorded mortality of 76.66, 40.00 and 26.66 per cent respectively. Next to leaf extract, flower and whole plant dust at 10 per cent concentration proved its superiority by causing 76.66 and 73.33 per cent mortality, respectively. Stem dust showed the maximum mortality at 10 per cent (56.66%).

2. 5 Botanicals on growth and yield

Efficacy of acetone and hexane extracts were studied against leafhopper (*Amrasca biguttula biguttula*) and shoot and fruit borer of okra (*Earias vittella*) under laboratory conditions and revealed that the leaf extract of *Annona squamosa* at one, two and three per cent and leaf extract of *Datura stramonium* at three per cent showed maximum reduction of leafhopper population (100%). The number of eggs laid by *Earias vittella* were less on the plants treated with two and three per cent seed extract of *Azadirachta indica* followed by two per cent leaf extract of *Mentha arvensis*, two per cent leaf extract of *Datura stramonium* and one per cent leaf extract of *Lantana camara*. The hatching of the eggs of the *Earias vittella* was affected in *Mentha arvensis*, *Argemone mexicana*, *Lantana camara* and *Calotropis gigantea* at one per cent, *Datura strumarium* at two per cent and *Azadirachta* indica and *Acorus calamus* at three per cent concentration of extracts. The survival of larvae of *Earias vittella* was affected in *Argemone mexicana*, *Lantana camara* and *Azadirachta indica* at one, two and three per cent concentration. Under field condition three per cent rhizome extract of *Acorus calamus* and two per cent leaf extract of *Lantana camara* were effective in managing the leafhopper population than untreated control. In case of shoot and fruit borer management, under field conditions, treatment with three per cent leaf extract of *Datura stramonium* and three per cent rhizome extract of *Acorus calamus* were effective. The yield of marketable fruits was maximum in three per cent leaf extract of *Datura stramonium*, three per cent rhizome extract of *Acorus calamus* and two per cent leaf extract of *Lanatna camara*. It could be concluded from laboratory and field studies that for the management of the leafhopper and fruit borer in okra in summer season, three per cent leaf extract of *Datura stramonium*, three per cent rhizome extract of *Acorus calamus*, one per cent seed extract of *Azadirachta indica* and two per cent leaf extract of *Lantana camara* were found to be effective against the pest with moderate increase in yield (Gavane, 1999).

Abd-El-Khair *et al.*, (2007) studied the efficacy of nine Egyptian medicinal plant species, basil leaves (*Ocimum bacilicum*), chilli fruits (*Capsicum frutescens*), eucalyptus leaves (*Eucalyptus globulus*), garlic bulbs (Allium sativum), lemon grass leaves (*Cymbopogon citratus*), marjoram leaves (*Majorana hortensis*), onion seeds (*Allium cepa*) and peppermint leaves (*Mentha piperita*) against late blight (*Phytophthora infestans*) and early blight (*Alternaria solani*) of potato. Aqueous extracts of these plants were evaluated against *Phytophthora infestans* and *Alternaria solani* under lab conditions, and in field. Plant extracts reduced mycelial growth and inhibited spore germination of both fungal species. The extracts reduced the disease infection with both fungal species comparing with control in detached leaves technique. The extracts of all medicinal plants reduced the disease severity of late blight in winter growing season. Lemon grass leaves and/or chilli fruit extracts gave the most reduction in late blight disease severity comparing with control. Results also showed that all tested medicinal plant extracts lowered the disease severity of early blight in summer growing season, especially the extracts of lemon grass leaves, garlic bulbs, basil leaves and marjoram leaves, respectively. The aqueous extract of lemon grass leaves was the best one in controlling both late and early blights. Data indicated that an increase in some vegetative growth characters (average stem height and average leaves number per plant) and tubers yield of potato were corresponded with the reduction of disease severity.

Venkateshalu *et al.* (2009) conducted an evaluation study to test the bio-efficacy of a new herbal pesticide, Proton obtained from Universal Crop Science Ltd, Mumbai during 2006-07 and 2007-08. Proton @ 1.50 ml l^{-1} recorded significantly lower *Helicoverpa armigera* (Hubner) larval population (0.77 and 0.62 larva $plant^{-1}$, respectively) which was on par with proton @ 2.0 ml l^{-1} and standard check spinosad 45 SC @ 0.12 ml l^{-1}. Similarly, Proton @ 2.00 ml l^{-1} recorded significantly lowest fruit damage (6.80%) which was at par with Proton @ 1.50 ml l^{-1} (7.22%). Proton @ 1.50 ml l^{-1} recorded higher green chilli yield (34.38 and 31.68 q ha^{-1} during 2006 and 2007, respectively) which was on par with Proton @ 2.00 ml l^{-1} and standard check spinosad 45 SC @ 0.12 ml l^{-1} (34.92 and 30.28 q ha^{-1} during 2006 and 2007, respectively). Proton @ 1.50 ml l^{-1} recorded higher net profit of Rs.36, 962 ha^{-1} and B: C ratio of 3.32, which is next best to spinosad 45 SC @ 0.12 ml l^{-1} but superior to nimbecidine 1500 ppm @ 3 ml l^{-1}.

Chaubey *et al.* (2017) observed minimum leaf curl virus incidence (34.63- 37.88%) in chilli plots treated with *Clerodendrum aculeatum* (leaf extract) followed by three foliar sprays of *Terminalia arjuna* (bark extract) along with fresh fruit yield (2.35-2.07 kg $plot^{-1}$) and an increase in fresh fruit yield (58.75-58.24%), maximum plant height

(55.83-55.19cm), maximum plant canopy (72.31-67.55cm), days to 50 per cent flowering (85.04-85.79 DAT), maximum fruit weight (2.31-2.23g), maximum total number of fruits per plant (72.29-70.63) and maximum number of seeds per fruit (58.35-57.70).

Melia azedarach and *Eucalyptus globulus* caused an increase of 5.32 and 5.09 per cent in plant length, 11.01 and 10.51 per cent in plant fresh weight, 32.16 and 27.98 per cent in plant dry weight and 18.36 and 16.30 per cent in number of branches plant^{-1} respectively over control. The growth promoting and disease suppressive effect of *Calotropis procera* was recorded least but statistically significant ($p \leq 0.05$) over positive as well as negative control (Khan, 2018).

Materials and Methods

3. MATERIALS AND METHODS

The study entitled "Evaluation of medicinal plant-based formulations for growth, yield and pest management in Chilli (*Capsicum annuum* Linn.)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellanikkara during the period from October 2020 to May 2021. The materials used and methodology adopted in this study are presented in this chapter.

3.1 Materials

3.1.1 Experimental site

The field experiments were conducted at the farm of Department of Plantation Crops and Spices, College of Agriculture, Vellanikkara, Thrissur, Kerala. Chilli variety Anugraha was selected for the study. It is a back cross breeding progeny between Ujwala and Pusa Jwala, developed from College of Agriculture, Vellanikkara, KAU. Plants are of short stature, spreading with attractive long, light green medium pungent fruits, which turn deep red on ripening. Salient features are high yielding, early maturing, resistant to bacterial wilt disease and more suitable as green chilli. Fruit length is 12 cm. Average fruit weight is 3.6 g. Average yield is 27 t ha^{-1}.

3.1.2 Experimental material

Three medicinal plant-based trial products (P_1, P_2, and P_3 and their combinations P_4, P_5 and P_6), developed and screened at AMPRS Aromatic and Medicinal Plants Research Station, Odakkali were utilized for the study. P_1 was developed from Vayambu (*Acorus calamus*), P_2 from Manja Koova (*Curcuma zedoaria*), P_3 from Erukku (*Calotropis gigantea*), P_4 from *Acorus calamus* and *Curcuma zedoaria*, P_5 from *Curcuma zedoaria* and *Calotropis gigantea* and P_6 from *Acorus calamus* and *Calotropis gigantea.* Solid soap formulations of these three and their combination were supplied from AMPRS, Odakkali. Liquid pesticidal soap formulations from these were evaluated at one and two per cent concentrations. The treatment details are given in table 1.

3.2 Methods

3.2.1 Raising of chilli seedlings

Seeds of chilli variety Anugraha were sown in pro trays in the first week of October 2020. Seedlings in the pro trays were maintained in poly house till transplanting to grow bags at 3-4 leaves stage.

3.2.2 Filling grow bags and field lay out

Field was cleared and levelled properly and mulched using black polythene mulch. Grow bags were filled with soil, sand, cowdung and vermicompost in the ratio 1.5:0.5:0.5:0.5. Bone meal and neem cake were also added to the potting mixture. Lime was added at 20 g per grow bag and mixed with potting mixture. Grow bags were arranged at 60 * 45 cm spacing in two rows of ten plants per treatment for all the three replications.

3.2.3 Transplanting of seedling

Chilli seedlings of variety Anugraha raised in pro trays were carefully lifted with the root ball intact and planted in shallow pits at the centre of each filled grow bag at the rate of one seedling per grow bag. Seedlings were firmly pressed to the soil and were given temporary shade and were irrigated using rose can and mulched with glyricidia leaves.

3.2.4 Manuring, irrigation and care of seedlings

All plants were given manures uniformly following KAU organic package of practices. For this liquid manuring with jeevamruthum, groundnut cake slurry and cow dung slurry were given alternatively at weekly intervals. The plants were irrigated twice a day till the establishment of seedlings, after that irrigation was given once in a day. Biocontrol agent *Pseudomonas fluorescens* was applied as foliar spray at two per cent concentration at weekly intervals to manage bacterial wilt disease caused by *Ralstonia solanacearum.*

3.3. Lay out of Experiments

Following experiments were conducted.

A. Influence of medicinal plant based formulations on growth and yield of chilli

The chilli plants raised in grow bags were sprayed with liquid formulations of medicinal plant based products and their combinations as given in Table 1 at ten days intervals. One control of one per cent soap solution without any botanicals (T13) and a positive control of one per cent Neem garlic extract (T14) were also included in the treatments for comparison. Effect of the sprays on growth parameters and yield was recorded.

B. Influence of medicinal plant based formulations on pest management in chilli

Effect of spraying the liquid formulations of medicinal plant based products and their combinations at ten days interval on the pest population and disease incidence were recorded. Population density of sucking pests *viz*, thrips, whitefly, mite and aphids were recorded as pretreatment observations one day before spraying and as post treatment observations on the third, seventh and tenth day after spraying.

3.3.1 Preparation of spray solution and application

Required quantity of pesticidal soap for each treatment were weighed and dissolved in one litre of water each with thorough stirring and kept for one hour in a plastic jar. Solutions were then filtered using muslin cloth and transfered to a hand sprayer. Spraying was done after light irrigation during evening hours.

Control (T13) was prepared using soap at one per cent concentration. Positive control (T14) was prepared with neem garlic extract at one per cent.

Table 1: Details of treatments and pesticidal formulations

Sl. No.	Treatment	Pesticidal soap formulation	Concentration (%)
1	T1	*Acorus calamus*	1%
2	T2	*Curcuma zedoaria*	1%
3	T3	*Calotropis gigantea*	1%
4	T4	*Acorus calamus*	2%
5	T5	*Curcuma zedoaria*	2%
6	T6	*Calotropis gigantea*	2%
7	T7	*Acorus calamus* and *Curcuma zedoaria*	1%
8	T8	*Acorus calamus* and *Calotropis gigantea*	1%
9	T9	*Curcuma zedoaria* and *Calotropis gigantea*	1%
10	T10	*Acorus calamus* and *Curcuma zedoaria*	2%
11	T11	*Acorus calamus* and *Calotropis gigantea*	2%
12	T12	*Curcuma zedoaria* and *Calotropis gigantea*	2%
13	T13	Control without botanicals (Soap solution)	1%
14	T14	Pest management as per Organic POP (Neem garlic extract)	1%

Acorus calamus **- Rhizome**

Curcuma zedoaria **- Rhizome**

Calotropis gigantea **- Flower**

Plate 1: Source plants for the trial products

Plate 2: Pesticidal soap formulations

Plate 3: Spray solution

3.3.2 Details of experiment:

The details of field experiment are summarised below.

1. **Name of the crop : Chilli (*Capsicum annuum* Linn.)**
2. **Variety : Anugraha**
3. **Season : October – May**
4. **Type of soil : Laterite**
5. **Design of experiment : Completely randomized design**
6. **Number of treatments 14**
7. **Number of replication 3**
8. **Number of plants per replication 10**
9. **Spacing : 60 * 45 cm**
10. **Date of sowing : 3rd October, 2020**
11. **Date of transplanting : 16th November, 2020**
12. **Date of first spray : 16th December, 2020**

3.4 Observations

3.4.1 Plant characters

Observations on plant characters were made at monthly intervals from 16th December, 2020 onwards.

3.4.1.1 Plant height (cm)

Plant height was measured using a meter scale from base of the plant to the tip of plants for all the plants per replication and mean value were taken for the statistical analysis.

3.4.1.2 Leaf length (cm)

Leaf length of five leaves from top third leaf was measured from all the plants from replication and mean value were taken for the statistical analysis.

3.4.1.3 Leaf breadth (cm)

Leaf breadth of five leaves from top third leaf was measured from all the plant from replication and mean value was taken for the statistical analysis.

3.4.1.4 Days to 50% flowering

Number of days taken for the 50 per cent of the plants to flower per treatment replications was recorded.

3.4.1.5 Days to 50% fruiting

Number of days taken for the 50 per cent of the plants to fruit per treatment replications was recorded.

3.4.2 Fruit characters

3.4.2.1 Fruit length (cm)

Length of fruits was measured from five fruits from each plant per treatment replications during each harvest and mean value was taken for the statistical analysis.

Plate 4: View of Experimental Field

3.4.2.2 Fruit width (cm)

Fruit width was measured for five fruits from each plant per treatment replications during each harvest and mean value was taken for the statistical analysis.

3.4.2.3 Fruit weight (g)

Individual fruit weight of five fruits was measured from each plant per treatment replications during each harvest and mean value was taken for the statistical analysis.

3.4.2.4 Number of fruits per plant

Numbers of fruits were taken for each plant per treatment replications from all the harvests during experimental period.

3.4.2.5 Fresh fruit yield per plant (g)

Fruits were harvested at green mature stage from each plant at intervals and yield recorded. Total fresh fruit yield per plant was calculated by adding the yield from all the harvests per plant during the experimental period.

3.4.3 Qualitative characters

3.4.3.1 Vitamin C (mg/100g)

Vitamin C content of fruit was estimated by 2,6-dichlorophenol indophenol dye method (Sadasivam and Manickam, 1992).

Reagents

1. Oxalic acid 4 %
2. Ascorbic acid standard

The stock solution was prepared by dissolving 100 mg pure ascorbic acid salt in 100 ml, four per cent oxalic acid. 10 ml of this stock solution was diluted to 100 ml with four per cent oxalic acid to get working standard solution.

3. 2,6-dichlorophenol indophenol dye

Forty two mg sodium bicarbonate was dissolved in a small volume of distilled water. 52 mg of 2,6-dichlorophenol indophenol was added into this and made up to 200 ml with distilled water.

4. Working standard

Diluted 10 ml of stock solution to 100 ml with four per cent oxalic acid. The concentration of working standard is 100 mg per ml.

Procedure

Pipetted out 5 ml of the working standard solution into a 100 ml conical flask and added 10 ml of four per cent oxalic acid. Titrated it against the dye (V_1 ml). End point is the appearance of pink colour which persisted for at least 5 seconds. Five gram of fresh fruit was extracted in four per cent oxalic acid medium, filtered the extract and volume was made up to 100 ml using oxalic acid . From this, five ml aliquot was taken, added 10 ml of four per cent oxalic acid and titrated as above against dye and determined the endpoint (V_2 ml).

Titration was repeated thrice and the average titer value was taken for the calculation of vitamin C content.

Amount of ascorbic acid mg 100 g^{-1} sample = (0.5 mg / V1 ml) * (V_2 / 5ml) * (100ml * 100/ Wt. Of the sample)

3.4.3.2 Oleoresin (%)

Oleoresin content was estimated by solvent extraction method using Soxhlet apparatus. Chilli fruits harvested at red ripe stage were dried in a hot air oven at 50^0 C and powdered in a mixer grinder. Weighed 5 g of chilli powder and packed in Whatman no.1 filter paper and tied tightly with cotton thread and placed in the Soxhlet extractor. Empty weight of the distillation flask was weighed before connecting to the Soxhlet apparatus. Spice packet was placed in the extractor after siphoning using acetone. Filled the Soxhlet extractor with acetone and connected the extractor to the condenser. The apparatus was kept over a hot water bath with set temperature of 60-65^0C. Extraction was carried out for 5-6 hours until solvent inside the extractor become colourless. Separated the condenser and the extractor with spice packet. The distillation flask was kept on water bath and acetone was allowed to evaporate. After solvent get evaporated the distillation flask was cooled and weighed.

Yield of oleoresin on dry weight basis was calculated using the formula,

Per cent of oleoresin = $(W_2 - W_1)$ / Weight of sample *100

W_1 = Weight of empty flask

W_2 = Weight of flask with oleoresin

Oleoresin was calculated for each treatment, replications and expressed as per cent.

3.5 Field evaluation

3.5.1 Population density of sucking pests

Population density of sucking pests was recorded from three plants per replications. The observations were recorded as pre-treatment observations at one day before spraying and at third, seventh and tenth days after the application of treatment formulations.

3.5.1.1 Thrips *(Scirtothrips dorsalis)*

Thrips count was recorded as the number of thrips on six leaves each, from top three shoots per three plants in all the treatment replication with the help of hand lens.

3.5.1.2 Mite (*Polyphagotarsonemus latus*)

Number of mites on six leaves each, from top three shoots per three plants in all the treatment replications were counted using hand lens.

3.5.1.3 Whitefly (*Bemicia tabaci*)

Leaf samples with white fly nymphs were collected and number of nymphs was counted from three leaves per plant in all the treatment replications using Binocular Stereo Microscope.

3.5.1.4 Aphids (*Aphis gossypii* and *Aphis craccivora*)

Number of aphids was counted from the whole plant of three plants each in all the treatment replications using hand lens.

3.5.2 Diseases

3.5.2.1 Bacterial wilt incidence

Daily observation of plants taken for incidence of bacterial wilt and number of bacterial wilt affected plants in all treatment replication noted.

3.5.2.2 Leaf curl virus incidence

Noted the number of plants with leaf curl virus incidence in all treatment replications.

Plate 5: ***Thrips dorsalis*** **tapped on white paper**

Aphis gossypii

Aphis craccivora

Plate 7: Aphid species

Plate 6: Whitefly nymphs

3.6 Statistical analysis

For statistical comparison of morphological and qualitative parameters, the data were subjected to one-way analysis of variance (ANOVA) using KAU GRAPES software. Data on mean population of sucking pests on three, seven and ten days after treatment application were tested by analysis of covariance (ANOCOVA) using R studio software, taking population counts prior to the treatments application as covariate. The result obtained was subjected to Duncan's Multiple Range Test (DMRT). The mean per cent reduction in population over pre count of sucking pests was also worked out at three days after treatment application.

Results

4. RESULTS

The results of the study "Evaluation of medicinal plant-based formulations for growth, yield and pest management in Chilli (*Capsicum annuum* Linn.) are presented in this chapter under four major headings *viz*.

4.1 Influence of medicinal plant based formulations on growth parameters of chilli

4.1.1 Plant characters

4.1.1.1 Effect of medicinal plant based formulations on plant height (cm)

Monthly data on plant height (cm) of chilli variety Anugraha under different treatments are presented in the Table (2). The observations on plant height were recorded at monthly intervals from one month after transplanting. The plant height showed an increment from first month after transplanting to fifth month after transplanting. At 30 DAT, the plant height ranged from 18.7 cm in T10 (*A. calamus* and *C. zedoaria* at 2%) to 23.6 cm in T4 (*A. calamus* at 2%). AT 60 DAT, it ranged from 41.8 cm for T11 (*A. calamus* and *C. gigantea* at 2%) to 52.46 cm for T3 (*C. gigantea* at 1%). At 90 DAT, the plant height ranged from 51.26 cm in T11 (*A. calamus* and *C. gigantea* at 2%) to 67.46 cm in T5 (*C. zedoaria* at 2%). At 120 DAT, the plant height ranged from 75.96 cm in T5 (*C. zedoaria* at 2%) to 60.46 cm in T14 (Pest management as per Organic POP). At 150 DAT, the plant height ranged from 78.4 cm for T12 (*C. zedoaria* and *C. gigantea* at 2%) to 93.7 cm for T3 (*C. gigantea* at 1%).

At 30 DAT, T4 (*A. calamus* at 2%) recorded highest plant height of 23.60 cm. T13- Control without botanicals (21.66 cm), T14- Pest management as per Organic POP (21.66 cm), T6- *C. gigantea* at 2 per cent (21.63 cm), T3- *C. gigantea* at 1per cent (21.46 cm), T5- *C. zedoaria* at 2 per cent (21.26 cm), T7- *A. calamus* and *C. zedoaria* at 1 per cent (21.10cm), T2- *C. zedoaria* at 1 per cent (20.73 cm), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (20.70 cm), T8- *A. calamus* and *C. gigantea* at 1 per cent (20.66 cm) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (20.60 cm) all were on par with each other. T11- *A. calamus* and *C. gigantea* at 2 per cent recorded plant height of 19.36 cm followed by T1- *A. calamus* at 1 per cent (18.90 cm) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (18.70 cm), which were on par with each other.

At 60 DAT, T3 (*C. gigantea* at 1%) recorded highest plant height of 52.46 cm. T10- *A. calamus* and *C. zedoaria* at 2 per cent (51.86 cm) and T2- *C. zedoaria* at 1 per cent (50.60 cm). T6- *C. gigantea* at 2 per cent (49.83 cm) which was on par with T5- *C. zedoaria* at 2 per cent (49.43 cm). T13- Control without botanicals (49.30 cm) and T12- **C.** *zedoaria* and *C. gigantea* at 2 per cent (48.90 cm). T7- *A. calamus* and *C. zedoaria* at 1 per cent (46.16 cm). T4- *A. calamus* at 2 per cent (44.23 cm), T8- *A. calamus* and *C. gigantea* at 1 per cent (44.10 cm) and T1- *A. calamus* at 1 per cent (43.86 cm) were on par with each other. T9- *C. zedoaria* and *C. gigantea* at 1 per cent recorded plant height of 43.20 cm, followed by T14- Pest management as per Organic POP (42.10 cm) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (43.20 cm).

At 90 DAT, T5 (*C. zedoaria* at 2%) recorded highest plant height of 67.46 cm, followed by T6- *C. gigantea* at 2 per cent (64.86 cm) and T3- *C. gigantea* at 1 per cent (63.83 cm). T2- *C. zedoaria* at 1 per cent (62.96 cm) which was on par with T10- *A. calamus* and *C. zedoaria* at 2 per cent (62.60 cm). T13- Control without botanicals recorded plant height of 60.36 cm, followed by T12- *C. zedoaria* and *C. gigantea* at 2 per cent (59.10 cm). T9- *C. zedoaria* and *C. gigantea* at 1 per cent (58.46 cm) which was on par with T1- *A. calamus* at 1 per cent (58.40 cm) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (57.93 cm). T8- *A. calamus* and *C. gigantea* at 1 per cent recorded plant height of 57.13 cm, followed by T14- Pest management as per Organic POP (54.43 cm) and T4- *A. calamus* at 2 per cent (53.53 cm), these two were on par with each other. T11- *A. calamus* and *C. gigantea* at 2 per cent recorded lowest plant height of 51.26 cm.

At 120 DAT, T5 (*C. zedoaria* at 2%) recorded highest plant height of 75.96 cm. T6- *C. gigantea* at 2 per cent (73.80 cm), T3- C. *gigantea* at 1 per cent (73.70 cm) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (72.83 cm) were on par with each other. T1- *A. calamus* at 1 per cent (71.56 cm) was on par with T13- Control without botanicals

(71.26 cm), T10- *A. calamus* and *C. zedoaria* at 2 per cent (71.06 cm), T2- *C. zedoaria* at 1 per cent (70.82 cm) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (70.40 cm). T11- *A. calamus* and *C. gigantea* at 2 per cent (68.56 cm) was on par with T8- *A. calamus* and *C. gigantea* at 1 per cent (67.73 cm). T9- *C. zedoaria* and *C. gigantea* at 1 per cent recorded plant height of 66.43 cm. T4- *A. calamus* at 2 per cent (61.36 cm) was on par with T14- Pest management as per Organic POP (60.46 cm).

