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An Exploration of Cymbopogon nardus or Cymbopogon winterianus and its Oil

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ABSTRACT-

Citronella grass, scientifically known as Cymbopogon nardus or Cymbopogon winterianus, is a tropical plant that is well-known for its strong citrus aroma. This grass is widely cultivated for the extraction of citronella oil, which is used in various products such as insect repellents, candles, and oils. The main reason for cultivating citronella grass is to extract citronella oil, which has a strong lemon-like scent. This oil is known for its insect-repelling properties and is commonly used in natural insect repellents. Citronella oil is a natural insect repellent. It is often used in outdoor candles, sprays, and lotions to help keep mosquitoes and other insects at bay. While citronella oil is not typically used in cooking, the leaves of citronella grass can be used to flavor certain dishes. However, it's important to note that there are different varieties of citronella grass, and not all are suitable for culinary purposes. Citronella grass is sometimes grown as an ornamental plant in gardens and landscapes due to its tall, slender stems and attractive, feathery leaves. Citronella grass is a tropical plant and thrives in warm, humid conditions. It is often grown in well-drained soil and requires regular watering. It can be cultivated in containers or planted directly in the ground. Citronella grass can be propagated through seeds or by dividing existing clumps. It's a relatively low-maintenance plant, but it does require adequate sunlight to thrive. There are different varieties of citronella grass, with Cymbopogon nardus and Cymbopogon winterianus being the most commonly cultivated for citronella oil production.

- Key words- Cymbopogon nardus, Citronella oil, Antioxidant effects

1. Introduction

Essential oils have been employed for traditional health benefits since million years ago [1], and their usage has continued into the modern era. Consequently, due to its active chemical concentration, it attracts an extensive number of businesses in the modern day. The active ingredients present in essential oils have a wide range of usage which include: -

- Food preservation
- Antioxidant effects
- Antibacterial effects
- Antifungal effects.

All sections of the plant—roots, stems, bark, branches, and leaves—store these active chemicals that are produced by secondary metabolism. Naturally, plants use secondary metabolism as a means of self-defense against pests. Citronella grass (Cymbopogon nardus) is one source of essential oil.

Perennial grasses of the Poaceae family include citronella grass. 140 aromatic species are included[2]. In Hindi, it is often referred to as ganjni; in Bengali, as kamakher; in Marathi, as usadhana; in Tamil, as kamachipillu; in Telgu as kamkshi-kasuvu; and Punjabi as khavai. Sri Lanka and South India are the original home of citronella grass[3]. The majority of the world's tropical and subtropical regions—including Brazil—which is a home to its cultivation[4].

Southeast Asian countries (primarily Burma, Sri Lanka, India, Ceylon, Taiwan, Indonesia) and the West Indies are the major growing regions for it commercially. Most people confuse citronella with lemongrass, however, lemongrass is derived from the Cymbopogon species C. citratus, C. pendulus, and C. flexuosus, and its active constituent is citral (both trans and cis)[5].

Cymbopogon nardus, or citronella grass, is a long-leaved medicinal plant that is mostly grown for commercial purposes in much of Asia, America, and Africa's tropical and subtropical regions[3]. The well recognized C. nardus and C. winterianus, sometimes referred to as Java and Ceylon citronella, are significant species of citronella grass that have been utilized for millennia in traditional medicine and the spice trade.[2,4,6–8]

The term "citronella" describes two species of perennial tropical grasses in the genus Cymbopogon that are known to produce essential oils: Java (C. winterianus) and Ceylon (C. nardus). These two species differ from one another in terms of both morphology and biochemistry.[9]. Furthermore, it is a physical representation of a C. nardus plant, with green to bluish green leaves, green to purplish red stems, and flat, elongated leaves that resemble reeds with clumpy, accidental roots. Squeezing the leaves releases a powerful, aromatic scent.[6] Although C. nardus may grow as high as 200–1000 m above sea level (ASL), it thrives at 350–600 m ASL, 18–25°C, 1,800–2,500 mm of precipitation annually, and year-round direct sunlight exposure. These conditions result in the maximum essential oil output and quality.