At 150 DAT, T3 (*C. gigantea* at 1%) and T1 (*A. calamus* at 1%) recorded highest plant height of 93.70 cm, followed by T10- *A. calamus* and *C. zedoaria* at 2 per cent (92.30 cm). T7- *A. calamus* and *C. zedoaria* at 1 per cent (91.50 cm) and T1- *A. calamus* at 1 per cent (91.33 cm) was on par with each other. T2- *C. zedoaria* at 1 per cent recorded plant height of 91.06 cm. T6- *C. gigantea* at 2 per cent (87.80 cm) was on par with T5- *C. zedoaria* at 2 per cent (87.10 cm) and T13- Control without botanicals (86.60 cm). T11- *A. calamus* and *C. gigantea* at 2 per cent recorded plant height of 83.70 cm. T8- *A. calamus* and *C. gigantea* at 1 per cent (79.10 cm), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (79.06 cm), T4- *A. calamus* at 2 per cent (79.03 cm), T14- Pest management as per Organic POP (78.70 cm) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (78.40 cm) which were all on par with each other.

Table (2) Monthly data on plant height (cm) of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Plant height (cm)				
		30DAT	60DAT	90DAT	120DAT	150DAT
1	T1 (*A. calamus* at 1%)	18.90 ^{c}	43.86 ^{f}	58.40^{ef}	71.56^{c}	93.70^{a}
2	T2 (*C. zedoaria* at 1%)	20.73^{b}	50.60^{bc}	62.96^{c}	70.82^{c}	91.06^{c}
3	T3 (*C. gigantea* at 1%)	21.6 ^{b}	52.46 ^{a}	63.83^{bc}	73.70^{b}	93.70^{a}
4	T4 (*A. calamus* at 2%)	23.60 ^{a}	44.23 ^{f}	53.53 ^{g}	61.36^{f}	79.03^{f}
5	T5 (*C. zedoaria* at 2%)	21.26^{b}	49.43^{cd}	67.46 ^{a}	75.96^{a}	87.10^{d}
6	T6 (*C. gigantea* at 2%)	21.63^{b}	49.83^{cd}	64.86 ^{b}	73.80^{b}	87.80^{d}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	21.10^{b}	46.16 ^{e}	57.93^{ef}	72.83^{b}	91.50^{bc}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	20.66 ^{b}	44.10 ^{f}	57.13 ^{f}	67.73^{d}	79.10^{f}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	20.60 ^{b}	43.20^{fg}	58.46^{ef}	66.43^{e}	79.06^{f}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	18.70 ^{c}	51.86^{ab}	62.60 ^{c}	71.06^{c}	92.30^{b}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	19.36 ^{c}	43.86 ^{f}	51.26 ^{h}	68.56^{d}	83.70^{e}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	20.70 ^{b}	48.90^{d}	59.10 ^{de}	70.40^{c}	78.40^{f}
13	T13 (Control without botanicals)	21.66 ^{b}	49.30^{d}	60.36 ^{d}	71.26^{c}	86.60^{d}
14	T14 (Pest management as per Organic POP)	21.66 ^{b}	42.10^{gh}	54.43 ^{g}	60.46^{f}	78.70^{f}
	CV (%)	3.487	1.639	1.885	1.052	0.859
	SE(m)	0.42	0.445	0.647	0.423	0.425
	SE(d)	0.594	0.629	0.915	0.599	0.601

T1

T4

T2

T5

T3

T6

T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%) and T6 (*CG* 2%)

Plate 8: Chilli plants under various treatments

4.1.1.2 Effect of medicinal plant based formulations on leaf length (cm)

Monthly data on leaf length (cm) of chilli variety Anugraha are presented in the Table (3). Leaf length observations were taken at monthly intervals and maximum leaf length was noticed for first two months after transplanting. After that nearly constant leaf length was observed for $3^{rd,}$ $4^{th,}$ 5^{th} and 6^{th} months after transplanting. The leaf length ranged from 6.0 cm of T11- (*A. calamus* and *C. gigantea* at 2%) to 7.5 cm of T2 (*C. zedoaria* at 1%) at 30 DAT, 5.2 cm of T12 (*C. zedoaria* and *C. gigantea* at 2%) to 7.6 cm of T1 (*A. calamus* at 1%) at 60 DAT, 4.1 cm of T10 (*A. calamus* and *C. zedoaria* at 2%) to 5.7 cm of T14 (Pest management as per Organic POP) at 90 DAT, 4.2 cm of T7 (*A. calamus* and *C. zedoaria* at 1%) to 4.8 cm of T1 (*A. calamus* at 1%) at 120 DAT and 4.4 cm of T3 (*C. gigantea* at 1%), T7 (*A. calamus* and *C. zedoaria* at 1%), T8 (*A. calamus* and *C. gigantea* at 1%) and T10 (*A. calamus* and *C. zedoaria* at 2%) to 4.8 cm of T2 (*C. zedoaria* at 1%) at 150 DAT. There was significance among treatments with leaf length up to first three months after transplanting.

At 30 DAT, T2- *C. zedoaria* at 1 per cent recorded highest leaf length (7.53 cm), followed by T4- *A. calamus* at 2 per cent (7.43 cm), T5- *C. zedoaria* at 2 per cent (7.10 cm), T3- *C. gigantea* at 1 per cent (6.93 cm) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (6.73 cm), T1- *A. calamus* at 1 per cent (6.66 cm). T10- *A. calamus* and *C. zedoaria* at 2 per cent (6.63 cm) was on par with T14- Pest management as per Organic POP (6.60 cm). T8- *A. calamus* and *C. gigantea* at 1 per cent (6.53 cm) was on par with T12- *C. zedoaria* and *C. gigantea* at 2 per cent (6.46 cm), T7- *A. calamus* and *C. zedoaria* at 1 per cent (6.46 cm) and T6- *C. gigantea* at 2 per cent (6.43 cm). T13- Control without botanicals recorded leaf length of 6.26 cm, followed by T11- *A. calamus* and *C. gigantea* at 2 per cent (6.00 cm).

At 60 DAT, highest leaf length was observed in T1- *A. calamus* at 1 per cent (7.66 cm), followed by T9- *C. zedoaria* and *C. gigantea* at 1 per cent (7.26 cm) which was on par with T2- *C. zedoaria* at 1 per cent (7.20 cm) and T3- *C. gigantea* at 1 per cent (7.03

cm). T14- (Pest management as per Organic POP) recorded leaf length of 6.60 cm. T13- Control without botanicals (6.53 cm), T4- *A. calamus* at 2 per cent (6.53 cm) and T5- *C. zedoaria* at 2 per cent (6.36 cm) were all on par with each other. T6- *C. gigantea* at 2 per cent recorded leaf length of 6.23 cm, followed by T8- *A. calamus* and *C. gigantea* at 1 per cent (5.90 cm), T10- *A. calamus* and *C. zedoaria* at 2 per cent (5.63 cm), T7- *A. calamus* and *C. zedoaria* at 1 per cent (5.56 cm), T11- *A. calamus* and *C. gigantea* at 2 per cent (5.26 cm) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (5.20 cm).

AT 90 DAT, highest leaf length of 5.7 cm was recorded in T14- Pest management as per Organic POP, which was on par with T1- *A. calamus* at 1 per cent (5.56 cm) and T3- *C. gigantea* at 1 per cent (5.53 cm). T13- Control without botanicals recorded leaf length of 5.2 cm, followed by T2- *C. zedoaria* at 1 per cent (4.83 cm) and T4- *A. calamus* at 2 per cent (4.63 cm). T12- *C. zedoaria* and *C. gigantea* at 2 per cent (4.53 cm) was on par with T9- *C. zedoaria* and *C. gigantea* at 1 per cent (4.53 cm), T11- *A. calamus* and *C. gigantea* at 2 per cent (4.50 cm) and T5- *C. zedoaria* at 2 per cent (4.46 cm). T6- *C. gigantea* at 2 per cent recorded leaf length of 4.40 cm, followed by T8- *A. calamus* and *C. gigantea* at 1 per cent (4.33 cm), T7- *A. calamus* and *C. zedoaria* at 1 per cent (4.16 cm) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (4.13 cm).

Table (3) Monthly data on leaf length (cm) of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Leaf length (cm)				
		30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
1	T1 (*A. calamus* at 1%)	6.66^{de}	**7.66^{a}**	5.56^{a}	4.80	4.43
2	T2 (*C. zedoaria* at 1%)	**7.53^{a}**	7.2^{b}	4.83^{c}	4.76	4.80
3	T3 (*C. gigantea* at 1%)	6.93^{cd}	7.03^{b}	5.53^{a}	4.53	4.40
4	T4 (*A. calamus* at 2%)	7.43^{ab}	6.53^{cd}	4.63^{cd}	4.63	4.60
5	T5 (*C. zedoaria* at 2%)	7.10^{bc}	6.36^{cd}	4.46^{de}	4.67	4.53
6	T6 (*C. gigantea* at 2%)	6.43^{ef}	6.23^{de}	4.40^{def}	4.53	4.53
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	6.46^{ef}	5.56^{fg}	4.16^{fg}	4.26	4.40
8	T8 (*A. calamus* and *C. gigantea* at 1%)	6.53^{ef}	5.90^{ef}	4.33^{efg}	4.40	4.40
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	6.73^{cde}	7.26^{b}	4.53^{de}	4.53	4.53
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	6.63^{def}	5.63^{f}	4.13^{g}	4.31	4.40
11	T11 (*A. calamus* and *C. gigantea* at 2%)	6.00^{g}	5.26^{gh}	4.50^{de}	4.50	4.53
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	6.46^{ef}	5.20^{h}	4.53^{de}	4.53	4.50
13	T13 (Control without botanicals)	6.26^{fg}	6.53^{cd}	5.20^{b}	4.46	4.46
14	T14 (Pest management as per Organic POP)	6.60^{def}	6.60^{c}	5.70^{a}	4.76	4.63
	CV (%)	3.493	3.319	3.295	5.405	3.808
	SE(m)	0.135	0.122	0.09	0.142	0.099
	SE(d)	0.191	0.172	0.128	0.2	0.14

4.1.1.3 Effect of medicinal plant based formulations on leaf breadth (cm)

Monthly data on leaf breadth (cm) of chilli variety Anugraha under different treatments are presented in the Table (4). The leaf breadth ranged from 2.9 cm (T11- *A. calamus* and *C. gigantea* at 2%) to 3.4 cm (T10 - *A. calamus* and *C. gigantean* at 1%) at 30 DAT, 2.4 cm (T11- *A. calamus* and *C. gigantea* at 2%) to 3.2 cm (T1- *A. calamus* at 1%) at 60 DAT, 1.8 cm (T10- *A. calamus* and *C. zedoaria* at 2%) to 2.8 cm (T12- *C. zedoaria* and *C. gigantea* at 2%) at 90 DAT, 1.9 cm (T8- *A. calamus* and *C. gigantea* at 1%) to 2.6 cm (T14- Pest management as per Organic POP) at 120 DAT and 2.06 cm (T11- *A. calamus* and *C. gigantea* at 2%) to 2.7 cm (T14- Pest management as per Organic POP) at 150 DAT.

At 30 DAT, T10- *A. calamus* and *C. zedoaria* at 2 per cent recorded leaf breadth of **(**3.43 cm**)** which was on par with T12- *C. zedoaria* and *C. gigantea* at 2 per cent (3.40 cm), T13- Control without botanicals (3.40 cm) and T6- *C. gigantea* at 2 per cent (3.40 cm). T8- *A. calamus* and *C. gigantea* at 1 per cent (3.33 cm) was on par with T14- Pest management as per Organic POP (3.33 cm). T2- *C. zedoaria* at 1 per cent recorded leaf breadth of 3.30 cm. T9- *C. zedoaria* and *C. gigantea* at 1 per cent (3.23 cm) and T4- *A. calamus* at 2 per cent (3.20 cm) were on par with each other. T7- *A. calamus* and *C. zedoaria* at 1 per cent (3.13 cm) was on par with T5- *C. zedoaria* at 2 per cent (3.10 cm). T3- *C. gigantea* at 1 per cent recorded leaf breadth of 3.06 cm, followed by T1- *A. calamus* at 1 per cent (3.03 cm). The lowest leaf breadth was recorded in T11- *A. calamus* and *C. gigantea* at 2 per cent (2.93 cm).

At 60 DAT, T1- *A. calamus* at 1 per cent recorded leaf breadth of 3.20 cm, which was on par with T5- *C. zedoaria* at 2 per cent (3.20 cm) and T2- *C. zedoaria* at 1 per cent (3.16 cm). T13- Control without botanicals (3.06 cm) was on par with T4- *A. calamus* at 2 per cent (3.06 cm,) T14- Pest management as per Organic POP (3.00 cm), T3- *C. gigantea* at 1 per cent (3.00 cm) and T6- *C. gigantea* at 2 per cent (3.00 cm). T7- *A. calamus* and *C. zedoaria* at 1 per cent recorded leaf breadth of 2.90 cm, followed by T9- *C. zedoaria* and *C. gigantea* at 1 per cent (2.70 cm). T12- *C. zedoaria* and *C. gigantea* at

2 per cent (2.60 cm) was on par with T8- *A. calamus* and *C. gigantea* at 1 per cent (2.60 cm) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (2.53 cm). The lowest leaf breadth was recorded in T11- *A. calamus* and *C. gigantea* at 2 per cent (2.40 cm).

At 90 DAT, T12- *C. zedoaria* and *C. gigantea* at 2 per cent recorded leaf breadth of 2.80 cm which was on par with T14- Pest management as per Organic POP (2.73 cm). T1- *A. calamus* at 1 per cent (2.56 cm) was on par with T13- Control without botanicals (2.56 cm). T2- *C. zedoaria* at 1 per cent recorded leaf breadth of 2.40 cm. T3- *C. gigantea* at 1 per cent (2.23 cm) was on par with T9- *C. zedoaria* and *C. gigantea* at 1 per cent (2.23 cm). T11- *A. calamus* and *C. gigantea* at 2 per cent (2.20 cm) was on par with T4- *A. calamus* at 2 per cent (2.20 cm) and T6- *C. gigantea* at 2 per cent (2.16 cm). T5- *C. zedoaria* at 2 per cent (2.10 cm) was on par with T7- *A. calamus* and *C. zedoaria* at 1 per cent (2.10 cm). T8- *A. calamus* and *C. gigantea* at 1 per cent (1.86 cm) was on par with T10- *A. calamus* and *C. zedoaria* at 2 per cent (1.83 cm).

At 120 DAT, T14- Pest management as per Organic POP recorded the highest leaf breadth of 2.60 cm, followed by T12- *C. zedoaria* and *C. gigantea* at 2 per cent (2.50 cm) which was on par with T13- Control without botanicals (2.50 cm). T1- *A. calamus* at 1 per cent (2.43 cm) was on par with T3- *C. gigantea* at 1 per cent (2.43 cm). T2- *C. zedoaria* at 1 per cent recorded leaf breadth of 2.36 cm, followed by T4- *A. calamus* at 2 per cent (2.33 cm) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (2.23 cm). T11- *A. calamus* and *C. gigantea* at 2 per cent (2.16 cm) was on par with T6- *C. gigantea* at 2 per cent (2.16 cm). T7- *A. calamus* and *C. zedoaria* at 1 per cent (2.06 cm) was on par with T5- *C. zedoaria* at 2 per cent (2.06 cm) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (2.00 cm). The lowest leaf breadth was recorded in T8- *A. calamus* and *C. gigantea* at 1 per cent (1.96 cm).

At 150 DAT, T14- Pest management as per Organic POP recorded the highest leaf breadth of 2.70 cm, followed by T12- *C. zedoaria* and *C. gigantea* at 2 per cent (2.56 cm), T13- Control without botanicals (2.50 cm), T1- *A. calamus* at 1 per cent (2.43 cm) and T2- *C. zedoaria* at 1 per cent (2.36 cm). T9- *C. zedoaria* and *C. gigantea* at 1 per cent

(2.30 cm) was on par with T7- *A. calamus* and *C. zedoaria* at 1 per cent (2.26 cm). T3- *C. gigantea* at 1 per cent (2.23 cm) was on par with T4- *A. calamus* at 2 per cent (2.23 cm), T5- *C. zedoaria* at 2 per cent (2.23 cm) and T8- *A. calamus* and *C. gigantea* at 1 per cent (2.23 cm). T6- *C. gigantea* at 2 per cent (2.16 cm) was on par with T10- *A. calamus* and *C. zedoaria* at 2 per cent (2.13 cm). The lowest leaf breadth was observed in T11- *A. calamus* and *C. gigantea* at 2 per cent (2.06 cm).

Table (4) Monthly data on leaf breadth (cm) of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Leaf breadth (cm)				
		30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
1	T1 (*A. calamus* at1%)	3.03^{de}	3.20^{a}	2.56^{b}	2.43^{abc}	2.43^{bcd}
2	T2 (*C. zedoaria* at 1%)	3.30^{abc}	3.16^{a}	2.40^{c}	2.36^{abcd}	2.36^{cde}
3	T3 (*C. gigantea* at 1%)	3.06^{cde}	3.00^{ab}	2.23^{d}	2.43^{abc}	2.23^{efg}
4	T4 (*A. calamus* at 2%)	3.20^{abcd}	3.06^{ab}	2.20^{de}	2.33^{bcd}	2.23^{efg}
5	T5 (*C. zedoaria* at 2%)	3.10^{bcde}	3.20^{a}	2.10^{e}	2.06^{ef}	2.23^{efg}
6	T6 (*C. gigantea* at 2%)	3.40^{a}	3.00^{ab}	2.16^{de}	2.16^{def}	2.16^{fg}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	3.13^{bcde}	2.90^{bc}	2.10^{e}	2.06^{ef}	2.26^{def}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	3.33^{ab}	2.60^{de}	1.86^{f}	1.96^{f}	2.23^{efg}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	3.23^{abcd}	2.70^{cd}	2.23^{d}	2.23^{cde}	2.30^{def}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	3.43^{a}	2.53^{de}	1.83^{f}	2.00^{ef}	2.13^{fg}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	2.93^{e}	2.40^{e}	2.20^{de}	2.16^{def}	2.06^{g}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	3.40^{a}	2.60^{de}	2.80^{a}	2.50^{ab}	2.56^{ab}
13	T13 (Control without botanicals)	3.40^{a}	3.06^{ab}	2.56^{b}	2.50^{ab}	2.50^{bc}
14	T14 (Pest management as per Organic POP)	3.33^{ab}	3.00^{ab}	2.73^{a}	2.60^{a}	2.70^{a}
	CV (%)	4.422	4.749	3.238	6.145	5.116
	SE(m)	0.083	0.079	0.043	0.081	0.068
	SE(d)	0.117	0.112	0.06	0.114	0.097

4.1.1.4 Effect of medicinal plant based formulations on days to 50 per cent flowering

Monthly data on days to 50 per cent flowering in chilli variety Anugraha are presented in the Table (5). Number of days to 50 per cent flowering for various treatments varied from 42.66 to 47.66 days. Minimum days to 50 per cent flowering (42.66 days) were noted for T6- *C. gigantea* at 2 per cent and T5- *C. zedoaria* at 2 per cent (42.66 days). T3- *C. gigantea* at 1 per cent recorded 43 days to 50 per cent flowering followed by T4- *A. calamus* at 2 per cent (43.66 days), T2- *C. zedoaria* at 1 per cent (44.66 days) and T1- *A. calamus* at 1 per cent (45.33 days). T9- *C. zedoaria* and *C. gigantea* at 1 per cent (45.66 days) which were on par with T7- *A. calamus* and *C. zedoaria* at 1 per cent (45.66 days). T14- Pest management as per Organic POP (46.33 days) was on par with T11- *A. calamus* and *C. gigantea* at 2 per cent (46.33 days). T13- Control without botanicals recorded 46.66 days to 50 per cent flowering, followed by T12- *C. zedoaria* and *C. gigantea* at 2 per cent (47.00 days). Maximum days to 50 per cent flowering were noted in T10- *A. calamus* and *C. zedoaria* at 2 per cent (47.33 days) and T8- *A. calamus* and *C. gigantea* at 1 per cent (47.66 days).

Table (5) Days to 50 per cent flowering in chilli variety Anugraha under different treatments

Sl. no.	Treatments	Days to 50 per cent flowering
1	T1 (*A. calamus* at 1%)	45.33^{ef}
2	T2 (*C. zedoaria* at 1%)	44.66^{f}
3	T3 (*C. gigantea* at 1%)	43.00^{gh}
4	T4 (*A. calamus* at 2%)	43.66^{g}
5	T5 (*C. zedoaria* at 2%)	42.66^{h}
6	T6 (*C. gigantea* at 2%)	42.66^{h}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	45.66^{de}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	47.66^{a}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	45.66^{de}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	47.33^{ab}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	46.33^{cd}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	47.00^{abc}
13	T13 (Control without botanicals)	46.66^{bc}
14	T14 (Pest management as per Organic POP)	46.33^{cd}
	CV (%)	1.318
	SE(m)	0.345
	SE(d)	0.488

4.1.1.5 Effect of medicinal plant based formulations on days to 50 per cent fruiting

The effect of medicinal plant based formulations on days to 50 per cent fruiting in chilli variety Anugraha are presented in the Table (6). Mean number of days to 50 per cent fruiting for various treatments varied from 55 to 62.66 days. The number of days to 50 per cent fruiting was minimum for T9- *C. zedoaria* and *C. gigantea* at 1 per cent (55 days) which was on par with T6- *C. gigantea* at 2 per cent (55.33 days) and T14- Pest management as per Organic POP (55.33 days). T5- *C. zedoaria* at 2 per cent recorded 55.66 days to 50 per cent flowering. T3- *C. gigantea* at 1 per cent (56.33 days) was on par with T11- *A. calamus* and *C. gigantea* at 2 per cent (56.33 days). T2- *C. zedoaria* at 1 per cent (57.33 days), T4- *A. calamus* at 2 per cent (57.33 days), T13- Control without botanicals (57.33 days) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (57.66 days) which were all on par with each other with respect to days to 50 per cent fruiting. T12- *C. zedoaria* and *C. gigantea* at 2 per cent recorded 60.66 days to 50 per cent fruiting, followed by T1- *A. calamus* at 1 per cent (61.66 days) and T8- *A. calamus* and *C. gigantea* at 1 per cent (62.33 days). T10- *A. calamus* and *C. zedoaria* at 2 per cent took maximum days to 50 per cent fruiting (62.66 days).

Table (6) Days to 50 per cent fruiting for chilli variety Anugraha under different treatments

Sl. no.	Treatments	Days to 50 per cent fruiting
1	T1 (*A. calamus* at 1%)	61.66^{b}
2	T2 (*C. zedoaria* at 1%)	57.33^{d}
3	T3 (*C. gigantea* at 1%)	56.33^{e}
4	T4 (*A. calamus* at 2%)	57.33^{d}
5	T5 (*C. zedoaria* at 2%)	55.66^{ef}
6	T6 (*C. gigantea* at 2%)	55.33^{f}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	57.66^{d}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	62.33^{ab}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	55.00^{f}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	62.66^{a}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	56.33^{e}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	60.66^{c}
13	T13 (Control without botanicals)	57.33^{d}
14	T14 (Pest management as per Organic POP)	55.33^{f}
	CV (%)	0.96
	SE(m)	0.321
	SE(d)	0.454

4.2 Influence of medicinal plant based formulations on yield of chilli

4.2.1 Effect of medicinal plant based formulations on fruit length (cm)

The data on fruit length (cm) of chilli under different treatments are presented in the Table (7). Fruit length under different treatments varied from 6.13 to 6.80 cm. Highest fruit length (6.80 cm) was noticed in T6- *C. gigantea* at 2 per cent which was on par with T10- *A. calamus* and *C. zedoaria* at 2 per cent (6.73 cm), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (6.73 cm). T2- *C. zedoaria* at 1 per cent recorded fruit length of 6.70 cm, T13- control without botanicals (6.66 cm) and T14- Pest management as per Organic POP (6.66 cm). The lowest mean fruit length (6.13 cm) was noticed in T7- *A. calamus* and *C. zedoaria* at 1 per cent.

4.2.2 Effect of medicinal plant based formulations on fruit breadth (cm)

The data on fruit breadth (cm) of chilli variety Anugraha under different treatments are presented in the Table (8). Fruit breadth under different treatments varied from 2.16 to 2.76 cm. Highest fruit length was noticed in T5- *C. zedoaria* at 2 per cent (2.76 cm) which was on par with T3- *C. gigantea* at 1 per cent (2.73 cm), T2- *C. zedoaria* at 1 per cent (2.70 cm), T4- *A. calamus* at 2 per cent (2.63 cm) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (2.63 cm). The lowest fruit length was noticed in T14- Pest management as per Organic POP (2.16 cm).

Table (7) Data on fruit length (cm) of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Fruit length (cm)
1	T1 (*A. calamus* at 1%)	6.567^{cde}
2	T2 (*C. zedoaria* at 1%)	6.700^{abc}
3	T3 (*C. gigantea* at 1%)	6.600^{bcde}
4	T4 (*A. calamus* at 2%)	6.633^{bcd}
5	T5 (*C. zedoaria* at 2%)	6.533^{de}
6	T6 (*C. gigantea* at 2%)	6.800^{a}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	6.133^{f}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	6.467^{e}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	6.733^{ab}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	6.733^{ab}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	6.633^{bcd}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	6.533^{de}
13	T13 (Control without botanicals)	6.667^{abcd}
14	T14 (Pest management as per Organic POP)	6.667^{abcd}
	CV (%)	1.441
	SE(m)	0.055
	SE(d)	0.078

Table (8) Fruit breadth (cm) of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Fruit breadth (cm)
1	T1 (*A. calamus* at 1%)	2.20^{g}
2	T2 (*C. zedoaria* at 1%)	2.70^{ab}
3	T3 (*C. gigantea* at 1%)	2.73^{ab}
4	T4 (*A. calamus* at 2%)	2.63^{abc}
5	T5 (*C. zedoaria* at 2%)	2.76^{a}
6	T6 (*C. gigantea* at 2%)	2.60^{bcd}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	2.63^{abc}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	2.46^{def}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	2.53^{cde}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	2.36^{f}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	2.40^{ef}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	2.53^{cde}
13	T13 (Control without botanicals)	2.46^{def}
14	T14 (Pest management as per Organic POP)	2.16
	CV (%)	3.417
	SE(m)	0.05
	SE(d)	0.07

4.2.3 Effect of medicinal plant based formulations on fruit weight (g)

The data on mean fruit weight (g) of chilli variety Anugraha under different treatments during experimental period are presented in the Table (9). Fruit weight ranged from 1.22 to 1.62 g. The highest fruit weight (1.63 g) was recorded in T3- *C. gigantean* at 2 per cent which was on par with T1- *A. calamus* at 1 per cent (1.62 g), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (1.57 g), T11- *A. calamus* and *C. gigantea* at 2 per cent (1.50 g), T6- *C. gigantea* at 2 per cent (1.49 g) and T4- *A. calamus* at 2 per cent (1.47 g). The lowest fruit weight (1.22 g) was recorded in T13- Control without botanicals, which was on par with T12- *C. zedoaria* and *C. gigantea* at 2 per cent (1.23 g), T7- *A. calamus* and *C. zedoaria* at 1 per cent (1.24 g), T14- Pest management as per Organic POP (1.34 g) and T8- *A. calamus* and *C. gigantea* at 1 per cent (1.40 g).

4.2.4 Effect of medicinal plant based formulations on number of fruits per plant

The data on number of fruits per plant of chilli variety Anugraha under different treatments are presented in the Table (10). Number of fruits per plant ranged from 35.15 to 104.95. The highest number of fruits per plant (104.95) was recorded in T6- *C. gigantea* at 2 per cent which was on par with T7- *A. calamus* and *C. zedoaria* at 1 per cent (87.66). The lowest number of fruits per plant (35.15) was recorded in T9- *C. zedoaria* and *C. gigantea* at 1 per cent which was on par with T14- Pest management as per Organic POP (52.00), T13- Control without botanicals (55.47) and T8- *A. calamus* and *C. gigantea* at 1 per cent (56.30).

Table (9) Fruit weight (g) of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Fruit weight (g)
1	T1 (*A. calamus* at 1%)	1.62[a]
2	T2 (*C. zedoaria* at 1%)	1.44[bc]
3	T3 (*C. gigantea* at 1%)	1.63[a]
4	T4 (*A. calamus* at 2%)	1.47[abc]
5	T5 (*C. zedoaria* at 2%)	1.42[bcd]
6	T6 (*C. gigantea* at 2%)	1.49[abc]
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	1.24[de]
8	T8 (*A. calamus* and *C. gigantea* at 1%)	1.40[bcde]
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	1.57[ab]
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	1.42[bcd]
11	T11 (*A. calamus* and *C. gigantea* at 2%)	1.50[abc]
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	1.23[e]
13	T13 (Control without botanicals)	1.22[e]
14	T14 (Pest management as per Organic POP)	1.34[cde]
	CV (%)	6.23
	SE(m)	0.063
	SE(d)	0.09

Table (10) Number of fruits per plant for chilli variety Anugraha under different treatments

Sl. no.	Treatments	Number fruits per plant
1	T1 (*A. calamus* at 1%)	66.85[cde]
2	T2 (*C. zedoaria* at 1%)	70.40[bcde]
3	T3 (*A. calamus* at 1%)	64.43[cde]
4	T4 (*A. calamus* at 2%)	69.03[cde]
5	T5 (*C. zedoaria* at 2%)	79.86[bc]
6	T6 (*C. gigantea* at 2%)	104.95[a]
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	87.66[ab]
8	T8 (*A. calamus* and *C. gigantea* at 1%)	56.30[def]
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	35.15[f]
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	77.70[bc]
11	T11 (*A. calamus* and *C. gigantea* at 2%)	70.25[bcde]
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	74.55[bcd]
13	T13 (Control without botanicals)	55.47[def]
14	T14 (Pest management as per Organic POP)	52.00[ef]
	CV (%)	14.62
	SE(m)	7.208
	SE(d)	10.194

4.2.5 Effect of medicinal plant based formulations on fresh fruit yield per plant (g)

The data on fresh fruit yield per plant (g) of chilli variety Anugraha under different treatments are presented in the Table (11). The fresh fruit yield per plant ranged from 54.95 to 121.90 g among the treatments. The highest fresh fruit yield per plant (121.90 g) was recorded in T6- *C. gigantea* at 2 per cent which was on par with T5- *C. zedoaria* at 2 per cent (121.45 g), T10- *A. calamus* and *C. zedoaria* at 2 per cent (111.15 g), T11- *A. calamus* and *C. gigantea* at 2 per cent (110.90 g), T2- *C. zedoaria* at 1 per cent (108.70 g), T7- *A. calamus* and *C. zedoaria* at 1 per cent (103.45 g), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (102.90 g) and T4- *A. calamus* at 2 per cent (102.53 g). The lowest fresh furit yield per plant (54.95 g) was recorded in T9- *C. zedoaria* and *C. gigantea* at 1 per cent which was on par with by T14- Pest management as per Organic POP (59.85 g), T13- Control without botanicals (75.35 g), T3- *C. gigantea* at 2 per cent (77.90 g) and T8- *A. calamus* and *C. gigantea* at 1 per cent (79.55 g).

Table (11) Fresh fruit yield per plant for chilli variety Anugraha under different treatments

Sl. no.	Treatments	Fresh fruit yield per plant (g $plant^{-1}$)
1	T1 (*A. calamus* at 1%)	88.50^{bcd}
2	T2 (*C. zedoaria* at 1%)	108.70^{ab}
3	T3 (*A. calamus* at 1%)	77.90^{cde}
4	T4 (*A. calamus* at 2%)	102.53^{abcd}
5	T5 (*C. zedoaria* at 2%)	121.45^{a}
6	T6 (*C. gigantea* at 2%)	121.90^{a}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	103.45^{abc}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	79.55^{cde}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	54.95^{e}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	111.15^{ab}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	110.90^{ab}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	102.90^{abcd}
13	T13 (Control without botanicals)	75.35^{e}
14	T14 (Pest management as per Organic POP)	59.85^{e}
	CV (%)	13.169
	SE(m)	9.31
	SE(d)	13.93

4.3 Influence of medicinal plant based formulations on qualitative parameters of chilli

4.3.1 Effect of medicinal plant based formulations on Vitamin C (mg $100g^{-1}$)

The data on Vitamin C content (mg $100g^{-1}$) of chilli variety Anugraha under differernt treatments are presented in the Table (12). Vitamin C content of 91.28 mg $100g^{-1}$ was recorded for all the treatments.

4.3.2 Effect of medicinal plant based formulations on Oleoresin (%)

The data on Oleoresin content (%) of chilli variety Anugraha under different treatments are presented in the Table (13). Oleoresin content of various treatments was ranged from 2 per cent to 6 per cent. The highest oleoresin content of 6 per cent was recorded in T3 (*C. gigantea* at 1%), T5 (*C. zedoaria* at 2%), T9 (*C. zedoaria* and *C. gigantea* at 1%), T10 (*A. calamus* and *C. zedoaria* at 2%), T12 (*C. zedoaria* and *C. gigantea* at 2%), T13 (Control without botanicals) and T14 (Pest management as per Organic POP). Oleoresin content of 4 per cent was recorded by T1 (*A. calamus* at 1%), T2 (*C. zedoaria* at 1%), T4 (*A. calamus* at 2%), T7 (*A. calamus* and *C. zedoaria* at 1%) and T11 (*A. calamus* and *C. gigantea* at 2%). The lowest Oleoresin content of 2 per cent was recorded by T6 (*C. gigantea* at 2%) and T8 (*A. calamus* and *C. gigantea* at 1%).

Table (12) Vitamin C content of chilli variety Anugraha under different treatments

Sl. no.	**Treatments**	**Vitamin C (mg $100g^{-1}$)**
1	T1 (*A. calamus* at1%)	91.28
2	T2 (*C. zedoaria* at 1 %)	91.28
3	T3 (*C. gigantea* at 1 %)	91.28
4	T4 (*A. calamus* at 2%)	91.28
5	T5 (*C. zedoaria* at 2%)	91.28
6	T6 (*C. gigantea* at 2%)	91.28
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	91.28
8	T8 (*A. calamus* and *C. gigantea* at 1%)	91.28
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	91.28
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	91.28
11	T11 (*A. calamus* and *C. gigantea* at 2%)	91.28
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	91.28
13	T13 (Control without botanicals)	91.28
14	T14 (Pest management as per Organic POP)	91.28
	CV (%)	0
	SE(m)	0
	SE(d)	0

Table (13) Oleoresin content of chilli variety Anugraha under different treatments

Sl. no.	Treatments	Oleoresin content (%)
1	T1 (*A. calamus* at 1%)	4^{b}
2	T2 (*C. zedoaria* at 1%)	4^{b}
3	T3 (*C. gigantea* at 1%)	6^{a}
4	T4 (*A. calamus* at 2%)	4^{b}
5	T5 (*C. zedoaria* at 2%)	6^{a}
6	T6 (*C. gigantea* at 2%)	2^{c}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	4^{b}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	2^{c}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	6^{a}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	6^{a}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	4^{b}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	6^{a}
13	T13 (Control without botanicals)	6^{a}
14	T14 (Pest management as per Organic POP)	6^{a}
	CV (%)	0
	SE(m)	0
	SE(d)	0

4.4 Influence of medicinal plant based formulations on pests and disease incidence of chilli

4.4.1 Effect of medicinal plant based formulations on pests

4.4.1.1 Effect of medicinal plant based formulations on population of thrips

The data on the population of thrips in chilli variety Anugraha under different treatments are presented in the Table (14), Table (15) and Table (16). Population of thrips was observed in the field from the last week of February, 2021. The precount population of thrips ranged from 2.66 to 4.88 per three shoots. Two days after the application of the botanicals, the treatments T3- *C. gigantea* at 1 per cent and T4- *A. calamus* at 2 per cent recorded minimum number of thrips (1.33 per three shoots). However, there were no significant difference in thrips count among the treatments two days after the treatments.

During first week of March, precount population of thrips ranged from 4.44 to 9.99 per three shoots. Overall reduction in the population of thrips was observed after imposing the pesticidal soap formulations. Two days after the application of the botanicals, significantly lower population of thrips was observed in T11- *A. calamus* and *C. gigantea* at 2 per cent (3.75 per three shoots) which was on par with T6- *C. gigantea* at 2 per cent (3.77 per three shoots). The treatment T5 (*C. zedoaria* at 2 per cent) recorded thrips population of 4.44 per three shoots, followed by T2- *C. zedoaria* at 1 per cent (4.55 per three shoots), T9- *C. zedoaria and C. gigantea* at 1 per cent (4.76 per three shoots), T7- *A. calamus* and *C. zedoaria* at 1 per cent (4.77 per three shoots), T3- *A. calamus* at 1 per cent (4.77 per three shoots), T14- Pest management as per Organic POP (4.99 per three shoots) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (4.99 per three shoots) were all on par with each other. This was followed by T1- *A. calamus* at 1 per cent (5.44 per three shoots), T8- *A. calamus* and *C. gigantea* at 1 per cent (5.88 per three shoots) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (5.88 per three shoots) which were all on par with each other. The treatment T4- *A. calamus* at 2 per cent recorded a population of

6.77 thrips per three shoots, followed by T13- Control without botanicals (7.87 per three shoots).

During second week of March, precount population of thrips ranged from 4.50 to 6.86 per three shoots. Reduction in the population of thrips was observed in various treatments as in the previous treatment. Two days after the application of the botanicals, significantly lower population of thrips was observed in T1- *A. calamus* at 1 per cent (3.5 per three shoots), followed by T3- *C. gigantea* at 1 per cent (3.77 per three shoots). T2- *C. zedoaria* at 1 per cent (4.07 per three shoots) and T6- *C. gigantea* at 2 per cent (4.21 per three shoots) which were on par with each other. All other treatments recorded thrips population on par with T13- Control without botanicals (4.32 per three shoots). The treatments T12- *C. zedoaria* and *C. gigantea* at 2 per cent (4.32 per three shoots), T5- *C. zedoaria* at 2 per cent (4.44 per three shoots), T11- *A. calamus* and *C. gigantea* at 2 per cent (4.44 per three shoots), T4- *A. calamus* at 2 per cent (4.55 per three shoots), T8- *A. calamus* and *C. gigantea* at 1 per cent (4.77 per three shoots), T14- Pest management as per Organic POP (4.77 per three shoots), T10- *A. calamus* and *C. zedoaria* at 2 per cent (4.77 per three shoots), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (4.88 per three shoots) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (5.10 per three shoots) did not differ significantly.

Table (14) Efficacy of medicinal plant based formulations against thrips on chilli during last week of February, 2021

Sl. no.	Treatments	Mean number of thrips/three shoots	
		0 DAT	**2 DAT**
1	T1 (*A. calamus* at 1%)	4.88	3.75[a]
2	T2 (*C. zedoaria* at 1%)	4.10	1.87[a]
3	T3 (*C. gigantea* at 1%)	2.99	1.33[a]
4	T4 (*A. calamus* at 2%)	4.44	1.33[a]
5	T5 (*C. zedoaria* at 2%)	4.66	2.11[a]
6	T6 (*C. gigantea* at 2%)	3.33	2.11[a]
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	4.33	3.33[a]
8	T8 (*A. calamus* and *C. gigantea* at 1%)	3.33	2.77[a]
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	4.44	2.88[a]
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	3.22	2.22[a]
11	T11 (*A. calamus* and *C. gigantea* at 2%)	2.66	1.77[a]
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	2.66	1.86[a]
13	T13 (Control without botanicals)	3.77	3.77[a]
14	T14 (Pest management as per Organic POP)	3.9	2.66[a]
	CV (%)		101.17

Table (15) Efficacy of medicinal plant based formulations on thrips in chilli during first week of March, 2021

Sl. no.	Treatments	Mean number of thrips/three shoots	
		0 DAT	2 DAT
1	T1 (*A. calamus* at 1%)	6.65	5.44^{bc}
2	T2 (*C. zedoaria* at 1%)	6.08	4.55^{cd}
3	T3 (*C. gigantea* at 1%)	6.10	4.77^{cd}
4	T4 (*A. calamus* at 2%)	8.77	6.77^{ab}
5	T5 (*C. zedoaria* at 2%)	4.44	4.44^{cd}
6	T6 (*C. gigantea* at 2%)	4.44	3.77^{d}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	5.55	4.77^{cd}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	7.66	5.88^{bc}
9	T9 (*C. zedoariaandC. gigantea* at 1%)	5.88	4.76^{cd}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	8.33	5.88^{bc}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	5.21	3.75^{d}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	6.88	4.99^{cd}
13	T13 (Control without botanicals)	9.99	7.87^{a}
14	T14 (Pest management as per Organic POP)	7.99	4.99^{cd}
	CV (%)		15.31

Table (16) Efficacy of medicinal plant based formulations against thrips on chilli during second week of March, 2021

Sl. no.	Treatments	Mean number of thrips/three shoots	
		0 DAT	2 DAT
1	T1 (*A. calamus* at 1%)	4.50	3.5[d]
2	T2 (*C. zedoaria* at 1%)	5.42	4.07[bcd]
3	T3 (*C. gigantea* at 1%)	4.88	3.77[cd]
4	T4 (*A. calamus* at 2%)	5.66	4.55[abc]
5	T5 (*C. zedoaria* at 2%)	5.88	4.44[abc]
6	T6 (*C. gigantea* at 2%)	5.33	4.21[bcd]
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	6.86	5.10[a]
8	T8 (*A. calamus* and *C. gigantea* at 1%)	6.50	4.77[ab]
9	T9 (*C. zedoaria*and*C. gigantea* at 1%)	5.50	4.88[ab]
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	6.06	4.77[ab]
11	T11 (*A. calamus* and *C. gigantea* at 2%)	5.50	4.44[abc]
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	5.41	4.32[abc]
13	T13 (Control without botanicals)	5.55	4.32[abc]
14	T14 (Pest management as per Organic POP)	5.55	4.77[ab]
	CV (%)		9.69

4.4.1.2 Effect of medicinal plant based formulations on mite population in chilli

Mite population was negligible during the experimental period.

4.4.1.3 Effect of medicinal plant based formulations on mealy bug population in chilli

Mealy bug incidence was negligible during the experimental period.

4.4.1.4 Effect of medicinal plant based formulations on population of whitefly

The effect of medicinal plant based formulations on the population of whitefly is presented in the Table (17), Table (18), Table (19) and Table (20).

a. First week of April, 2021

The mean count of white fly nymphs before imposing first spray application during first week of April, 2021 ranged from 35.4 to 72.1 per six leaves/plant.

Reduction in the mean count of whitefly nymphs at three days after treatment was noticed in all the treatments. But there was difference in the rate of reduction in the mean count of whitefly nymphs among the treatments. It ranged from 22.02 to 54.82 per cent.

At third day after spraying, the mean count of white fly nymphs ranged from to 21.86 to 42.50 per six leaves/plant. The lowest mean nymph population of 21.86 per six leaves/ plant was recorded in T7 (*A. calamus* and *C. zedoaria* at 1%). This was followed by T3- *C. gigantea* at 1 per cent (22.60 per six leaves/plant), T4- *A. calamus* at 2 per cent (23.16 per six leaves/plant), T5- *C. zedoaria* at 2 per cent (25.76 per six leaves/plant), T1- *A. calamus* at 1 per cent (26.33 per six leaves/plant), T6- *C. gigantea* at 2 per cent (27.73 per six leaves/plant) and T14- Pest management as per Organic POP (28.93 per six leaves/plant) which were all on par with each other with respect to whitefly nymphs population. The treatment T12 recorded mean whitefly nymphs population of 32.66 per six leaves/plant and was on par with T11- *A. calamus* and *C. gigantea* at 2 per cent (34.86 per six leaves/plant), T13- Control without botanicals (36.96 per six leaves/plant) and T8-

A. calamus and *C. gigantea* at 1 per cent (37.83 per six leaves/plant). This was followed by T10- *A. calamus* and *C. zedoaria* at 2 per cent (41.86 per six leaves/plant), T2- *C. zedoaria* at 1 per cent (42.06 per six leaves/plant) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (42.50 per six leaves/plant) which were all on par with each other.

At seventh day after spraying, the mean count of white fly nymphs ranged from 24.63 to 52.73 per six leaves/plant. Reduction in the mean count of whitefly nymph at seven days after treatments was noticed in all the treatments. But, a slight increase in the mean whitefly population was observed from three days to seven days after treatment. The lowest mean whitefly nymph population of 24.63 per six leaves/plant was recorded in T1 (*A. calamus* at 1%) followed by T7- *A. calamus* and *C. zedoaria* at 1 per cent (25.03 per six leaves/plant), T4- *A. calamus* at 2 per cent (25.66 per six leaves/plant), T5- *C. zedoaria* at 2 per cent (26.90 per six leaves/plant), T14- Pest management as per Organic POP (29.96 per six leaves/plant), T6- *C. gigantea* at 2 per cent (31.73 per six leaves/ plant), T3- *C. gigantea* at 1 per cent (31.83 per six leaves/plant), which were all on par with each other with respect to whitefly nymph population. The treatment T12- *C. zedoaria* and *C. gigantea* at 2 per cent (37.06 per six leaves/plant) was on par with T3- *C. gigantea* at 1 per cent (31.83 per six leaves/plant), T6- *C. gigantea* at 2 per cent (27.73 per six leaves/plant) and T14- Pest management as per Organic POP (29.96 per six leaves/plant). This was followed by T13- Control without botanicals (38.30 per six leaves/plant), T2- *C. zedoaria* at 1 per cent (42.16 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (42.16 per six leaves/plant), T8- *A. calamus* and *C. gigantea* at 1 per cent (42.86 per six leaves/plant), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (48.30 per six leaves/plant) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (52.73 per six leaves/plant).

At tenth day after spraying, the mean count of white fly nymph ranged from 27.16 to 56.20 per six leaves/plant. Reduction in the mean count of whitefly nymph at ten days after treatments was noticed in all the treatments except T11- *A. calamus* and *C. gigantea* at 2 per cent (7.57% increase in the mean whitefly nymph population compared to precount). But, slight increase in the mean whitefly population was observed at ten days after treatments from seven to ten days after treatment. Significantly lower whitefly population (27.16 per six leaves/plant) was recorded in T6- *C. gigantea* at 2 per cent, which was on par with T5- *C. zedoaria* at 2 per cent (27.63 per six leaves/plant),T4- *A. calamus* at 2 per cent (30.60 per six leaves/plant), T7- *A. calamus* and *C. zedoaria* at 1 per cent (31.33 per six leaves/plant),T1- *A. calamus* at 1 per cent (32.00per six leaves/plant), T14- Pest management as per Organic POP (36.74 per six leaves/plant), T2- *C. zedoaria* at 1 per cent (37.06 per six leaves/plant), T13- Control without botanicals (38.50 per six leaves/plant), T3- *C. gigantea* at 1 per cent (42.30 per six leaves/plant) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (44.06 per six leaves/plant). This was followed by T11- *A. calamus* and *C. gigantea* at 2 per cent (48.73 per six leaves/plant), T8- *A. calamus* and *C. gigantea* at 1 per cent (50.66 per six leaves/ plant), T10- *A. calamus* and *C. zedoaria* at 2 per cent (54.73 per six leaves/plant) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (56.20 per six leaves/plant) which were all on par with each other.