2. Plant Profile of Cymbopogon nardus

Kingdom: Plantae
Phylum: Antoophyta
Class: Monocotyledons
Order: Cyperales
Family: Poaceae
Genus: Cymbopogon
Species: Nardu

Types of complementary medicines: -

- Energy therapy
- Biological therapy
- Nature-based therapy

Citronella is referred to as Pangiri in Ayurveda and is employed for medicinal purposes: -

- Redness
- Irritation
- Toothaches
- Inflammation of the skin
- Rheumatism

- Digestive problems
- Headache
- Infectious diseases
- Fatigue and childbirth

Other nations, such as China and Thailand, have traditionally used citronella essential oil for the treatment of: -

- Irritable bowel
- Stomach ache
- Intestinal cramps
- Gastritis, indigestion
- Flatulence
- Blood tonic.[10-11]

It has been used as a diuretic, vermifuge, antipyretic, and aromatic tea since the Vedic era. It has also been used to treat mental illnesses.[12] It is also used in aromatherapy to cure colds, headaches, and the flu, as well as digestive issues and fever.[11] These days, it's discovered that the extracted essential oil has uses in the pharmaceutical, body care, personal hygiene, tobacco, cosmetics, and insect repellent packaging sectors. [12, 13] Cats were also kept away from using the essential oil.[14] It has been discovered that C. nardus contains cellulosic fibres, which are employed in the paper industry to create pulp that has less environmental risks.[15] The characteristics of C. nardus raw materials, pulp, and paper are the same as those of non-wood products. The extractives of C. nardus had low alcohol-benzene (5.14%), low lignin content, low ash content (3.66%), low sodium hydroxide extractives (25.99%), high α-cellulose (35%), and holocellulose. Compared to wood pulp, C. nardus pulp requires less energy to pulp, and it can have its qualities enhanced by pounding it for up to 500 PFI rotations. C. nardus grass might take the role of hardwood pulp in writing materials, newspapers, and toilet paper. Thus, it is advised to use C. nardus grass for the manufacturing of paper.[15] Analyses have been carried out on the effects of citronella essential oil fumigation on potato tuber quality and sprout suppression during storage. These include fumigating potato tubers with citronella essential oil. According to reports, fumigation with citronella essential oil lowers the amount of sugar present, slows the breakdown of starch, suppresses the synthesis of gibberellin, and lowers the level of α-solanine. Therefore, fumigation with citronella oil reduces sprouting and enhances the quality of potato tubers during storage.[16]

3. Physical Property

Citronella essential oil, with a yellowish color and a boiling point of 70°C, was produced at 20°C using several procedures. Its specific gravity is 0.89 g/cm^3 and its refractive index is 1.47. It was also mentioned that citronella oil is red and yellow. Citronella oil may have a crimson color because of trans-β-caryophyllene and γ-cadinene. The development of the red color may also be due to lipids oxidizing in the extraction processes. During the hydro distillation extraction procedure, no red color was seen.[17]

4. Chemical composition

The chemical composition of C. nardus essential oil was studied and its major constituents included camphene, β-caryophyllene, limonene, myrcene, terpinolene, borneol, citronellol, geraol, linalool, piperit0l, citral (cis and trans), citronellal, methyl heptenone, citr0nellic acid, piperitone, citronellyl acetate, caryophyllene oxide, geranyl acetate, geranyl butyrate, methyl eugenol, chavicol, eugenol, methyl isoeugenol, nerol, ocimene, elemol, η-propyl alcohol, 4-terpineol, menthane, α-terpinene, α-thujiene, α-terpineol, α-pinene and β-pinene.[18]

The citronella essential oil mainly consists of monoterpenes. It contained 16 monoterpenes (73.3%), 2- aldehydes (30%), 5- hydrocarbons (8.9%), 8-alcohols (40.4%), 1-phenolic hydrocarbon. The major component identified was citronellal (29.7%) followed by geraniol (24.2%), γ-terpineol (9.2%), along with cis-sabinene hydrate, β-myrcene, borneol and nerol with concentrations 3.8, 2.9, 2.5, 1.5%, respectively. Nine sesquiterpenes (11.5%) including 3-alcoh0ls (6.5%) and 6-hydrocarbons (5%) were also identified. Predominant sesquiterpene was (E)-nerolidol (4.8%) f0ll0wed by caryophyllene and germacrene-4-ol, 2.2 and 1.5%, respectively. Four non-terpenic components which comprised 1.4% of the total sample were also detected.[19]

Citronella essential oil was characterized by the presence of 2 major chemical groups, monoterpenes and sesquiterpenes, along with a great amount of their oxygenated derivatives. C. nardus essential oil was characterized by large amount of β- citr0nellal, β-citronellol, nerol, limonene, elemol, β-element, α-cadin0l, germacrene-D, cubenol, δ-cadinene, geranyl acetate and τ-cadinol.[20]