Per cent reduction in whitefly population was recorded based on the whitefly population on the third day after treatment. Maximum reduction in whitefly population of 54.82 per cent was observed in T1 (*A. calamus* at 1%), while T6 (*C. gigantea* at 2%) and T7 (*A. calamus* and *C. zedoaria* at 1%) recorded a per cent reduction of 53.9 and 52.1 per cent respectively. This was followed by T3- *C. gigantea* at 1 per cent (44.95%), T14- Pest management as per Organic POP (44.10%), T5- *C. zedoaria* at 2 per cent (42.72%), T8- *A. calamus* and *C. gigantea* at 1 per cent (42.27%), T2- *C. zedoaria* at 1 per cent (41.66%), T4- *A. calamus* at 2 per cent (34.50%), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (31.71%), T10- *A. calamus* and *C. zedoaria* at 2 per cent (30.41%), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (28.16%), T11- *A. calamus* and *C. gigantea* at 2 per cent (23.04%) and T13- Control without botanicals (22.02%).

Table (17) Efficacy of medicinal plant based formulations on whitefly nymphs population in chilli during first week of April, 2021

Sl. no.	Treatments	Mean nymph counts/six leaves/plant				Per cent reduction at 3 DAT (%)
		0 DAT	3 DAT	7 DAT	10 DAT	
1	T1 (*A. calamus* at 1%)	58.28	26.33[def]	24.63[f]	32.00[de]	54.82
2	T2 (*C. zedoaria* at 1%)	72.10	42.06[a]	42.16[bc]	37.06[cde]	41.66
3	T3 (*C. gigantea* at 1%)	41.06	22.60[f]	31.83[def]	42.30[abcde]	44.95
4	T4 (*A. calamus* at 2%)	35.4	23.16[ef]	25.66[f]	30.60[de]	34.5
5	T5 (*C. zedoaria* at 2%)	46.6	25.76[def]	26.90[f]	27.63[de]	42.72
6	T6 (*C. gigantea* at 2%)	60.16	27.73[cdef]	31.73[def]	27.16[e]	53.9
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	45.7	21.86[f]	25.03[f]	31.33[de]	52.1
8	T8 (*A. calamus* and *C. gigantea* at 1%)	65.53	37.83[ab]	42.86[bc]	50.66[abc]	42.27
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	59.16	42.50[a]	48.30[ab]	56.20[a]	28.16
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	60.16	41.86[a]	52.73[a]	54.73[ab]	30.41
11	T11 (*A. calamus* and *C. gigantea* at 2%)	45.3	34.86[abcd]	42.16[bc]	48.73[abc]	23.04
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	47.83	32.66[abcde]	37.06[cde]	44.06[abcd]	31.71
13	T13 (Control without botanicals)	47.4	36.96[abc]	38.30[cd]	38.50[bcde]	22.02
14	T14 (Pest management as per Organic POP)	51.76	28.93[bcdef]	29.96[ef]	36.74[cde]	44.10
	CV (%)		16.30	11.62	21.71	

b. Second week of April, 2021

The mean count of white fly nymphs before imposing second spray application during second d week of April, 2021 ranged from 27.16 to 56.20 per six leaves/plant.

At third day after spraying, reduction in the mean count of whitefly nymphs was noticed in all the treatments, which ranged from 20.72 to 49.80 per cent. The mean count of white fly nymphs ranged from15.36 per six leaves/ plant to 39.43 per six leaves/ plant. Significantly lower mean whitefly nymphs population of 15.36 per six leaves/plant was recorded in T4 (*A. calamus* at 2%) which was on par with T5- *C. zedoaria* at 2 per cent (16.40 per six leaves/plant), followed by T7- *A. calamus* and *C. zedoaria* at 1 per cent (20.83 per six leaves/plant), T2- *C. zedoaria* at 1 per cent (21.06 per six leaves/plant), T6- *C. gigantea* at 2 per cent (21.53 per six leaves/plant), T14- Pest management as per Organic POP(24.20 per six leaves/plant), T3- *C. gigantea* at 1 per cent (24.73 per six leaves/plant) and T1- *A. calamus* at1 per cent (24.96 per six leaves/plant). Treatment T8- *A. calamus* and *C. gigantea* at 1 per cent recorded a population of 31.80 per six leaves/plant, and was on par with T13- Control without botanicals (28.90 per six leaves/plant). Significantly higher population was recorded in T12- *C. zedoaria* and *C. gigantea* at 2 per cent (33.63 per six leaves/plant), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (35.73 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (36.76 per six leaves/plant) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (39.43 per six leaves/plant).

At seventh day after spraying, the mean count of white fly nymphs ranged from 18.60 to 43.86 per six leaves/ plant. Reduction in mean whitefly nymphal count was observed in all treatments with the lowest mean whitefly nymphal population of 18.60 per six leaves/plant in T4 (*A. calamus* at 2%), followed by T5- *C. zedoaria* at 2 per cent (19.73 per six leaves/plant). The treatment T6- *C. gigantea* at 2 per cent (22.76 per six leaves/plant) was on par with T7- *A. calamus* and *C. zedoaria* at 1 per cent (23.60 per six leaves/plant). Treatment T2 (*C. zedoaria* at 1%) recorded mean whitefly nymph population of 27.76 per six leaves/plant followed by T14- Pest management as per

Organic POP (28.06 per six leaves/plant) and T13- Control without botanicals (29.43 per six leaves/plant) which were all on par with one another. T1- *A. calamus* at1 per cent (30.06 per six leaves/plant) was on par with T3- *C. gigantea* at 1 per cent (30.63 per six leaves/plant), followed by T8- *A. calamus* and *C. gigantea* at 1 per cent (37.73 per six leaves/plant). The treatments T12- *C. zedoaria* and *C. gigantea* at 2 per cent (40.00 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (41.83 per six leaves/plant), T10- *A. calamus* and *C. zedoaria* at 2 per cent (42.86 per six leaves/plant) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (43.86 per six leaves/plant) were on par with one another.

At tenth day after spraying, T5- *C. zedoaria* at 2 per cent recorded the lowest mean white fly nymphal count of 14.53 per six leaves/plant, which was on par with T4- *A. calamus* at 2 per cent (17.00 per six leaves/plant) and T6- *C. gigantea* at 2 per cent (17.76 per six leaves/plant). T7 (A. *calamus* and *C. zedoaria* at 1 per cent) recorded mean whitefly population of 22.20 per six leaves/plant. The treatments T3- *C. gigantea* at 1 per cent (33.86 per six leaves/plant) and T14- Pest management as per Organic POP (36.10 per six leaves/plant) were on par with T13- Control without botanicals (32.86 per six leaves/plant). This was followed by T1- *A. calamus* at1 per cent (37.86 per six leaves/plant). T12- *C. zedoaria* and *C. gigantea* at 2 per cent (40.20 per six leaves/plant) was on par with T8- *A. calamus* and *C. gigantea* at 1 per cent (40.73 per six leaves/plant) and T2- *C. zedoaria* at 1 per cent (40.20 per six leaves/plant). The treatments T11- *A. calamus* and *C. gigantea* at 2 per cent (46.10 per six leaves/plant), T10- *A. calamus* and *C. zedoaria* at 2 per cent (48.76 per six leaves/plant) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (51.86 per six leaves/plant) recorded significantly higher whitefly population.

Per cent reduction in whitefly population was recorded based on the whitefly population on the third day after treatment. Maximum reduction in whitefly population of 49.80 per cent was observed in T4 (*A. calamus* at 2%), while T2 (*C. zedoaria* at 1%), T3 (*C. gigantea* at 1%) and T5 (*C. zedoaria* at 2%) recorded a per cent reduction of 43.17 per cent, 42.72 per cent and 41.53 per cent respectively. This was followed by T8- *A. calamus* and *C. gigantea* at 1 per cent (37.22%), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (36.42%), T14- Pest management as per Organic POP (34.13%), T7- *A. calamus* and *C. zedoaria* at 1 per cent (33.51%), T10- *A. calamus* and *C. zedoaria* at 2 per cent (27.95%), T13- Control without botanicals (24.90%), T11- *A. calamus* and *C. gigantea* at 2 per cent (24.56%), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (23.67%) and T1- *A. calamus* at 1 per cent (22.00%).

Table (18) Efficacy of medicinal plant based formulations on whitefly nymphs population in chilli during second week of April, 2021

Sl. no.	Treatments	Mean nymph counts/six leaves/ plant				Per cent reduction at 3 DAT (%)
		0 DAT	3 DAT	7 DAT	10 DAT	
1	T1 (*A. calamus* at 1%)	32.00	24.96^{cde}	30.06^{bc}	37.86^{bcd}	22.00
2	T2 (*C. zedoaria* at 1%)	37.06	21.06^{ef}	27.76^{cd}	40.20^{abcd}	43.17
3	T3 (*C. gigantea* at 1%)	42.30	24.73^{cde}	30.63^{bc}	33.86^{de}	41.53
4	T4 (*A. calamus* at 2%)	30.60	15.36^{f}	18.60^{e}	17.00^{f}	49.80
5	T5 (*C. zedoaria* at 2%)	27.63	16.40^{f}	19.73^{de}	14.53^{f}	41.34
6	T6 (*C. gigantea* at 2%)	27.16	21.53^{def}	22.76^{cde}	17.76^{f}	20.72
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	31.33	20.83^{ef}	23.60^{cde}	22.20^{ef}	33.51
8	T8 (*A. calamus* and *C. gigantea* at 1%)	50.66	31.80^{abc}	37.73^{ab}	40.73^{abcd}	37.22
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	56.2	35.73^{ab}	43.86^{a}	51.86^{a}	36.42
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	54.73	39.43^{a}	42.86^{a}	48.76^{ab}	27.95
11	T11 (*A. calamus* and *C. gigantea* at 2%)	48.73	36.76^{a}	41.83^{a}	46.10^{abc}	24.56
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	44.06	33.63^{ab}	40.00^{a}	40.20^{abcd}	23.67
13	T13 (Control without botanicals)	38.50	28.90^{bcd}	29.43^{c}	32.86^{de}	24.90
14	T14 (Pest management as per Organic POP)	36.74	24.20^{cde}	28.06^{c}	36.10^{cd}	34.13
	CV (%)		15.39	14.20	19.16	

c. Third week of April, 2021

The mean count of white fly nymphs before imposing third spray application during third week of April, 2021 ranged from 14.55 to 51.86 per six leaves/plant.

At third day after spraying, reduction in the mean count of whitefly nymphs was noticed in all the treatments, which ranged from 16.57 to 56.88 per cent.

At third day after spraying, the mean count of white fly nymphs ranged from 7.33 to 27.53 per six leaves/plant. The lowest mean whitefly nymphs population of 7.33 per six leaves/plant was recorded in T4 (*A. calamus* at 2%) which was on par with T5- *C. zedoaria* at 2 per cent (8.66 per six leaves/plant). Treatment T7- *A. calamus* and *C. zedoaria* at 1 per cent recorded mean whitefly population of 13.53 per six leaves/plant, followed by T6- *C. gigantea* at 2 per cent (14.43 per six leaves/plant), T1- *A. calamus* at 1 per cent (17.33 per six leaves/plant) and T3- *C. gigantea* at 1 per cent (19.53 per six leaves/plant). All other treatments T12- *C. zedoaria* and *C. gigantea* at 2 per cent (21.53 per six leaves/plant), T14- Pest management as per Organic POP (21.53 per six leaves/plant), T8- *A. calamus* and *C. gigantea* at 1 per cent (23.63 per six leaves/plant), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (24.53 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (25.40 per six leaves/plant) and T13- Control without botanicals (26.43 per six leaves/plant) were all on par with each other with respect to mean whitefly nymphal population. Significantly higher whitefly population was recorded in T2- *C. zedoaria* at 1 per cent (27.53 per six leaves/plant) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (33.06 per six leaves/plant).

At seventh day after spraying, T6 (*C. gigantea* at 2%) recorded the lowest mean whitefly nymphal count of 9.20 per six leaves/plant. T4- *A. calamus* at 2 per cent (15.33 per six leaves/plant), T13- Control without botanicals (20.20 per six leaves/plant), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (21.43 per six leaves/plant), T7- *A. calamus* and *C. zedoaria* at 1 per cent (21.86 per six leaves/plant), T14- Pest management as per Organic POP (23.33 per six leaves/plant), T8- *A. calamus* and *C. gigantea* at 1 per cent (23.53 per six leaves/plant), T3- *C. gigantea* at 1 per cent (24.53 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (25.30 per six leaves/plant), T5- *C. zedoaria* at 2 per cent (25.60 per six leaves/plant), T2- *C. zedoaria* at 1 per cent (26.66 per six leaves/plant) and T1- *A. calamus* at1 per cent (26.76 per six leaves/plant) were all on par with each other. The treatments T10- *A. calamus* and *C. zedoaria* at 2 per cent (31.86 per six leaves/plant) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (32.10 per six leaves/plant) recorded significantly higher whitefly population.

At tenth day after spraying, T5 (*C. zedoaria* at 2%) recorded the lowest mean whitefly nymphal count of 20.00 per six leaves/plant followed by T1- *A. calamus* at 1 per cent (22.66 per six leaves/plant) and T6- *C. gigantea* at 2 per cent (26.43 per six leaves/plant) was on par with each other. T3- *C. gigantea* at 1 per cent recorded mean white fly nymphal count of 31.20 per six leaves/plant. T4- *A. calamus* at 2 per cent (35.33 per six leaves/plant) and T2- *C. zedoaria* at 1 per cent (37.66 per six leaves/plant) were on par with each other. T8- *A. calamus* and *C. gigantea* at 1 per cent (44.00 per six leaves/plant) and T10- *A. calamus* and *C. zedoaria* at 2 per cent (46.33 per six leaves/plant) were on par with each other with respect to mean whitefly nymphal count. This was followed by T14- Pest management as per Organic POP (49.10 per six leaves/plant), T13- Control without botanicals (56.53 per six leaves/plant), T9- C. *zedoaria* and *C. gigantea* at 1 per cent (60.66per six leaves/plant), T7- *A. calamus* and *C. zedoaria* at 1 per cent (66.43 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (73.66 per six leaves/plant) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (98.10 per six leaves/plant).

Per cent reduction in whitefly population was recorded based on the whitefly population on the third day after treatment. Maximum reduction in whitefly population of 56.88 per cent was observed in T4 (*A. calamus* at 2%), While T1 (*A. calamus* at 1%) and T9 (*C. zedoaria* and *C. gigantea* at 1%) recorded a per cent reduction of 52.69 and 52.58 per cent respectively. This was followed by T12- *C. zedoaria* and *C. gigantea* at 2 per cent (46.44%), T11- *A. calamus* and *C. gigantea* at 2 per cent (44.90%), T3- *C. gigantea* at 1 per cent (42.32%), T8- *A. calamus* and *C. gigantea* at 1 per cent (41.98%), T5- *C. zedoaria* at 2 per cent (40.48%), T14- Pest management as per Organic POP (40.36%), T7- *A. calamus* and *C. zedoaria* at 1 per cent (39.05%), T10- *A. calamus* and *C. zedoaria* at 1 per cent (32.19%), T13- Control without botanicals (19.56%), T6- *C. gigantea* at 2 per cent (18.79%) and T2- *C. zedoaria* at 1 per cent (16.57%).

Table (19) Efficacy of medicinal plant based formulations on whitefly in chilli during third week of April, 2021

Sl. no.	Treatments	Mean nymph counts/six leaves/plant				Per cent reduction at 3 DAT (%)
		0DAT	3DAT	7DAT	10DAT	
1	T1 (*A. calamus* at 1%)	37.86	17.33^{bcd}	26.76^{ab}	22.66^{fg}	54.22
2	T2 (*C. zedoaria* at 1%)	33.00	27.53^{ab}	26.66^{ab}	37.66^{defg}	16.57
3	T3 (*C. gigantea* at 1%)	33.86	19.53^{bcd}	24.53^{ab}	31.20^{efg}	42.32
4	T4 (*A. calamus* at 2%)	17.00	7.33^{d}	15.33^{ab}	35.33^{defg}	56.88
5	T5 (*C. zedoaria* at 2%)	14.55	8.66^{d}	25.60^{ab}	20.00^{g}	40.48
6	T6 (*C. gigantea* at 2%)	17.77	14.43^{bcd}	9.20^{b}	26.43^{fg}	18.79
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	22.20	13.53^{cd}	21.86^{ab}	66.43^{bc}	39.05
8	T8 (*A. calamus* and *C. gigantea* at 1%)	40.73	23.63^{abc}	23.53^{ab}	44.00^{cdefg}	41.98
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	51.86	24.53^{abc}	32.10^{a}	60.66^{bcd}	52.69
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	48.76	33.06^{a}	31.86^{a}	46.33^{cdefg}	32.19
11	T11 (*A. calamus* and *C. gigantea* at 2%)	46.10	25.40^{abc}	25.30^{ab}	73.66^{b}	44.90
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	40.2	21.53^{abc}	21.43^{ab}	98.10^{a}	46.44
13	T13 (Control without botanicals)	32.86	26.43^{abc}	20.20^{ab}	56.53^{bcde}	19.56
14	T14 (Pest management as per Organic POP)	36.10	21.53^{abc}	23.33^{ab}	49.10^{bcdef}	40.36
	CV (%)		33.64	44.01	30.37	

d. First week of May, 2021

The mean count of white fly nymphs before imposing the spray application of different treatments during first week of May, 2021 ranged from 22.6 to 98.10 per six leaves/plant.

At thrird day after spraying, the mean count of white fly nymphs ranged from 11.10 to 36.53 per six leaves/plant. The lowest mean whitefly nymphs population of 11.10 per six leaves/plant was recorded inT5 (*C. zedoaria* at 2%). This was followed by T3- *C. gigantea* at 1 per cent (15.33 per six leaves/plant), T6- *C. gigantea* at 2 per cent (15.53 per six leaves/plant), T4- *A. calamus* at 2 per cent (16.10 per six leaves/plant), T1- *A. calamus* at 1 per cent (20.33 per six leaves/plant), T8- *A. calamus* and *C. gigantea* at 1 per cent (20.63 per six leaves/plant), T14- Pest management as per Organic POP (21.33 per six leaves/plant), T2- *C. zedoaria* at 1 per cent (23.10 per six leaves/plant) , T7- *A. calamus* and *C. zedoaria* at 1 per cent (26.30 per six leaves/plant), T13- Control without botanicals (29.53 per six leaves/plant) and T12- *C. zedoaria* and *C. gigantea* at 2 per cent (29.93 per six leaves/plant) which were all on par with each other with respect to mean whitefly nymphal count. Treatment T10 (*A. calamus* and *C. zedoaria* at 2%) recorded mean whitefly nymphs population of 30.30 per six leaves/plant, followed by T11- *A. calamus* and *C. gigantea* at 2 per cent (36.53 per six leaves/plant) and T9- *C. zedoaria* and *C. gigantea* at 1 per cent (36.53 per six leaves/plant) all recording significantly higher population of whitefly.

At seventh day after spraying, the mean count of white fly nymphs ranged from 13.63 to 40.30 per six leaves/plant. The lowest mean whitefly nymphs population of 13.63 per six leaves/plant was recorded in T4 (*A. calamus* at 2%). This was followed by T2- *C. zedoaria* at 1 per cent (15.00 per six leaves/plant), T5- *C. zedoaria* at 2 per cent (18.10 per six leaves/plant), T6- *C. gigantea* at 2 per cent (18.53 per six leaves/plant), T13- Control without botanicals (23.73 per six leaves/plant), T3- *C. gigantea* at 1 per cent (26.53 per six leaves/plant), T10- *A. calamus* and *C. zedoaria* at 2 per cent (27.73 per six leaves/plant), T9- *C. zedoaria* and *C. gigantea* at 1 per cent (28.96 per six leaves/plant), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (33.76 per six leaves/plant), T8- *A. calamus* and *C. gigantea* at 1 per cent (34.20 per six leaves/plant), T1- *A. calamus* at 1 per cent (35.40 per six leaves/plant), T11- *A. calamus* and *C. gigantea* at 2 per cent (36.83 per six leaves/plant), T14- Pest management as per Organic POP (38.10 per six leaves/plant) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (40.30 per six leaves/plant), which were all on par with each other with respect to mean whitefly nymphal population.

Per cent reduction in whitefly population was recorded based on the whitefly population on the third day after treatment. Maximum reduction in whitefly population of 69.40 per cent was observed in T12 (*C. zedoaria* and *C. gigantea* at 2%), while T4 (*A. calamus* at 2%) and T9 (*C. zedoaria* and *C. gigantea* at 1%) recorded a per cent reduction of 54.43 and 52.58 per cent respectively. This was followed by T3- *C. gigantea* at 1 per cent (50.86%), T5- *C. zedoaria* at 2 per cent (45.97%), T11- *A. calamus* and *C. gigantea* at 2 per cent (44.90%), T8- *A. calamus* and *C. gigantea* at 1 per cent (41.98%), T14- Pest management as per Organic POP (40.36%), T7- *A. calamus* and *C. zedoaria* at 1 per cent (39.05%), T10- *A. calamus* and *C. zedoaria* at 1 per cent (32.19%), T13- Control without botanicals (19.56%), T6- *C. gigantea* at 2 per cent (18.79%) and T2- *C. zedoaria* at 1 per cent (16.57%) and T1- *A. calamus* at 1 per cent (10.28%).

Table (20) Efficacy of medicinal plant based formulations on whitefly nymphs in chilli during first week of May, 2021

Sl. no.	Treatments	Mean nymph counts /six leaves/ plant			Per cent reduction at 3 DAT (%)
		0 DAT	3 DAT	7 DAT	
1	T1 (*A. calamus* at 1%)	22.66	20.33[ab]	35.40[a]	10.28
2	T2 (*C. zedoaria* at 1%)	37.66	23.10[ab]	15.00[a]	38.66
3	T3 (*C. gigantea* at 1%)	31.20	15.33[ab]	26.53[a]	50.86
4	T4 (*A. calamus* at 2%)	35.33	16.10[ab]	13.63[a]	54.43
5	T5 (*C. zedoaria* at 2%)	20.00	11.10[b]	18.10[a]	44.50
6	T6 (*C. gigantea* at 2%)	26.43	15.53[ab]	18.53[a]	41.24
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	66.43	26.30[ab]	40.30[a]	60.40
8	T8 (*A. calamus* and *C. gigantea* at 1%)	44.00	20.63[ab]	34.20[a]	53.11
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	60.66	36.53[a]	28.96[a]	39.77
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	46.33	30.30[abc]	27.73[a]	34.59
11	T11 (*A. calamus* and *C. gigantea* at 2%)	73.66	34.30[a]	36.83[a]	53.43
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	98.10	29.93[ab]	33.76[a]	69.40
13	T13 (Control without botanicals)	56.53	29.53[ab]	23.73[a]	47.76
14	T14 (Pest management as per Organic POP)	49.1	21.33[ab]	38.10[a]	56.55
	CV (%)		45.62	59.41	

4.4.1.5 Effect of medicinal plant based formulations on population of aphids

Mean count of aphids observed on chilli plants under various treatments from third week of December, 2020 to first week of January, 2021 are presented in the Table (21), Table (22) and Table (23).

Aphid population was observed one month after transplanting the chilli seedlings during third week of December, 2020 to first week of January, 2021. The population gradually reduced after the rain during first week of January. Two aphid species *Aphis gossypi* and *Aphis craccivora* were observed on chilli plants. The population of aphids was recorded by counting total number of aphids from the whole plant. In each treatment, observations were made from three plants per replication.

a. Third week of December, 2020

The mean count of aphids before imposing the first spray application of different treatments ranged from 1.86 to18.74/plant. At two days after spraying, treatment T1 (*A. calamus* at 1%) recorded the lowest mean aphid population of 0.33/plant, followed by T8- *A. calamus* and *C. gigantea* at 1 per cent (4.63/plant). The treatments, T7- *A. calamus* and *C. zedoaria* at 1 per cent (7.30/plant), T12- *C. zedoaria* and *C. gigantea* at 2 per cent (7.73/plant), T14- Pest management as per Organic POP (7.74/plant), T4- *A. calamus* at 2 per cent (8.06/plant), T10- *A. calamus* and *C. zedoaria* at 2 per cent (8.30/plant) and T11- *A. calamus* and *C. gigantea* at 2 per cent (8.50/plant) which were on par with each other. The treatment, T2- *C. zedoaria* at 1 per cent (12.06/plant) was on par with T13- Control without botanicals (11.26/plant). The treatments T2-*C. zedoaria* at 1 per cent (12.06/plant), T5- *C. zedoaria* at 2 per cent **(**14.06/plant) and T3- *A. calamus* at 1 per cent (16.50/plant) recorded significantly higher aphid population compared to control.

Table (21) Efficacy of medicinal plant based formulations on mean count of aphids in chilli during third week of December, 2020

Sl. no.	**Treatments**	**Mean aphid counts / plant**	
		0 DAT	**2 DAT**
1	T1 (*A. calamus* at 1%)	1.86	0.33^{e}
2	T2 (*C. zedoaria* at 1%)	15.20	12.06^{abc}
3	T3 (*C. gigantea* at 1%)	15.10	16.50^{a}
4	T4 (*A. calamus* at 2%)	11.96	8.06^{cd}
5	T5 (*C. zedoaria* at 2%)	12.30	14.06^{ab}
6	T6 (*C. gigantea* at 2%)	12.10	8.86^{bcd}
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	10.16	7.30^{cd}
8	T8 (*A. calamus* and *C. gigantea* at 1%)	7.43	4.63^{de}
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	14.16	11.10^{bc}
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	16.63	8.30^{cd}
11	T11 (*A. calamus* and *C. gigantea* at 2%)	11.96	8.50^{cd}
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	9.16	7.73^{cd}
13	T13 (Control without botanicals)	18.74	11.26^{bc}
14	T14 (Pest management as per Organic POP)	9.20	7.74^{cd}
	CV (%)		31.25

b. Last week of December, 2020

The mean count of aphids before imposing the second spray application of different treatments ranged from 4.47 to 18.53/plant. At two days after spraying, the lowest mean aphid population of 0.76/plant was recorded in T1 (*A. calamus* at 1%), followed by T8- *A. calamus* and *C. gigantea* at 1 per cent (3.66/plant) and T7- *A. calamus* and *C. zedoaria* at 1 per cent (3.87/plant) which were on par with each other. The treatment, T14- Pest management as per Organic POP (5.21/plant), T10- *A. calamus* and *C. zedoaria* at 2 per cent (5.22/plant), T4- *A. calamus* at 2 per cent (5.64/plant) and T6- *C. gigantea* at 2 per cent (5.77/plant), which on par with each other. This was followed by T9- *C. zedoaria* and *C. gigantea* at 1 per cent (6.97/plant), T2- *C. zedoaria* at 1 per cent 7.53/plant, T13- Control without botanicals (7.55/plant), T5- *C. zedoaria* at 2 per cent (7.77/plant) and T11- *A. calamus* and *C. gigantea* at 2 per cent (7.99/plant) which on par with each other. The treatment T3- *A. calamus* at 2 per cent (13.55/plant) recorded significantly higher aphid population compared to control.

Aphid population was negligible from first week of January, 2021 onwards and no aphid infestation was observed in the plants during the remaining experimental period.

Table (22) Efficacy of medicinal plant based formulations against aphids on chilli during last week of December, 2020

Sl. no.	Treatments	Mean aphid counts / plant	
		0 DAT	2 DAT
1	T1 (*A. calamus* at 1%)	4.47	0.76[f]
2	T2 (*C. zedoaria* at 1%)	10.43	7.53[bc]
3	T3 (*C. gigantea* at 1%)	18.53	13.55[a]
4	T4 (*A. calamus* at 2%)	10.88	5.64[cde]
5	T5 (*C. zedoaria* at 2%)	10.88	7.77[bc]
6	T6 (*C. gigantea* at 2%)	9.10	5.77[bcde]
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	5.97	3.87[e]
8	T8 (*A. calamus* and *C. gigantea* at 1%)	6.44	3.66[e]
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	11.43	6.97[bcd]
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	9.21	5.22[de]
11	T11 (*A. calamus* and *C. gigantea* at 2%)	13.41	7.99[b]
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	10.74	7.76[bc]
13	T13 (Control without botanicals)	11.10	7.55[bc]
14	T14 (Pest management as per Organic POP)	9.42	5.21[de]
	CV (%)		18.77

Table (23) Efficacy of medicinal plant based formulations against aphids on chilli during first week of January, 2021

Sl. no.	Treatments	Mean aphid counts / plant	
		0 DAT	2 DAT
1	T1 (*A. calamus* at 1%)	0	0.00[b]
2	T2 (*C. zedoaria* at 1%)	0	0.00[b]
3	T3 (*C. gigantea* at 1%)	0	0.00[b]
4	T4 (*A. calamus* at 2%)	0	0.00[b]
5	T5 (*C. zedoaria* at 2%)	3.33	0.00[b]
6	T6 (*C. gigantea* at 2%)	0	0.00[b]
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	0.33	0.00[b]
8	T8 (*A. calamus* and *C. gigantea* at 1%)	0.77	0.66[ab]
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	0	0.00[b]
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	0	0.11[b]
11	T11 (*A. calamus* and *C. gigantea* at 2%)	1.55	0.66[ab]
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	0	0.00[b]
13	T13 (Control without botanicals)	1	3.53[a]
14	T14 (Pest management as per Organic POP)	0.66	0.88[ab]
	CV (%)		393.37

4.3.2 Diseases

4.3.2.1 Effect of medicinal plant based formulations on bacterial wilt incidence in chilli

The effects of medicinal plant based formulations on bacterial wilt incidence are presented in the Table (24). The incidence of bacterial wilt was negligible during the experimental period.

4.3.2.2 Effect of medicinal plant based formulations on leaf curl virus incidence in chilli

The effects of medicinal plant based formulations on leaf curl virus incidence are presented in the Table (25). The incidence of leaf curl virus incidence was negligible during the experimental period.

Plate 9: Chilli plant affected with bacterial wilt

Plate 10: Chilli Plant affected with leaf curl virus

Table (24) Efficacy of medicinal plant based formulations against bacterial wilt incidence on chilli

Sl. No.	Treatments	Number of wilted plants
1	T1 (*A. calamus* at 1%)	1
2	T2 (*C. zedoaria* at 1%)	2
3	T3 (*C. gigantea* at 1%)	2
4	T4 (*A. calamus* at 2%)	2
5	T5 (*C. zedoaria* at 2%)	5
6	T6 (*C. gigantea* at 2%)	2
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	2
8	T8 (*A. calamus* and *C. gigantea* at 1%)	0
9	T9 (*C. zedoaria* and *C. gigantea* at 1%)	0
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	0
11	T11 (*A. calamus* and *C. gigantea* at 2%)	3
12	T12 (*C. zedoaria* and *C. gigantea* at 2%)	0
13	T13 (Control without botanicals)	1
14	T14 (Pest management as per Organic POP)	1

Table (25) Efficacy of medicinal plant based formulations against leaf curl virus incidence on chilli

Sl. no.	Treatments	Number of plants affected with leaf curl virus
1	T1 (*A. calamus* at 1%)	2
2	T2 (*C. zedoaria* at 1%)	2
3	T3 (*C. gigantea* at 1%)	1
4	T4 (*A. calamus* at 2%)	5
5	T5 (*C. zedoaria* at 2%)	0
6	T6 (*C. gigantea* at 2%)	3
7	T7 (*A. calamus* and *C. zedoaria* at 1%)	0
8	T8 (*A. calamus* and *C. gigantea* at 1%)	3
9	T9 (*C. zedoaria*and *C. gigantea* at 1%)	4
10	T10 (*A. calamus* and *C. zedoaria* at 2%)	2
11	T11 (*A. calamus* and *C. gigantea* at 2%)	6
12	T12 (*C. zedoaria and C. gigantea* at 2%)	5
13	T13 (Control without botanicals)	5
14	T14 (Pest management as per Organic POP)	6

Discussion

5. DISCUSSION

The observations and inferences on the investigations undertaken to evaluate the efficacy of medicinal plant based formulations on growth, yield and pest management in chilli (*Capsicum annuum* Linn.) are discussed in this chapter in the light of available literature.

5.1 Influence of medicinal plant based formulations on growth parameters of chilli

Field study was conducted to evaluate the effect of medicinal plant based formulations on plant growth along with a positive control and an untreated control in chilli (*Capsicum annuum* Linn.) at the department of Plantation Crops and Spices, College of Agriculture, Vellanikkara during the period 3rd October 2020 – 7th May 2021. Morphological parameters like plant characters and fruit characters were observed.

5.1.1 Plant characters

5.1.1.1 Effect of medicinal plant based formulations on plant height (cm)

The effect of medicinal plant based formulations on plant height (cm) and cumulative plant height (cm) of chilli variety Anugraha under different treatments are presented in the Figure (1) and Figure (2) respectively. The plant height showed an increasing trend from one month after transplanting to five month after transplanting. The increment in plant height was reduced from three months onwards after attaining the reproductive stage. The treatments were significant with respect to the plant height throughout the experimental period from one to five month after transplanting. The maximum cumulative mean plant height of 61.05 cm was observed in T3 (*C. gigantea* at 1%) among the treatments. The positive control T14 (Pest management as per Organic POP) showed shortest plant height of 51.47 cm at the same time, T13 (Control without botanicals) recorded the medium plant height of 57.83 cm. *Calotropis*, *Acorus* and *Curcuma* reduced the plant height indicating the dwarfing effect at higher dose (2%) compared to lower dose (1%).

Ranjitha *et al.* (2018) recorded a plant height of 81.3cm for organically managed chilli plants using jeevamrutha spray and *Verticillium lecanii* at five per cent at 30 DAT and 60 DAT.

Melia azedarach and *Eucalyptus globulus* caused an increase of 5.32 and 5.09 per cent in plant length, 11.01 and 10.51 per cent in plant fresh weight, 32.16 and 27.98 per cent in plant dry weight and 18.36 and 16.30 per cent in number of branches plant^{-1} respectively over control. The growth promoting and disease suppressive effect of *Calotropis procera* was recorded least but statistically significant ($p \leq 0.05$) over positive as well as negative control in coriander under greenhouse condition (Khan, 2018).

5.1.1.2 Effect of medicinal plant based formulations on leaf length (cm) and leaf breadth (cm)

The effect of medicinal plant based formulations on leaf length (cm), cumulative leaf length (cm), leaf breadth (cm) and cumulative leaf breadth (cm) are presented in the Figure (3), Figure (4), Figure (5) and Figure (6) respectively.

Leaf length (cm) of the chilli plants was significantly different under various treatments up to three months after transplanting the chilli seedlings. At 30 DAT, highest leaf length of 7.53 cm recorded in T2 (*C. zedoaria* at 1%) which was on par with T4- *A. calamus* at 2 per cent (7.43 cm). At 60 DAT, highest leaf length of 7.66 cm recorded in T1 (*A. calamus* at 1%). At 90 DAT, highest leaf length of 5.7 cm recorded in T14 (Pest management as per Organic POP) which was on par with T1- *A. calamus* at 1 per cent (5.56 cm) and T3- *C. gigantea* at 1 per cent (5.53 cm). Leaf length was not significantly different under various treatments after three months after transplanting the seedlings. T1, T2 and T14 showed increase in leaf length. It was observed that higher doses and combinations of medicinal plant based formulations reduced the leaf length.

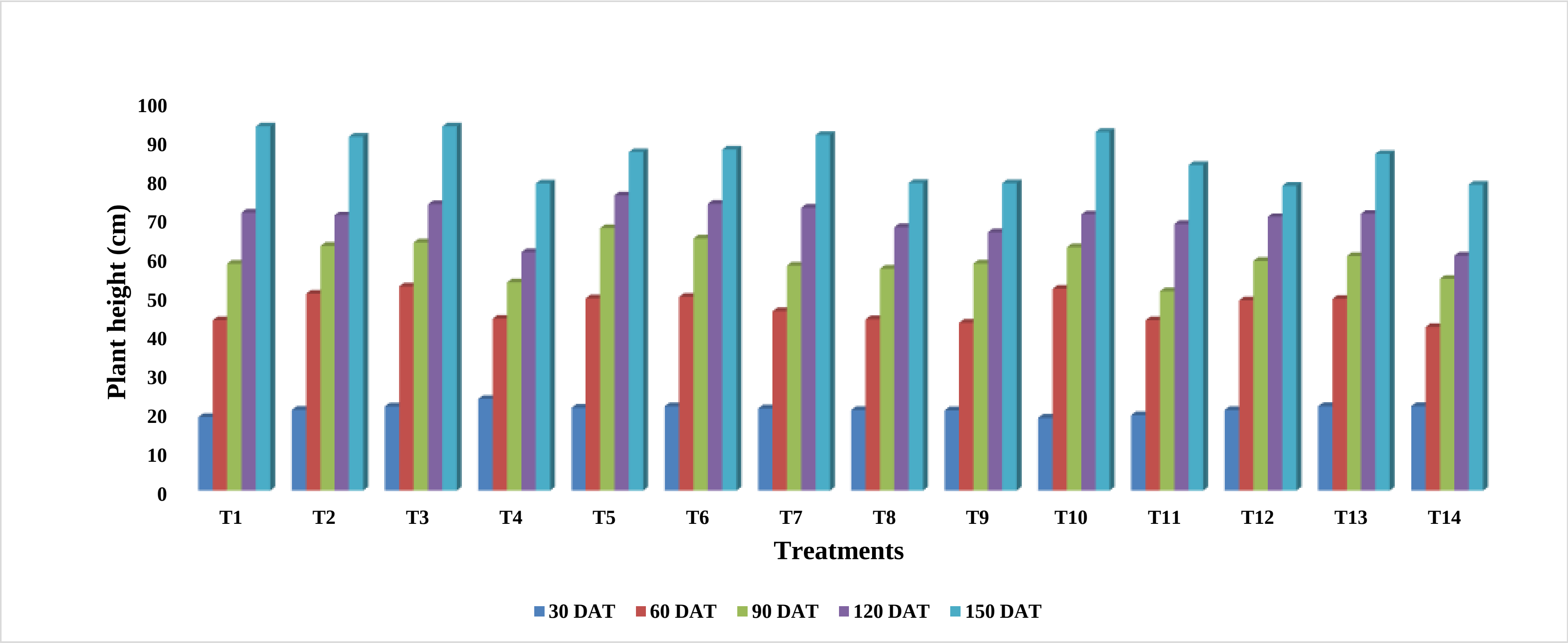
Leaf breadth (cm) of the chilli plants was significantly different under various treatments. At 30 DAT, highest leaf breadth of 3.43 cm recorded in T10- *A. calamus* and *C. zedoaria* at 2 per cent which was on par with T12- *C. zedoaria* and *C. gigantea* at 2 per cent (3.40 cm), T13- Control without botanicals (3.40 cm) and T6- *C. gigantea* at 2 per cent (3.40 cm). At 60 DAT, highest leaf breadth of 3.2 cm recorded in T1 (*A. calamus* at 1%) and T5 (*C. zedoaria* at 2%) which was on par with T2- *C. zedoaria* at 1 per cent (3.16 cm). At 90 DAT, highest leaf breadth of 2.8 cm recorded in T12 (*C. zedoaria* and *C. gigantea* at 2 %) which was on par with T14- Pest management as per Organic POP (2.73 cm). At 120 DAT, highest leaf breadth of 2.6 cm recorded in T14- Pest management as per Organic POP. At 150 DAT, highest leaf breadth of 2.7 cm recorded in T14 (Pest management as per Organic POP) which was on par with treatments T1 (*A. calamus* at 1%), T2 (*C. zedoaria* at 1 %), T3 (*C. gigantea* at 1 %) at 60 and 120 days.

The maximum cumulative leaf length of 5.82 cm was observed in T2 (*C. zedoaria* at 1%). The maximum cumulative leaf breadth of 2.84 cm was observed in T14 (Pest management as per Organic POP).

5.1.1.3 Effect of medicinal plant based formulations on days to 50 per cent flowering and days to 50 per cent fruiting

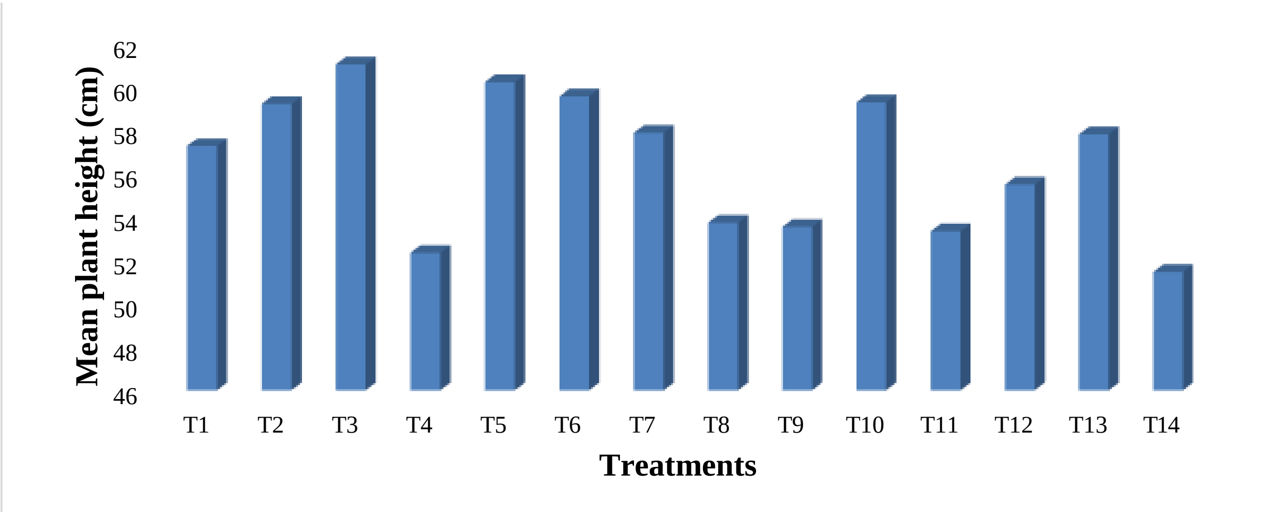
The effect of medicinal plant based formulations on days to 50 per cent flowering and days to 50 per cent fruiting are presented in the Figure (7) and Figure (8), respectively. Days to 50 per cent flowering for different treatments varied from 42.66 to 47.66 days. T6- *C. gigantea* at 2 per cent recorded minimum days to 50 per cent flowering (42.66 days) which was on par with T5- *C. zedoaria* at 2 per cent (42.66 days). The treatments T3 (*C. gigantea* at 1 %), T4 (*A. calamus* at 2%), T5 (*C. zedoaria* at 2%) and T6 (*C. gigantea* at 2%) significantly reduced number of days to 50 per cent flowering compared to positive and absolute control.

Days to 50 per cent fruiting for different treatments varied from 55 to 62.66 days. Treatments T9- *C. zedoaria* and *C. gigantea* at 1 per cent (55 days), T6- *C. gigantea* at 2 per cent (55.33 days), T14- Pest management as per Organic POP (55.33 days) and T5- *Curcuma zedoaria* at 2 per cent (55.66 days) showed early fruiting.



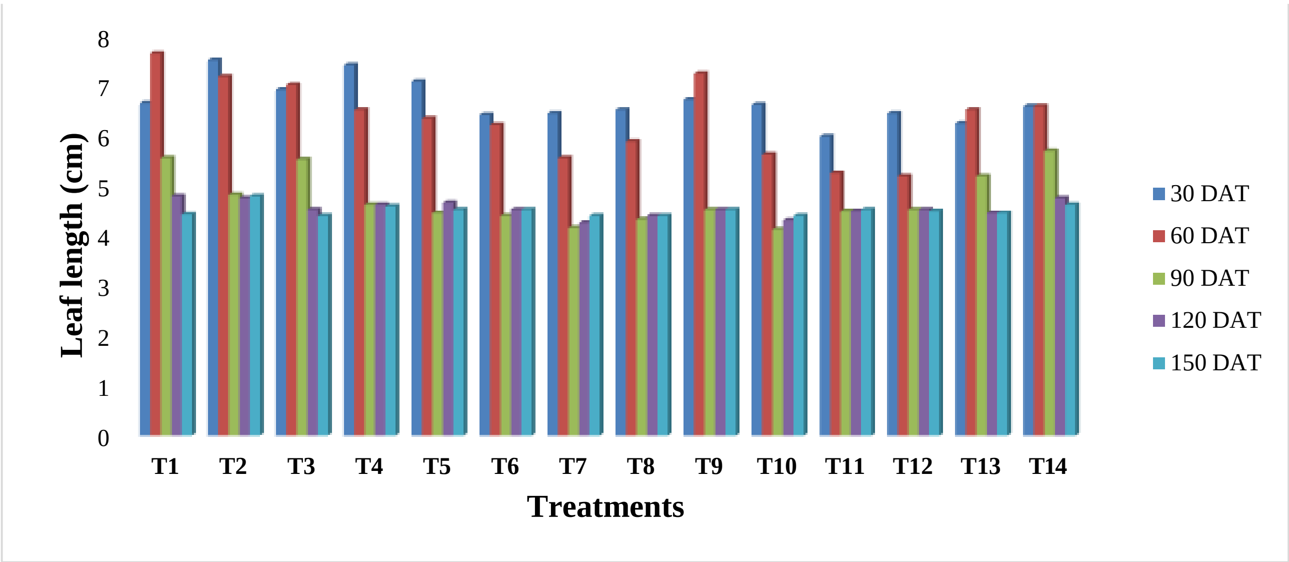
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (1) Effect of medicinal plant based formulations on plant height (cm)



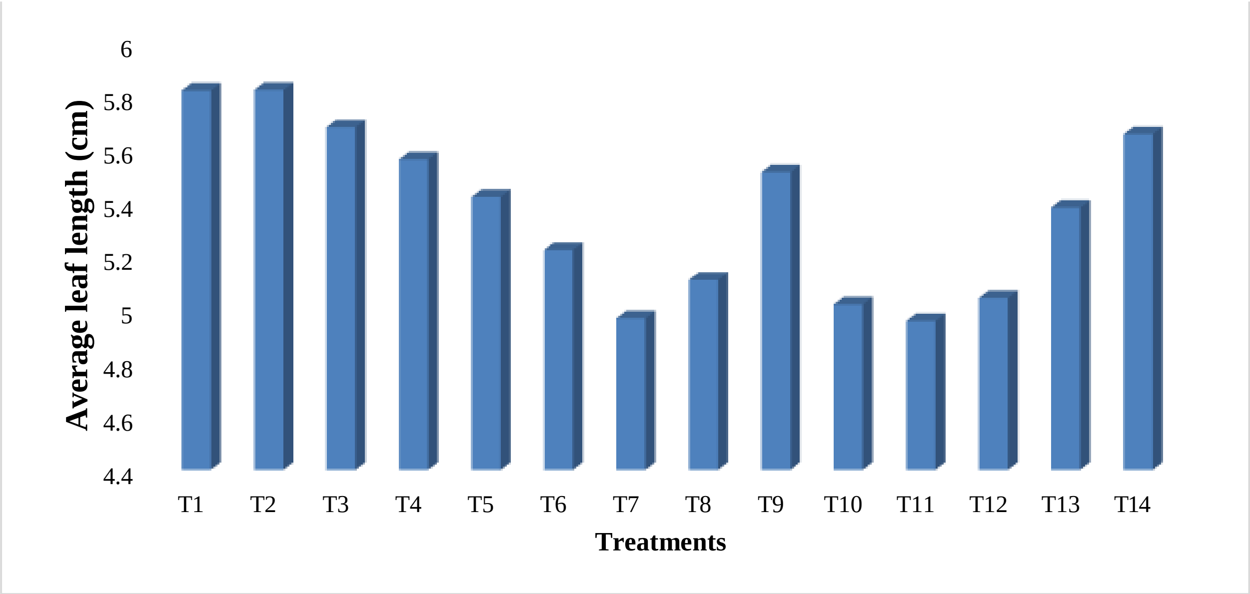
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (2) Effect of medicinal plant based formulations on cumulative plant height (c



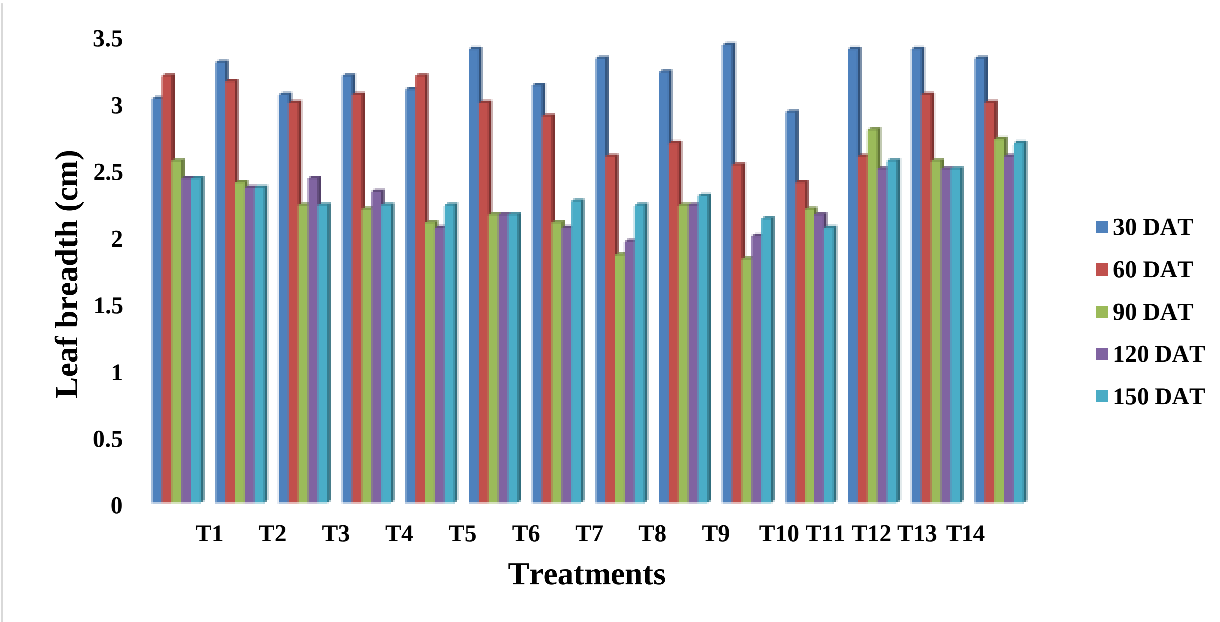
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (3) Effect of medicinal plant based formulations leaf length (cm)



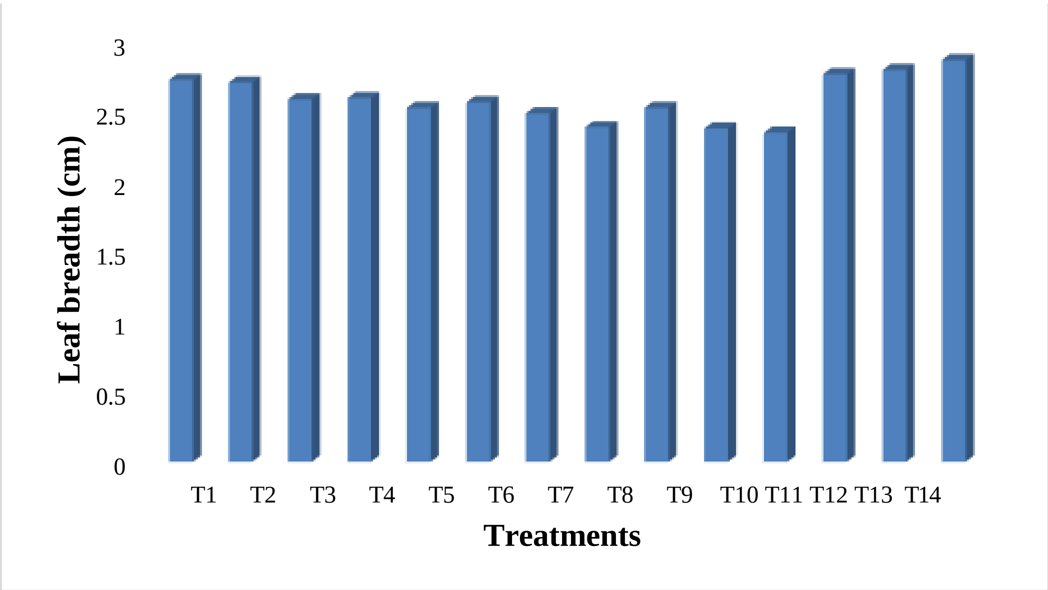
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (4) Effect of medicinal plant based formulations on cumulative leaf length (cm)



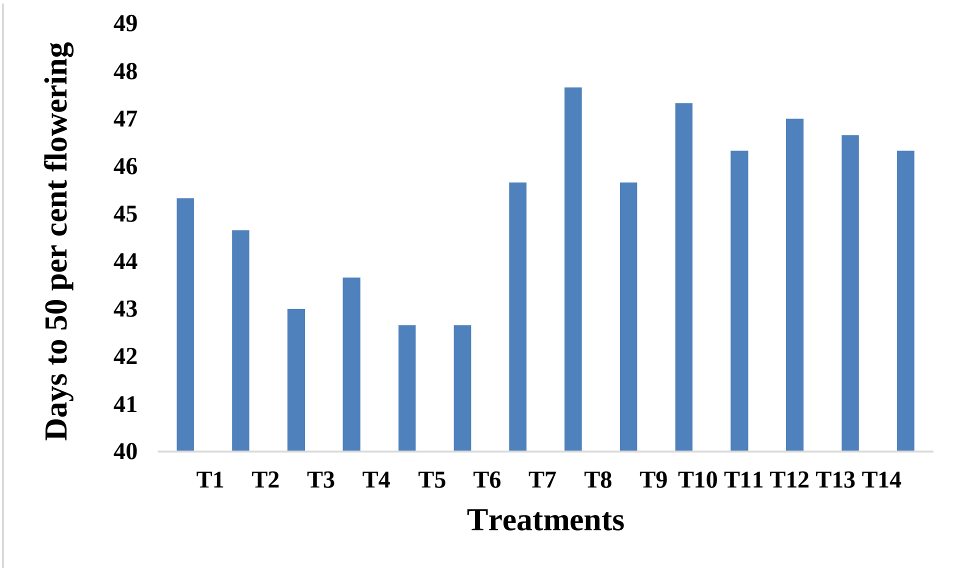
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (5) Effect of medicinal plant based formulations on leaf breadth (cm)



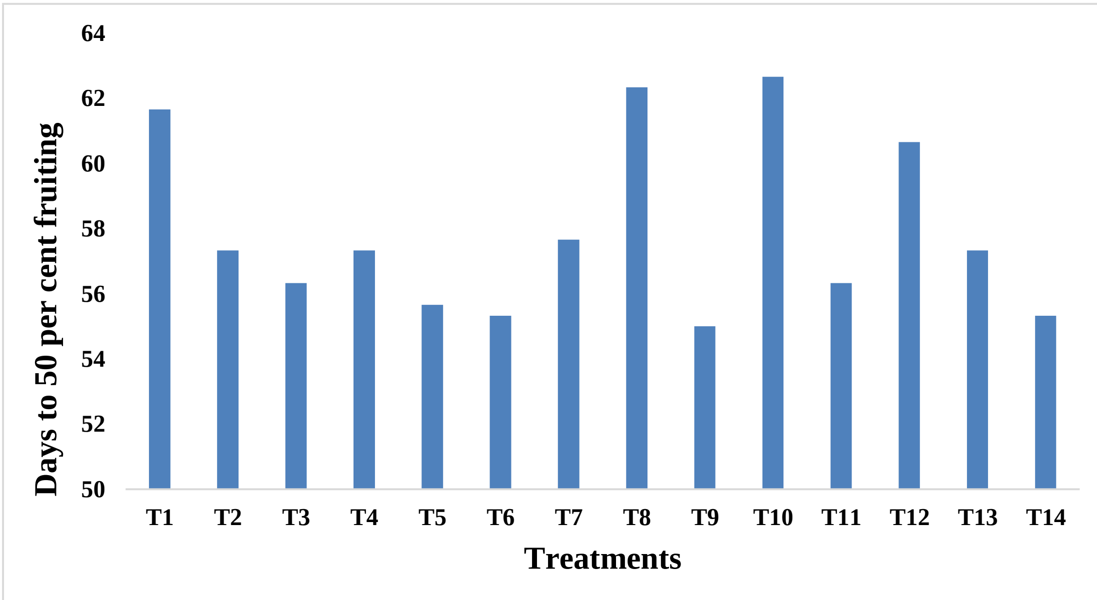
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (6) Effect of medicinal plant based formulations on cumulative leaf breadth (cm)



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (7) Effect of medicinal plant based formulations on Days to 50 per cent flowering



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (8) Effect of medicinal plant based formulations on Days to 50 per cent fruiting

5.2 Influence of medicinal plant based formulations on yield parameters of chilli

5.2.1 Effect of medicinal plant based formulations on fruit length (cm) and fruit breadth (cm)

The effect of medicinal plant based formulations on fruit length (cm) and fruit breadth (cm) are presented in the Figure (9) and Figure (10), respectively. Fruit length of chilli variety Anugraha under different treatments varied from 6.13 cm of T7- *A. calamus* and *C. zedoaria* at 1 per cent to 6.80 cm of T6- *C. gigantea* at 2 per cent. The maximum fruit length of 6.8 cm was recorded in T6 (*C. gigantea* at 2%).

Fruit breadth (cm) of chilli variety Anugraha under different treatments varied from 2.1 cm of T14 (Pest management as per Organic POP) to 2.76 cm of T5- *C. zedoaria* at 2 per cent. The maximum fruit breadth of 2.76 cm was recorded in T5- *C. zedoaria* at 2 per cent.

5.2.2 Effect of medicinal plant based formulations on fruit weight (g)

The effect of medicinal plant based formulations on fruit weight (g) is presented in the Figure (11). Per fruit weight ranged from 1.2 g of T13- Pest management as per Organic POP (Neem garlic extract) to 1.6 g of T3- *C. gigantea* at 1 per cent. The maximum per fruit weight of 1.6 g was recorded in T3 (*C. gigantea* at 1%).

5.2.3 Effect of medicinal plant based formulations on number of fruits per plant

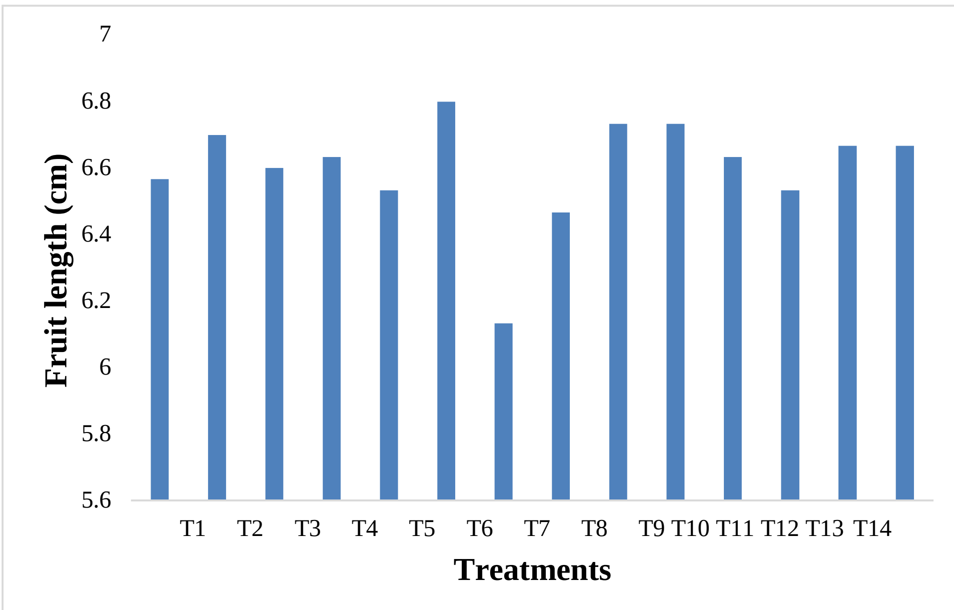
The effect of medicinal plant based formulations on number of fruits per plant is presented in the Figure (12). The maximum number of fruits per plant (104.95) was recorded in T6- *C. gigantea* at 2 per cent.

5.2.4 Effect of medicinal plant based formulations on fresh fruit yield per plant (g)

The effect of medicinal plant based formulations on fresh fruit yield per plant (g) is presented in the Figure (13). The fresh fruit yield per plant ranged from 54.95 g of T9 (*C. zedoaria* and *C. gigantea* at 1%) to 121.90 g of T6 (*C. gigantea* at 2%).

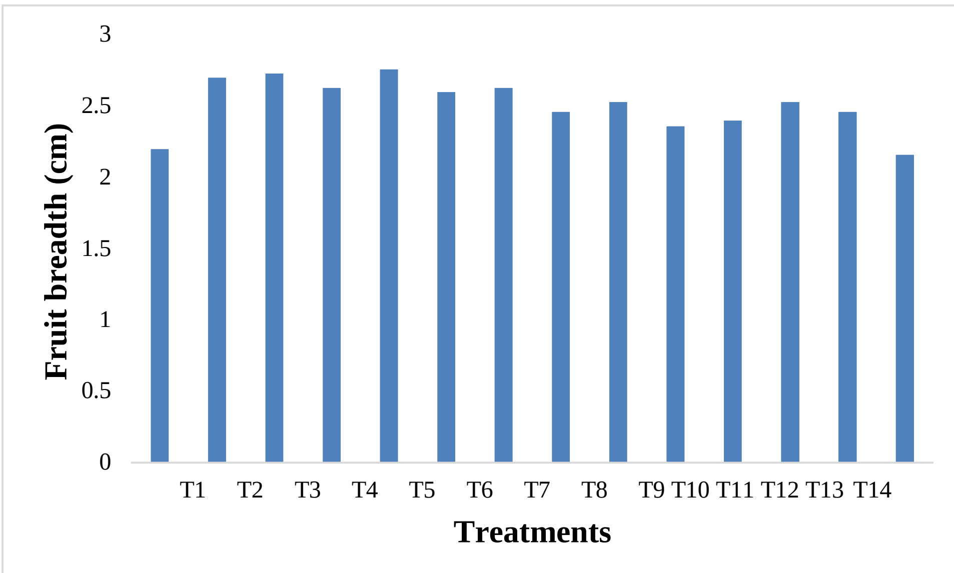
Factors which influence the yield of the crop like maximum plant height, Earliness (minimum days to 50 per cent flowering and fruiting), maximum fruit length, maximum number of fruits per plant were recorded in T6 (*C. gigantea* at 2%).

Results of present experiment are in agreement with the findings of Boraiah *et al.* (2017) who used jeevamrutha and cattle waste for chilli cultivation which showed there was a significant difference in yield of *Capsicum annuum* per hectare with the application of jeevamrutha. Singh and Lal (2019) emphasized that Jeevamrutha treated plants contained higher values of chlorophyll a and b. That study further suggested that Jeevamrutha was potent enough to resist the plants in proper growth under induced stress conditions. Karanatsidis and Berova (2009) also found that applying organic- N fertilizers provided vigorous plants while giving positive effects upon functional activities like photosynthesis and respiration.



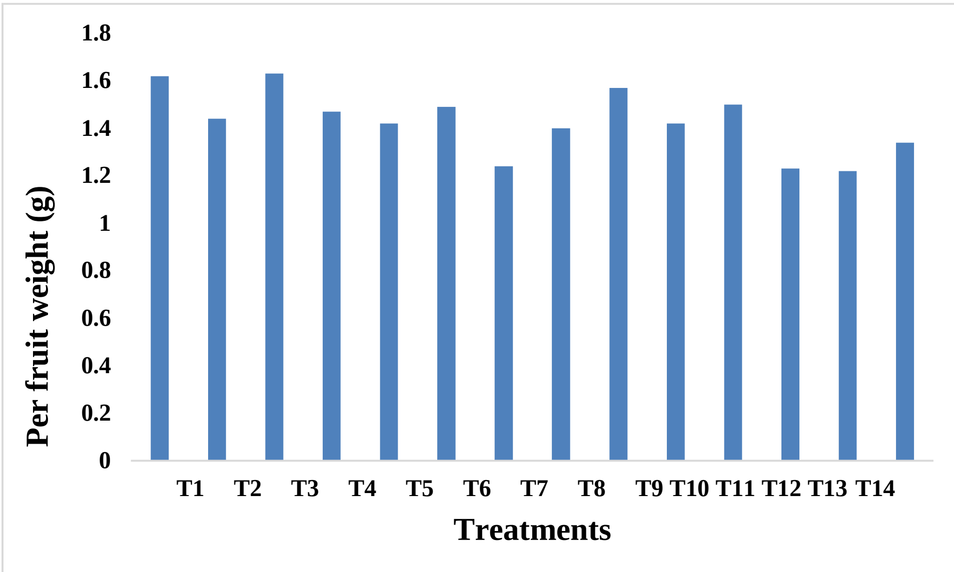
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%),

Figure (9) Effect of medicinal plant based formulations on fruit length (cm)



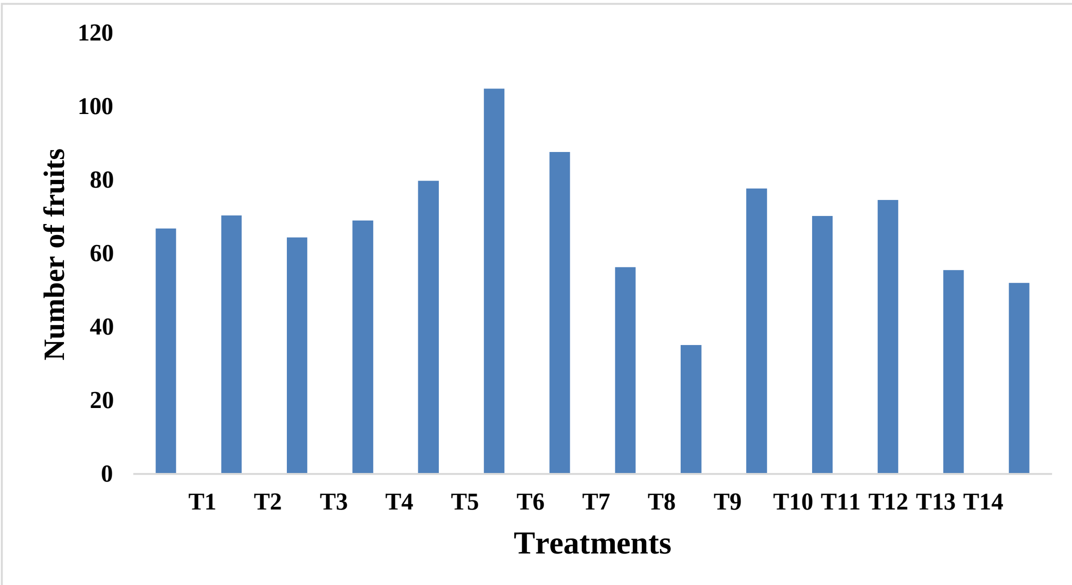
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (10) Effect of medicinal plant based formulations on fruit breadth (cm)



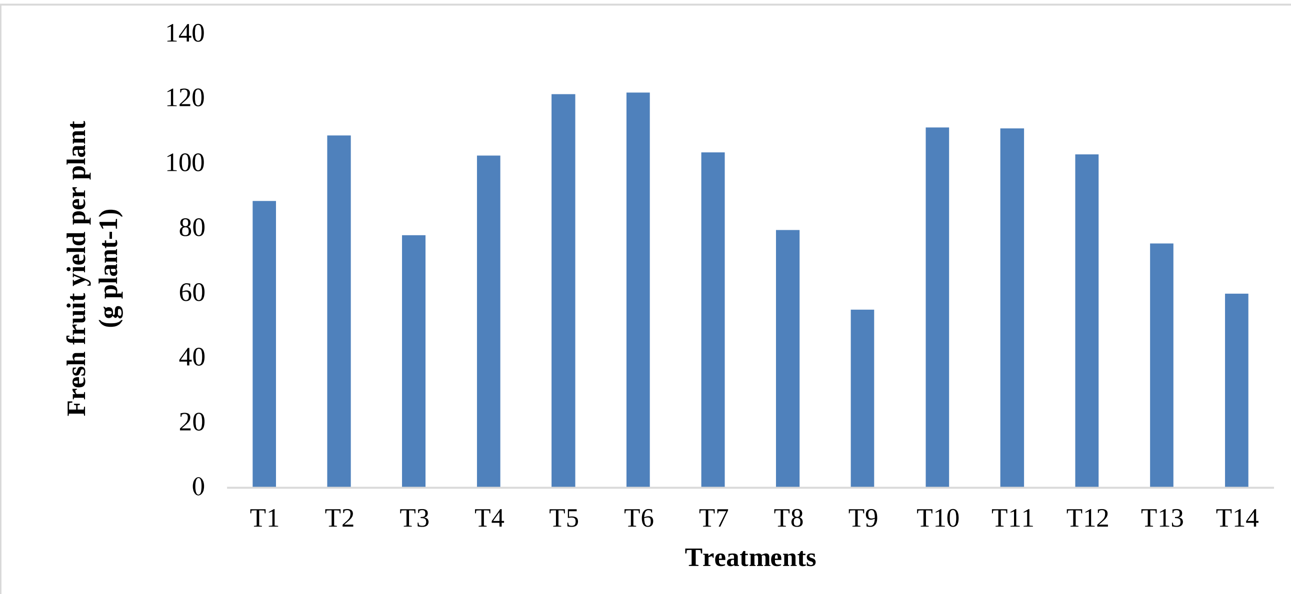
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (11) Effect of medicinal plant based formulations on per fruit weight (g)



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (12) Effect of medicinal plant based formulations on number of fruits



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (13) Effect of medicinal plant based formulations on fresh fruit yield per plant (g plant^{-1})

5.3 Influence of medicinal plant based formulations on qualitative parameters of chilli

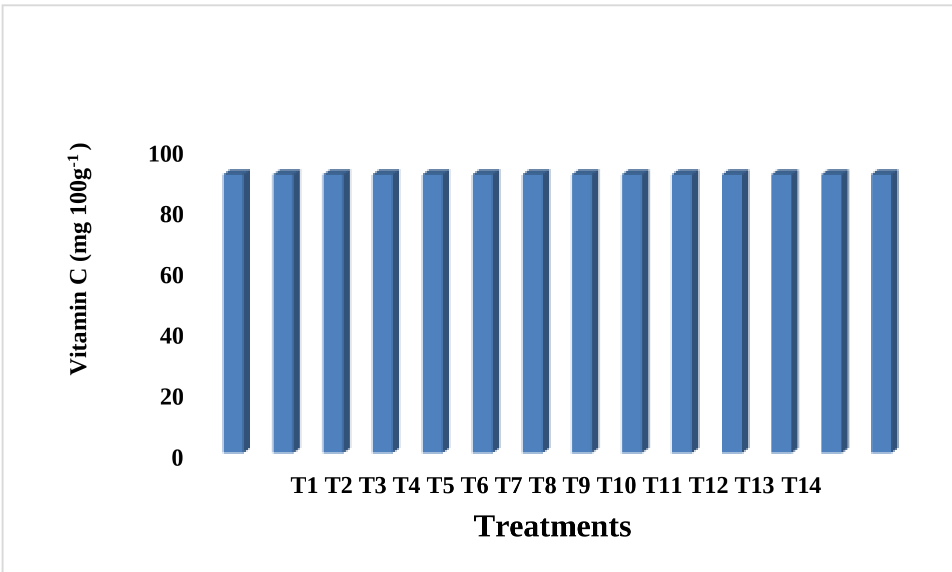
Qualitative parameters like vitamin C and oleoresin content were found not influenced by the application of medicinal plant based pesticidal soap solutions. All the plants in the experimental plots were managed under KAU organic POP. So there was no difference in the nutrient management.

5.3.1 Effect of medicinal plant based formulations on Vitamin C (mg 100g $^{-1}$)

The effect of medicinal plant based formulations on Vitamin C content (mg 100g $^{-1}$) are presented in the Figure (14). Vitamin C content of Anugraha chilli green fruits was 91.28mg 100g^{-1}.

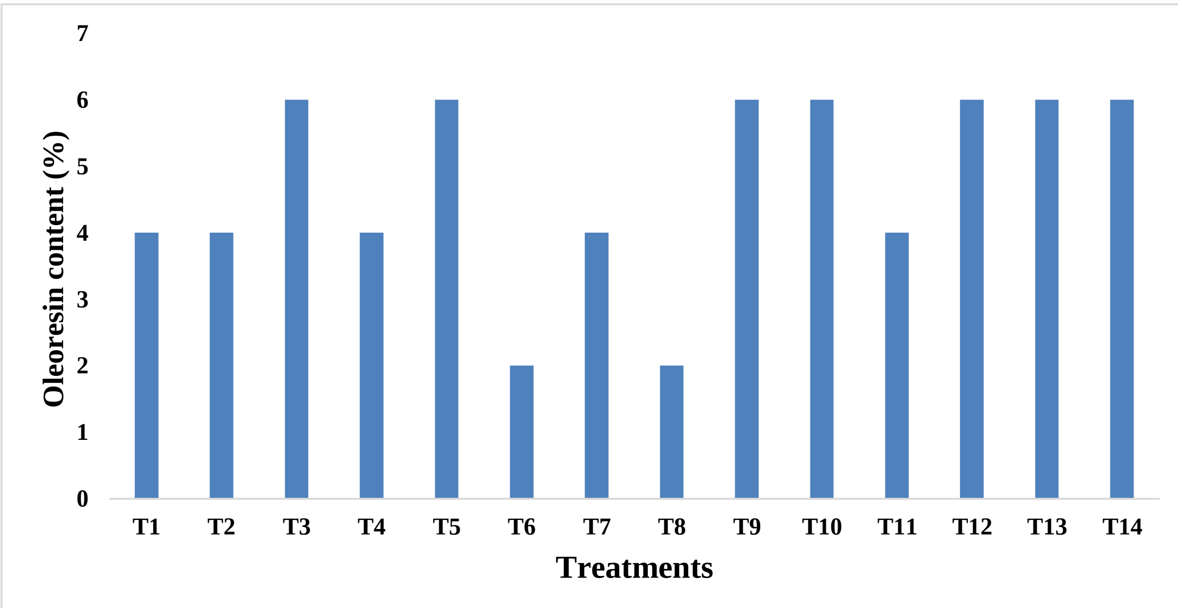
5.3.2 Effect of medicinal plant based formulations on Oleoresin (%)

The effect of medicinal plant based formulations on Oleoresin (%) is presented in the Figure (15). Oleoresin content of various treatments ranged from 2 per cent to 6 per cent. The maximum oleoresin content of 6 per cent was recorded by T3 (*C. gigantea* at 1%), T5 (*C. zedoaria* at 2%), T9 (*C. zedoaria* and *C. gigantea* at 1%), T10 (*A. calamus* and *C. zedoaria* at 2%), T12 (*C. zedoaria* and *C. gigantea* at 2%), T13 (Control without botanicals) and T14 (Pest management as per Organic POP).



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (14) Effect of medicinal plant based formulations on Vitamin C (mg $100g^{-1}$)



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (15) Effect of medicinal plant based formulations on oleoresin content (%)

5.4 Influence of medicinal plant based formulations on pests and disease incidence of chilli

5.4.1 Effect of medicinal plant based formulations on pests

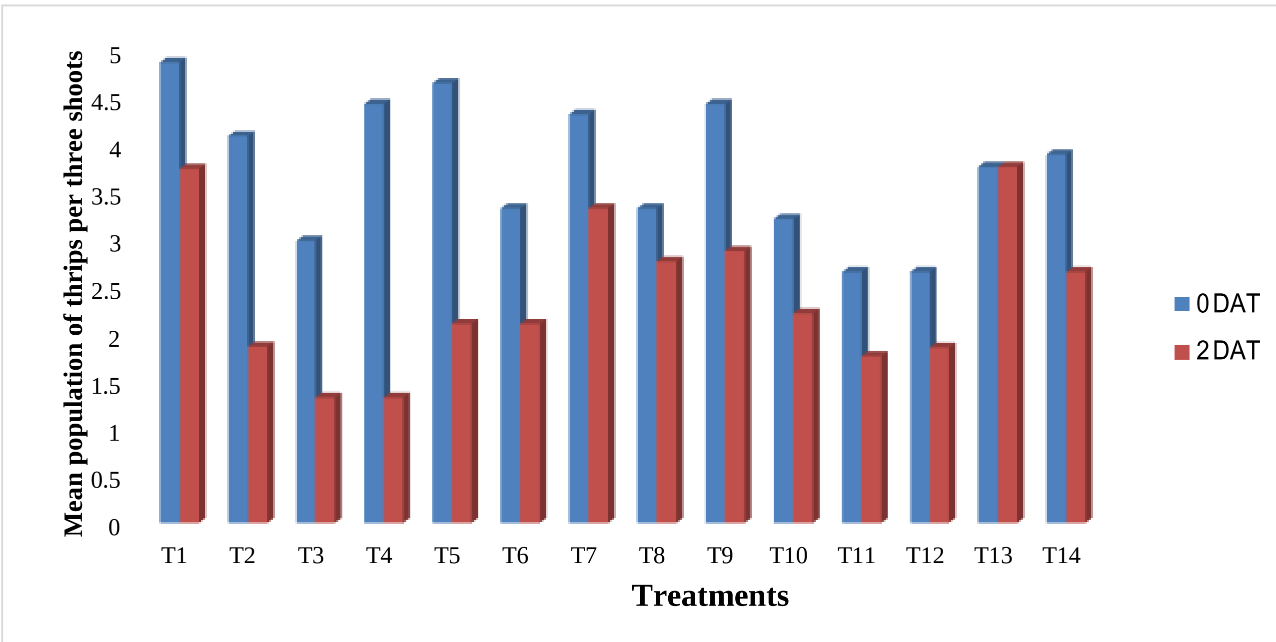
Medicinal plant based extracts are effective for the management various phytopathogens. Plant secondary metabolites are responsible for the pest management properties of these medicinal plant based extracts. Plant based pesticides are effective against pests, mostly through diverse modes of action and can express several properties such as growth retardation, feeding deterrent, oviposition deterrent and reduction in fertility. In the present study three medicinal plant based botanicals (*A. calamus*, *C. zedoaria* and *C. gigantea*) were used. In *A. calamus*, β - asarone extracted from rhizomes has showed antigonadial activity, causing complete Inhibition of ovarian development of different insects (Dubey *et al*., 2010). In calotropis, active ingredients lupeol, calotropin, calotoxin, and uscharidin exhibits the resistance against phytopathogens and insects (Al Sulaibi, *et al*., 2020). Calatropin and Calotoxin are the active principles present in calotropis, which show anti feedant, repellent, oviposition deterrent and insect growth regulator activity against insect pests (Sharma *et al*., 2012; Joseph *et al*., 2013; Kumar *et al*., 2013).

5.4.1.1 Effect of medicinal plant based formulations on population of thrips

Significant results were not observed among the various treatments against thrips population. *Calotropis gigantea* based pesticidal soap formulation showed comparatively better results against thrips population in chilli variety Anugraha under different treatments**.**

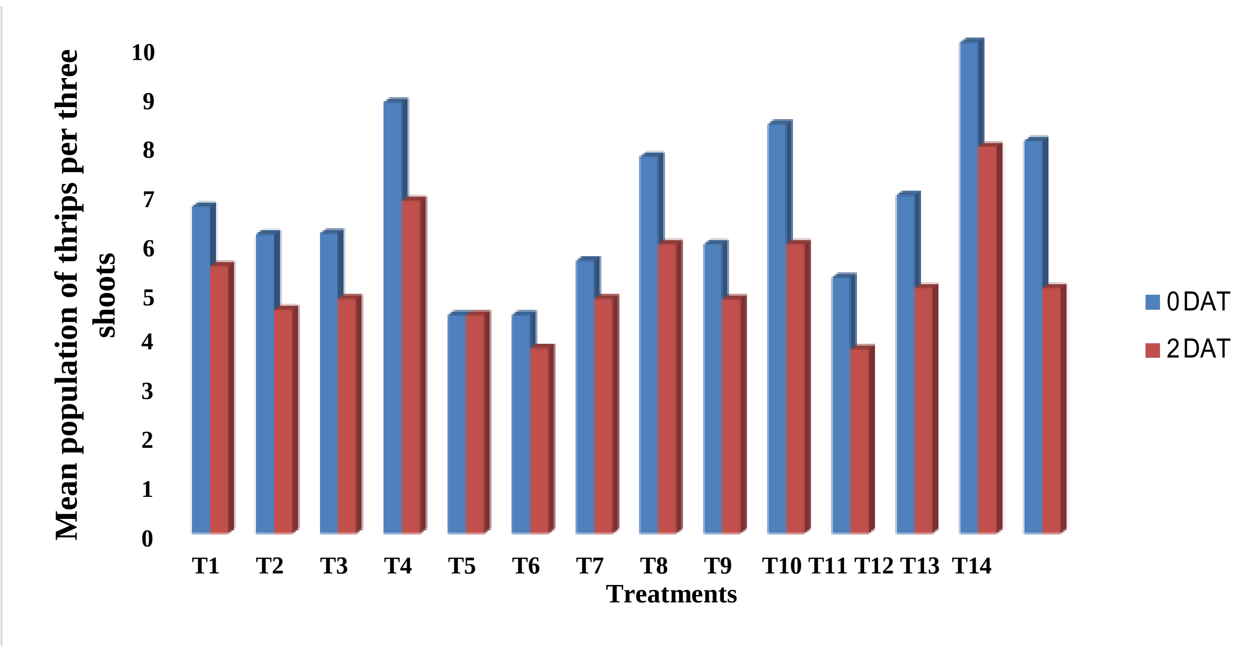
Shah and Jigarkumar (2016) observed that botanical extracts like *Datura metel* (L.) leaves extract 10 per cent (Highest Cost Benefit Ratio-CBR of 1:13.47) were best in reducing thrips population in garlic, followed by *Calotropis gigantea* (L.) leaves extract 10 per cent (1:12.89).

Chakroborty *et al.* (2019) also revealed the effect of *Calotropis gigantea* based botanical (500 gm Calotropis leaf + 2 whole lemon extract + 1 litre cow urine + 1 litre raw buttermilk) with minimum thrips population of 1.8-7.8/apical shoot (four top leaves) during 10-100 days after transplanting of chilli.



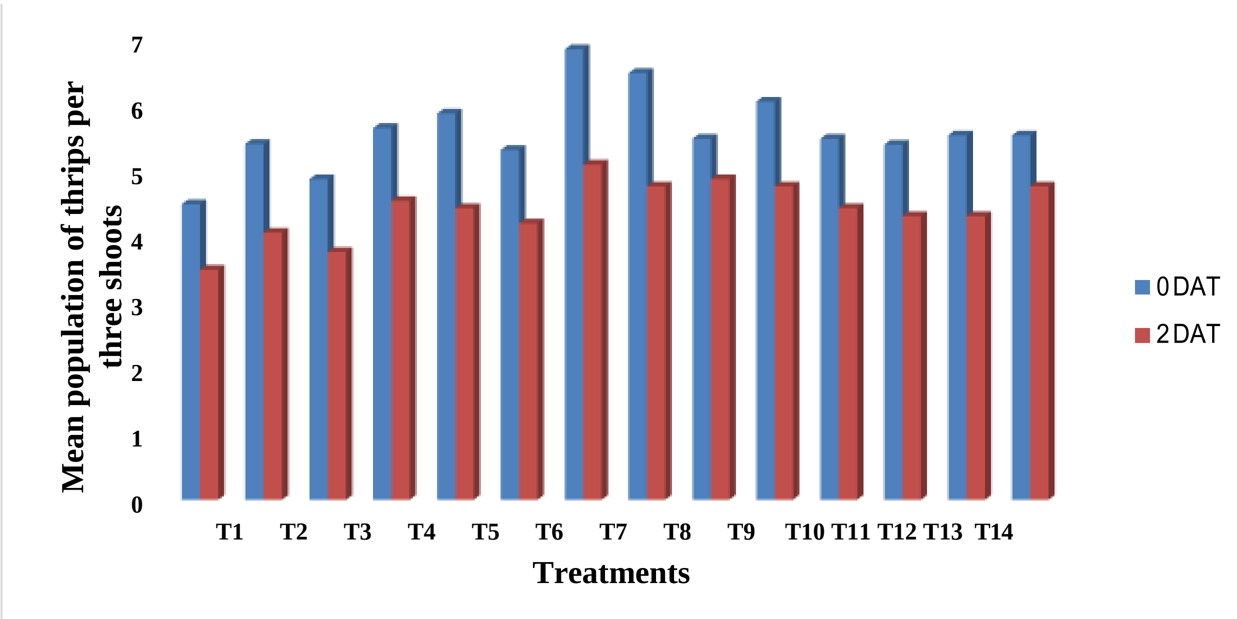
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (13) Effect of medicinal plant based formulations against thrips on chilli during last week of February, 2021



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (14) Effect of medicinal plant based formulations against thrips on chilli during first week of March, 2021



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (15) Effect of medicinal plant based formulations against thrips on chilli during second week of March, 2021

5.4.1.2 Effect of medicinal plant based formulations on population of whitefly

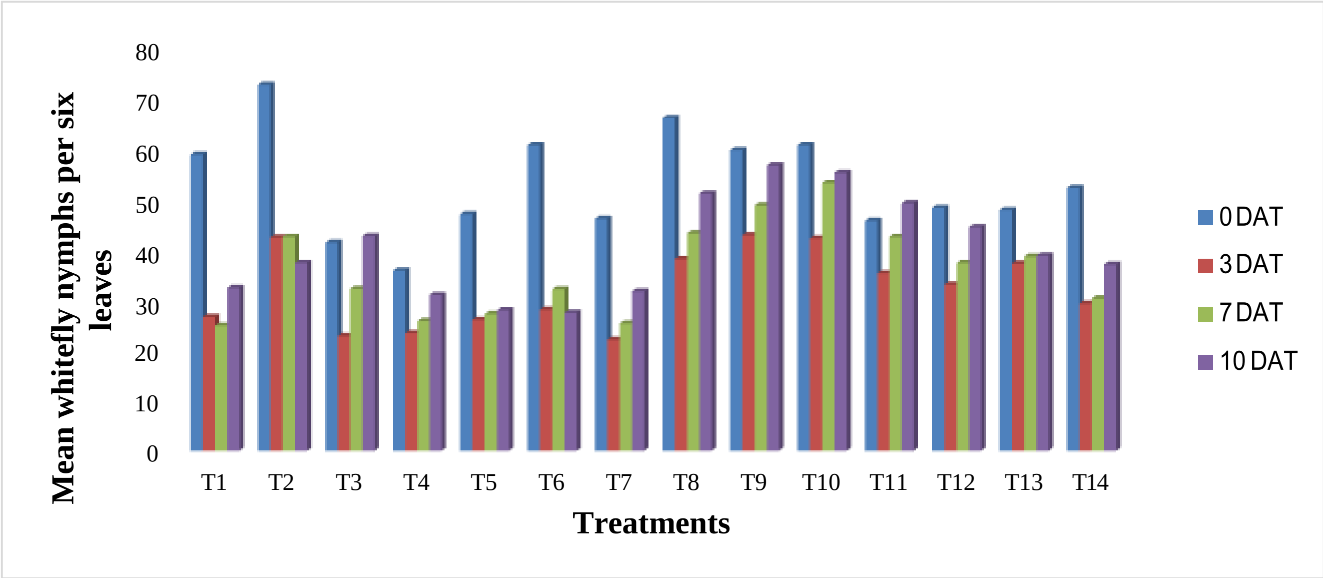
The effect of medicinal plant based formulations on population of whitefly is presented in the Figure (16), Figure (17), Figure (18) and Figure (19). Among the medicinal plant based pesticidal soap solutions, *A. calamus* showed pesticidal property against whitefly and minimum whitefly population was observed in the treatment T4- *A. calamus* at 2 per cent. Similar findings were reported by Shinthiya and Razak (2017) who studied the effect of *Acorus calamus* against whiteflies, sucking pest in brinjal and revealed that the mean population ranged from 4.86 to 28.58. Aqueous rhizome extract 1 per cent recorded 11.33 as whitefly population on third day after treatment which was followed by rhizome powder 25 kg ha^{-1} and vayambu dust 10 D 25kg ha^{-1} 15.67 and 15.00 respectively. Sweetflag rhizome powder 10 D with 2 per cent spray concentration has proved antifeedant, repellent contact and moult inhibitor mode of action against the cassava whitefly (Baskaran and Narayanasamy, 1995).

Venkatesan and Palanisami (2010) also revealed that two sprays of *A. calamus* 10 D at 25 kg ha^{-1} and Neem Seed Kernal Extract at 5 per cent at 15 days interval recorded significant reduction in whitefly population from 7 to 1 per leaf in cassava on fifth day after treatment and also recorded a tuber yield of 15.5 t ha^{-1} and benefit cost ratio of 2.80 when compared to the untreated control which recorded 7 adults per leaf with a tuber yield of 11.9 t ha^{-1}.

Manu and Nandihalli (2002) observed the efficacy of acetone extracts of *A. calamus* L. rhizome, *Adathoda vasica* leaves, *Allium sativum*, *Azadirachta indica* and *Clerodendrum inerme* to prevent the egg laying of spiraling whitefly, *Aleurodicus dispersus* Russell upto 15 days.

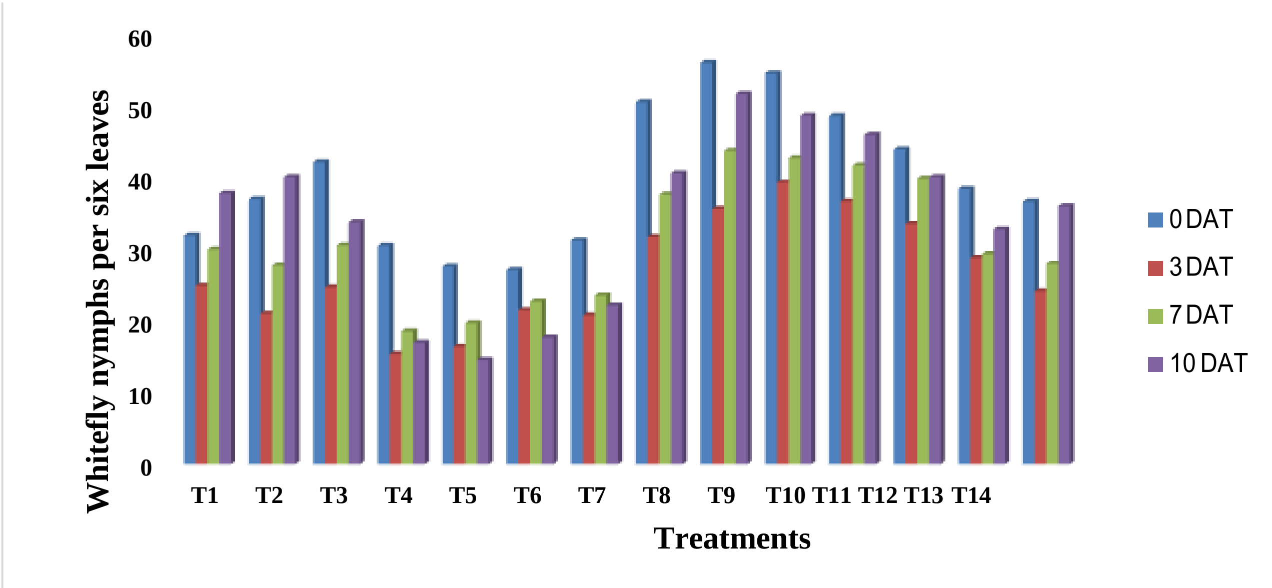
Application of ethanol extracts of *A. calamus* rhizome at four days interval showed promising results with 50 per cent lethality for 75 per cent concentration and 95 per cent lethality for 50 per cent concentration of extracts against whiteflies (Patil and Chavan, 2009).

Kumar *et al.* (2015) stated the insecticidal and genotoxic potential of ethanolic extract of *A. calamus* against *Drosophila melanogaster* and suggested as a safe alternative pest management strategy for minimizing the damage caused by the pest.



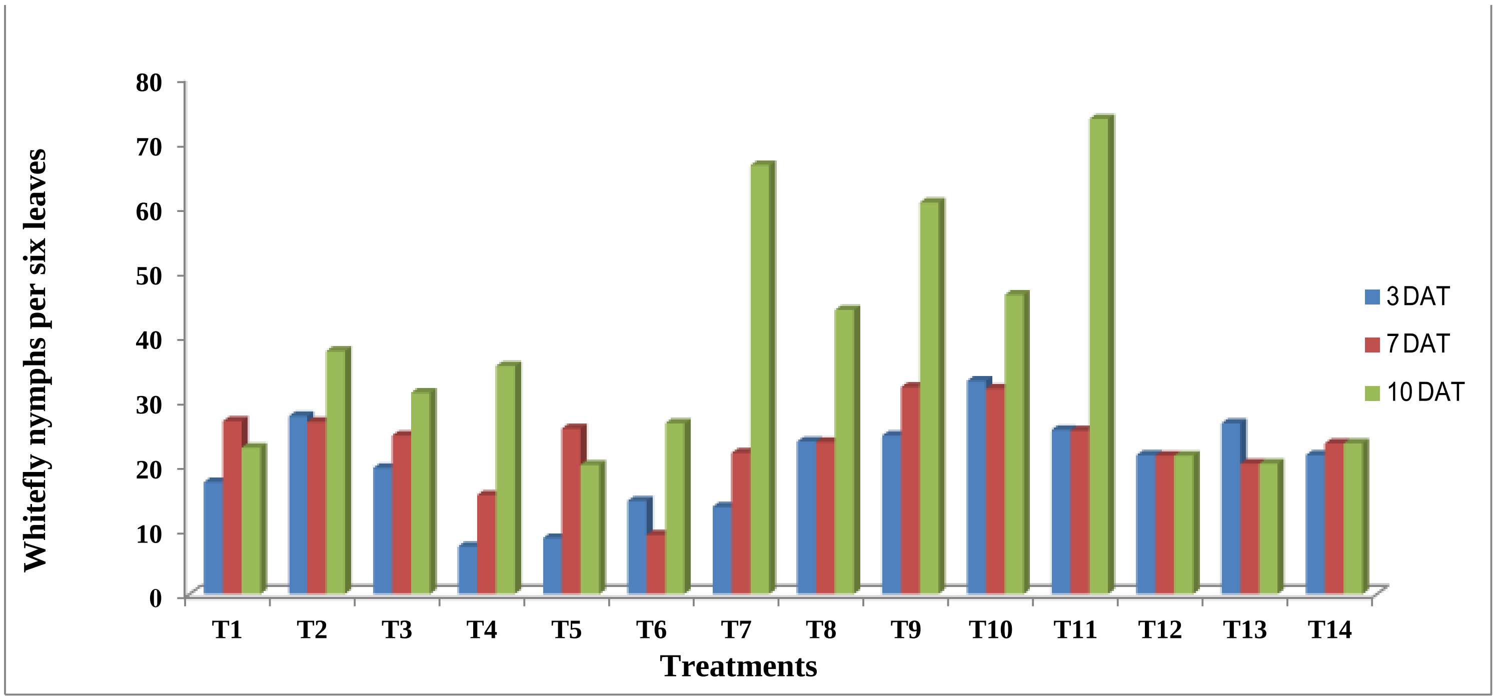
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (16) Effect of medicinal plant based formulations on population of whitefly during first week of April, 2021



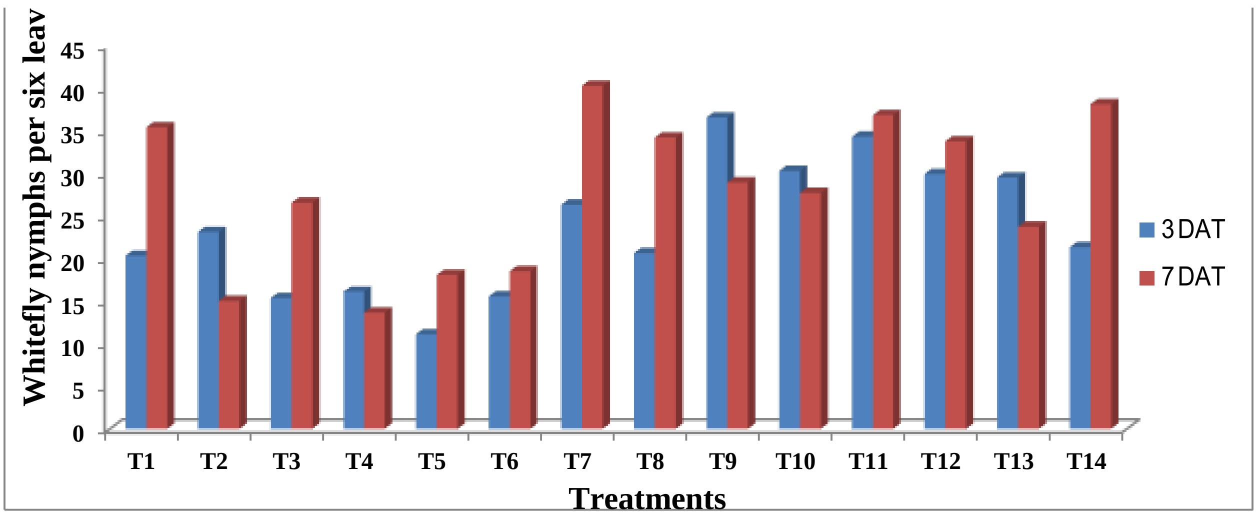
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (17) Effect of medicinal plant based formulations on population of whitefly during second week of April, 2021



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (18) Effect of medicinal plant based formulations on population of whitefly during third week of April, 2021



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (19) Effect of medicinal plant based formulations on population of whitefly during first week of May, 2021

5.4.1.3 Effect of medicinal plant based formulations on population of aphids

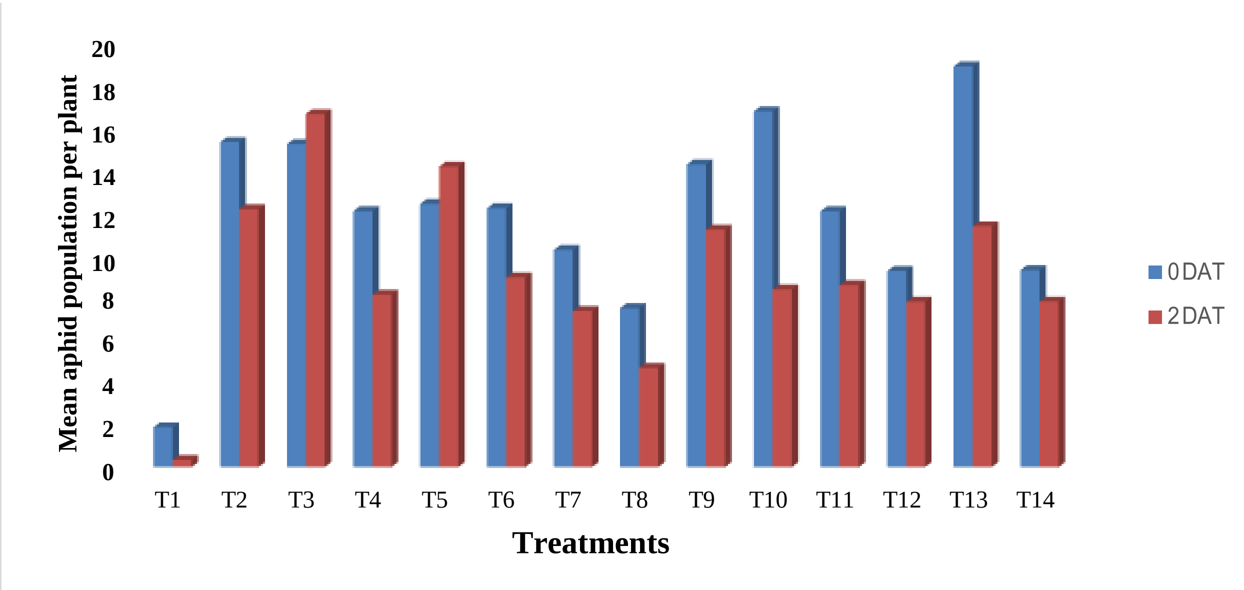
Minimum mean aphid population of 0.33 per plant was observed in T1 (*A. calamus* at 1%) compared to T13- absolute control (11.26 per plant) at two days after imposing the pesticidal soap formualtions. Minimum mean aphid population of 0.76 per plant in T1 (*A. calamus* at 1%), while in control 7.55 per plant were observed in the consecutive experimental treatments in third week of December, 2020 and last week of December, 2020 respectively. The findings obtained from the present study are in agreement with Shinthiya and Razak (2017), who observed that aqueous rhizome extract recorded the lowest mean population of aphids (9.28) in brinjal followed by rhizome powder. The reduction in aphid population might be due to reduction in progeny by affecting its reproductive system. The effect of *A. calamus* on the reproductive potential of aphids has been attributed to blocking the neurosecretory cells by the active ingredient asarone which disrupts adult maturation, egg production, survival and fecundity (Nelson *et al.*, 2005).

Tewary *et al.* (2005) reported that plant extracts prepared from leaves of *Hedera nepalensis*, roots of *Berberis lycium* and essential oil from the rhizomes of *A. calamus* and whole plant of *Valeriana jatamansi* were showed prominent results against cow pea aphid, *Aphis craccivora.* These four samples produced mortality in the range 91–95 per cent at lower testing dose (5000 ppm). The results revealed that the activity of the botanicals at 48-hour exposure against aphid (LC_{50} in the range 55–60 ppm) is comparable with the chemical insecticides at 24-hour exposure, which are commercially used against aphids (LC_{50} in the range 25–51 ppm). It is practically difficult to specifically relate the sensitivity of the crude extract with specific mode of action against insects as botanical extracts generally represent a complex mixture of compounds (phenolics, flavonoids, furanocoumarins, *etc*.). However, these compounds are known to generate free oxygen radicals, e.g., singlet oxygen ($^1O_2$), ground-state molecular oxygen ($^3O_2$), superoxide (O_2^-), hydrogen peroxide (H_2O_2) as well as hydro-peroxy and hydroxyl radicals that might strongly influence aphid's biology (Leszczynski *et al*., 1999).

Chandel *et al.* (2001) and Patil and Chavan (2009) reported that *A. calamus* caused mortality in cabbage aphid and sugarcane wolly aphid repectively. The reduction of progeny by rhizome powder of sweet flag in *Callosobruchus chinensis* and other storage pests was documented by Schmidt and Risha (1990).

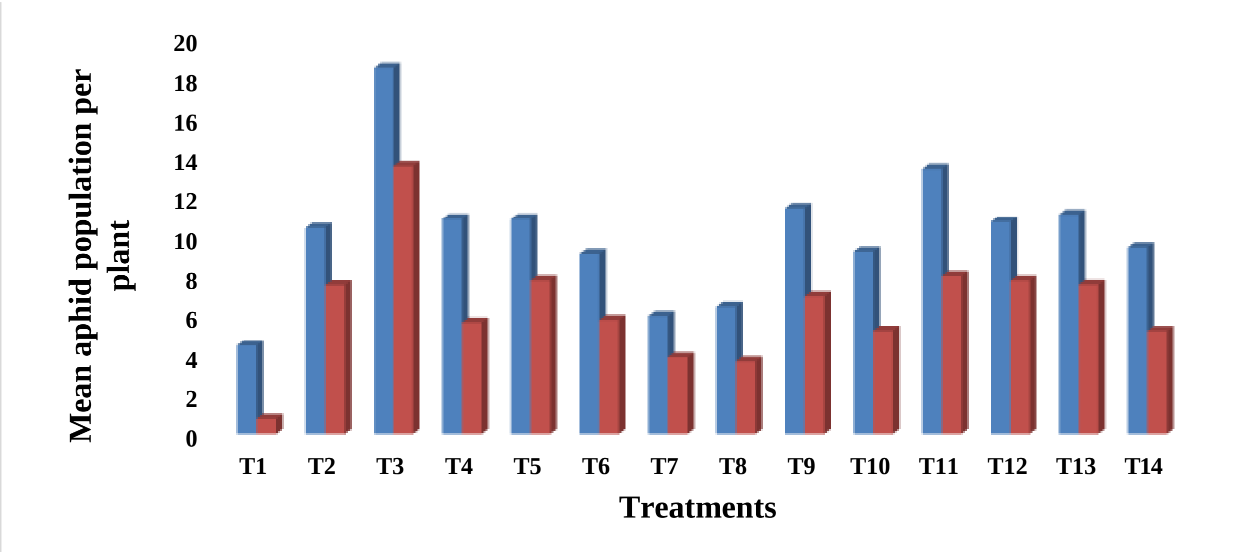
5.4.2 Effect of medicinal plant based formulations on diseases

Incidence of diseases was negligible in the chilli plants during the experimental period. Only bacterial wilt caused by *Ralstonia solanacearum* and leaf curl virus was noticed on chilli plants. Treatments T8 (*A. calamus* and *C. gigantea* at 1%), T9 (*C. zedoaria* and *C. gigantea* at 1%), T10 (*A. calamus* and *C. zedoaria* at 2%) and T12 (*C. zedoaria* and *C. gigantea* at 2%) were not affected with bacterial wilt and no leaf curl virus observed in T5 (*C. zedoaria* at 2%) and T7 (*A. calamus* and *C. zedoaria* at 1%).



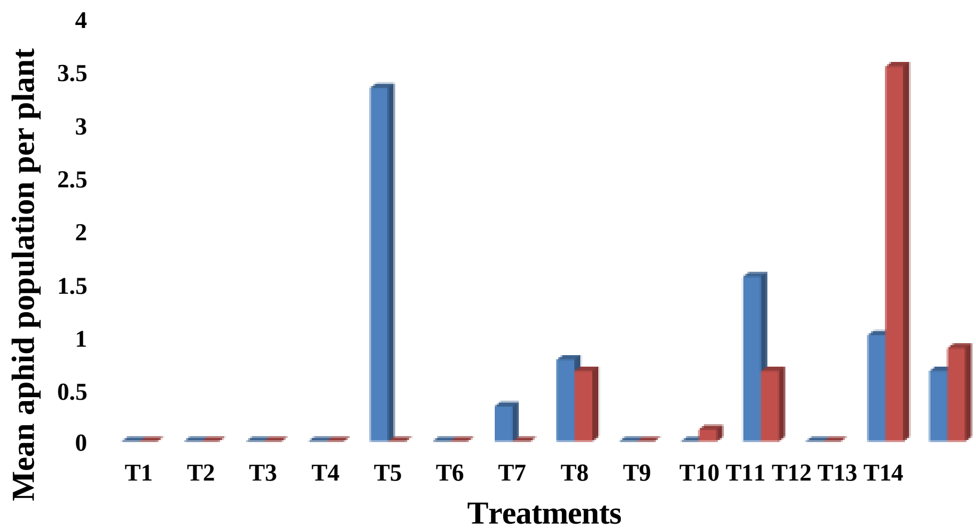
T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (20) Effect of medicinal plant based formulations on mean population of aphids during third week of December, 2020



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without botanicals), T14 (Organic POP)

Figure (21) Effect of medicinal plant based formulations on mean population of aphids during last week of December, 2020



T1 (*AC* 1%), T2 (*CZ* 1%), T3 (*CG* 1%), T4 (*AC* 2%), T5 (*CZ* 2%), T6 (*CG* 2%), T7 (*AC* +*CZ* 1%), T8 (*AC*+ *CG* 1%), T9 (*CZ* + *CG* 1%), T10 (*AC*+ *CZ* 2%), T11 (*AC* + *CG* 2%), T12 (*CZ* + *CG* 2%), T13 (Control without

Figure (22) Effect of medicinal plant based formulations on mean population of aphids during first week of January, 2021

Summary

6. SUMMARY

The study entitled "Evaluation of medicinal plant-based formulations for growth, yield and pest management in Chilli (*Capsicum annuum* Linn.)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellanikkara during the period from October 2020 to May 2021. Chilli variety Anugraha was used as a test crop for the study. The testing of the efficacy of such potential plant-based sources for antimicrobial and pest control activities could be an important step towards environmental safety and ultimately human health. Improvement in the understanding of the mechanisms of action can offer new prospects for using these substances in pest management. In this context a study was taken up for evaluation of medicinal plant-based formulations for growth, yield and pest management in chilli (*Capsicum annuum* Linn.).

Three medicinal plant based trial products (P_1, P_2, and P_3) and their combinations (P_4, P_5 and P_6), developed and screened at Aromatic and Medicinal Plants Research Station (AMPRS), Odakkali were utilized for the study. P_1 was developed from Vayambu (*Acorus calamus*), P_2 from Manja Koova (*Curcuma zedoaria*), P_3 from Erukku (*Calotropis gigantea*), P_4 from *A. calamus* and *C. zedoaria*, P_5 from *C. zedoaria* and *C. gigantea* and P_6 from *A. calamus* and *C. gigantea.* Solid soap formulations of these three and their combination were tried at one and two per cent concentrations at ten days intervals along with an absolute control (T13- 1% soap solution without any botanicals) and positive control (T14- 1% Neem garlic extract).

Influence of medicinal plant based formulations on growth, yield and pest management of chilli was studied. The growth parameters like plant height (cm), leaf length (cm) and breadth (cm), earliness characters like days to 50 per cent flowering and fruiting, yield characters like fruit length (cm) and breadth (cm), fruit weight (g), number of fruits and fresh fruit yield per plant and qualitative characters like Vitamin C (mg $100g^{-1}$) and oleoresin content (%) were recorded. Statistical comparison of morphological and qualitative parameters under various treatments was done through one-way analysis of variance (ANOVA) using KAU GRAPES software.

Effect of spraying the liquid formulations of medicinal plant based products and their combinations against sucking pests like thrips, whitefly and aphids during the experimental period (December, 2020 to May, 2021) were studied. Population density of sucking pests viz. thrips, white fly, mite, aphids were recorded as pretreatment observations one day before spraying and as post treatment observations on the third, seventh and tenth day after spraying. Data on mean population of sucking pests were tested by analysis of covariance (ANOCOVA) using R studio software, taking population counts prior to the treatments application as covariate. The result obtained was subjected to Duncan's Multiple Range Test (DMRT) and treatments were analysed.

The results of the present study are summarised below,

1. The plant height showed an increasing trend from one month after transplanting to five months after transplanting. The increment in plant height was reduced from three months onwards after attaining the reproductive stage. The maximum cumulative plant height of 61.05cm was observed in T3 (*Calotropis gigantea* at 1%) among the treatments.

2. The maximum cumulative leaf length of 5.82 cm was observed in T2 (*Curcuma zedoaria* at 1%). The maximum cumulative leaf breadth of 2.84cm was observed in T14 (Pest management as per Organic POP).

3. Days to 50 per cent flowering for different treatments varied from 42.66 to 47.66days. Treatment T6- *C. gigantea* at 2 per cent recorded minimum days to 50 per cent flowering (42.66 days) which was on par with T5- *C. zedoaria* at 2 per cent (42.66days).

4. Days to 50 per cent fruiting for different treatments varied from 55 days to 62.66days. Treatment T9- *C. zedoaria* and *C. gigantea* at 1 per cent recorded minimum days to 50 per cent fruiting (55 days) which was on par with T6- *C. gigantea* at 2 per cent (55.33 days) and T14- Pest management as per Organic POP (55.33 days).

5. Fruit length of chilli variety Anugraha under different treatments varied from 6.13 cm to 6.80 cm. The maximum fruit length of 6.8cm was recorded in T6 (*C. gigantea* at 2%).

Fruit breadth (cm) of chilli variety Anugraha under different treatments varied from 2.1 cm to 2.76 cm. The maximum fruit breadth of 2.76 cm was recorded in T5- *C. zedoaria* at 2 per cent.

6. Per fruit weight ranged from 1.2 to 1.6 g. The maximum per fruit weight of 1.6 g was recorded in T3 (*Calotropis gigantea* at 1%).

7. The maximum number of fruits per plant (104.95) was recorded in T6- *Calotropis gigantea* at 2 per cent.

8. The fresh fruit yield per plant ranged from 54.95 to 121.90 g. Factors which influence the yield of the crop like maximum plant height, Earliness (minimum days to 50 per cent flowering and fruiting), maximum fruit length, maximum number of fruits per plant were recorded in T6 (*C. gigantea* at 2%).

9. There were no significant difference among the qualitative characters like Vitamin C (mg $100g^{-1}$) and oleoresin content (%) among the various treatments.

10. *Calotropis gigantea* based pesticidal soap showed comparatively better results against thrips population in chilli variety Anugraha under different treatments**.**

11. Among the medicinal plant based pesticidal soap solutions, *Acorus calamus* and *Curcuma zedoaria* showed pesticidal property against whitefly. Minimum whitefly population was observed in the treatment T4 (*A. calamus* at 2%).

12. Minimum mean aphid population of 0.33 per plant was observed in T1 (*A. calamus* at 1%) compared to T13- absolute control (11.26 per plant), two days after imposing the pesticidal soap formualtions and a minimum population of 0.76 per plant in T1 (*A. calamus* at 1%), while in control (T13), 7.55 per plant in the consecutive experimental treatments third week of December, 2020 and last week of December, 2020 respectively.

13. Medicinal plant based formulations at lower dose (1%) showed growth inducing effect in terms of plant height and leaf length compared to the higher dose (2%).

14. *Calotropis gigantea* at 2 per cent was best among the treatments with respect to the crop yield.

15. *Acorus calamus* and *Calotropis gigantea* based formulations showed good performance in management of sucking pests of chilli.

16. Overall incidence of diseases was negligible on chilli plants during the experimental period. T8 (*A. calamus* and *C. gigantea* at 1%), T9 (*C. zedoaria* and *C. gigantea* at 1%), T10 (*A. calamus* and *C. zedoaria* at 2%) and T12 (*C. zedoaria* and *C. gigantea* at 2%) were not affected with bacterial wilt and no leaf curl virus observed in T5 (*C. zedoaria* at 2%) and T7 (*A. calamus* and *C. zedoaria* at 1%).

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EVALUATION OF MEDICINAL PLANT-BASED FORMULATIONS FOR GROWTH, YIELD AND PEST MANAGEMENT IN CHILLI
(*Capsicum annuum* Linn.)

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ABSTRACT OF THE THESIS

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ABSTRACT

Pest management is one of the important components of crop management to mitigate economic losses of agricultural crops and commodities. The harmful effects of chemical pesticides on environment and health concern have caused a shift to adapt various ecofriendly ways of pest management. Therefore, botanical pesticides are gaining popularity because they are safe to use on crops produced for human consumption and recently there is a lucrative market among consumers willing to pay more for organically produced food. This positive trend has encouraged the research field to focus more on ecofriendly and effective pest management strategies.

A study entitled "Evaluation of medicinal plant-based formulations for growth, yield and pest management in Chilli (*Capsicum annuum* Linn.)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellanikkara during the period from October 2020 to May 2021 with Chilli variety Anugraha as the test crop. Three medicinal plant based trial products (P_1, P_2, and P_3) and their combinations (P_4, P_5 and P_6), developed and screened at Aromatic and Medicinal Plants Research Station (AMPRS), Odakkali were utilized for the study. P_1 was developed from Vayambu (*Acorus calamus*), P_2 from Manja Koova (*Curcuma zedoaria*), P_3 from Erukku (*Calotropis gigantea*), P_4 from *Acorus calamus* and *Curcuma zedoaria*, P_5 from *Curcuma zedoaria* and *Calotropis gigantea* and P_6 from *Acorus calamus* and *Calotropis gigantea.* Solid soap formulations of these three and their combination were evaluated at one and two per cent concentrations at ten days intervals along with an absolute control (T13- 1% soap solution without any botanicals) and positive control (T14-1% Neem garlic extract).

The growth parameters like plant height (cm), leaf length (cm), breadth (cm),and days to 50 per cent flowering and fruiting, yield characters like fruit length (cm) and breadth (cm), fruit weight (g), number of fruits and fresh fruit yield per plant and qualitative characters like Vitamin C (mg $100g^{-1}$) and oleoresin content (%) were recorded. Statistical comparison of morphological and qualitative parameters under various treatments was done through one-way analysis of variance (ANOVA) using KAU GRAPES software.

Effect of spraying the liquid formulations of medicinal plant based products and their combinations against sucking pests like thrips, whitefly and aphids during the experimental period (December, 2020 to May, 2021) were studied. Population density of sucking pests *viz.* thrips, white fly and aphids were recorded. Data on mean population of sucking pests were tested by analysis of covariance (ANOCOVA) using R studio software, taking population counts prior to the treatments application as covariate. The result obtained was subjected to Duncan's Multiple Range Test (DMRT) and treatments were analysed.

The plant height showed an increasing trend from one month after transplanting to five month after transplanting. The increment in plant height was reduced from three months onwards after attaining the reproductive stage. The maximum cumulative plant height of 61.05 cm was observed in T3 (*Calotropis gigantea* at 1%) among the treatments.The maximum cumulative leaf length of 5.82 cm was observed in T2 (*Curcuma zedoaria*at 1%). The maximum cumulative leaf breadth of 2.87cm was observed in T14 (Pest management as per Organic POP).

Days to 50 per cent flowering for different treatments varied from 42.66 to 47.66 days. The minimum days to 50 per cent flowering recorded in T5- *Curcuma zedoaria* at 2 per cent and T6- *Calotropis gigantea* at 2 per cent. Days to 50 per cent fruiting for different treatments varied from 55 to 62.66 days. Treatment T9- *Curcuma zedoaria* and *Calotropis gigantea* at 1 per cent recorded minimum days to 50 per cent fruiting (55 days).

Fruit length of chilli variety Anugraha under different treatments varied from 6.13 cm to 6.80cm. The maximum fruit length of 6.8 cm was recorded in T6 (*Calotropis gigantea* at 2%). Fruit breadth (cm) varied from 2.16 to 2.76 cm. The maximum fruit breadth of 2.76 cm was recorded in T5- *Curcuma zedoaria* at 2 per cent.

Per fruit weight ranged from 1.22 to 1.63 g. The maximum per frit weight of 1.63 g was recorded in T3 (*Calotropis gigantea* at 1%).The number of fruits per plant ranged from 35.15 to 104.95 and the maximum number of fruits per plant (104.95) was recorded in T6- *Calotropis gigantea* at 2 per cent. The fresh fruit yield per plant ranged from 54.95 to 121.90 g. Treatment T6 (*Calotropis gigantea* at 2%) recorded the maximum fresh fruit yield per plant. Factors which influence the yield of the crop like maximum plant height, earliness (minimum days to 50 per cent flowering and fruiting), maximum fruit length, maximum number of fruits per plant were recorded in T6 (*Calotropis gigantea* at 2%).

There was no significant difference for the qualitative characters like Vitamin C (mg $100g^{-1}$) and oleoresin content (%) with respect to the application of the medicinal plant based formulations.

Efficacy of medicinal plant based formulations was studied against various sucking pests during the experimental period. *Calotropis gigantea* based pesticidal soap formulation showed comparatively good results against thrips population in chilli variety Anugraha under different treatments**.** Minimum population of whitefly was observed in the treatment T4- *Acorus calamus* at 2 per cent among various treatments. *Acorus calamus* based formulation also showed good results with lower pest load against aphids.

In general, over all disease incidence in the treatment plot was negligible during the experimental period and *Calotropis* and *Acorus* based formulations were showed comparatively good performance in the aspects of growth, yield and pest management in chilli variety Anugraha.