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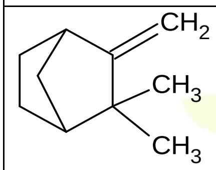
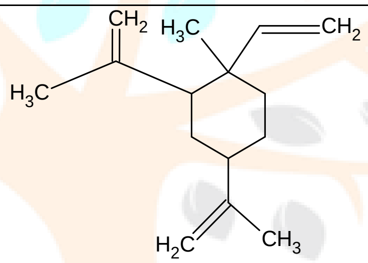
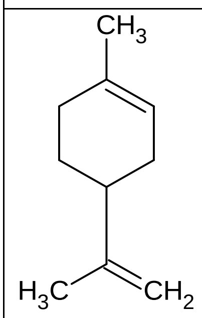
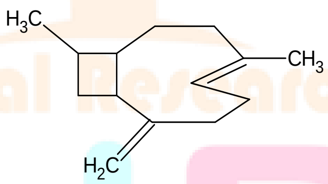
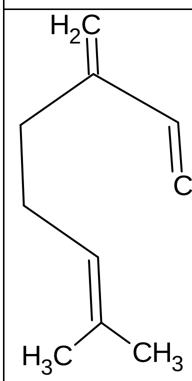
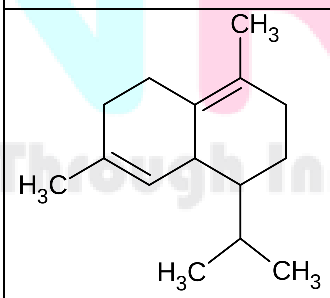
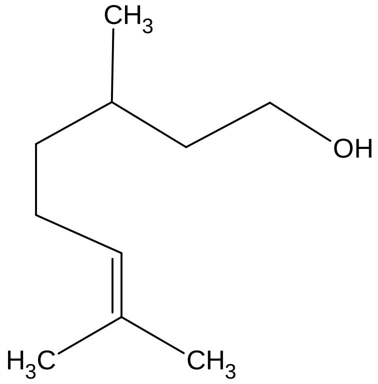
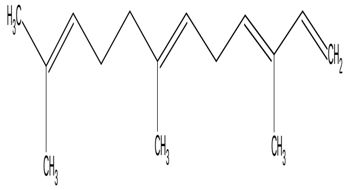
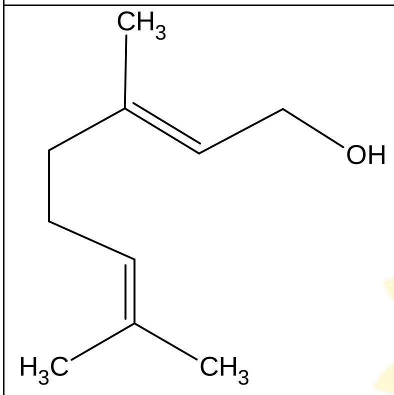
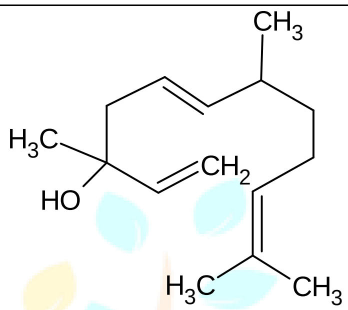
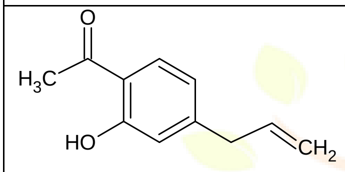
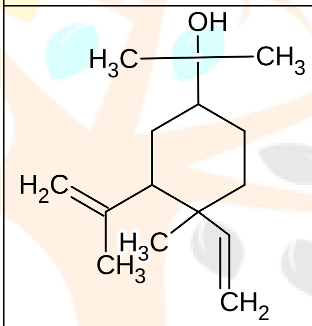
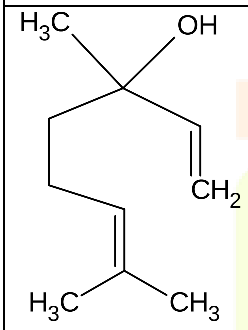
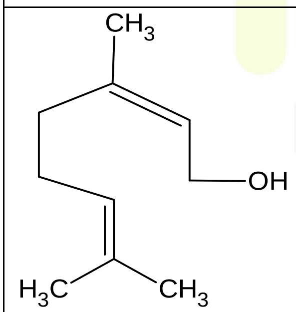
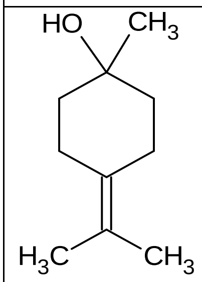
			
	Hydrocarbon		Hydrocarbon
			

			
	Alcohol		Alcohol
			
			
			
			

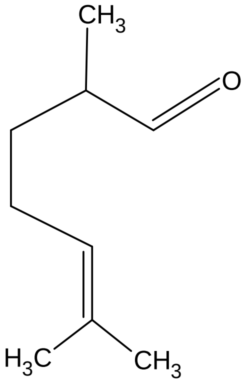
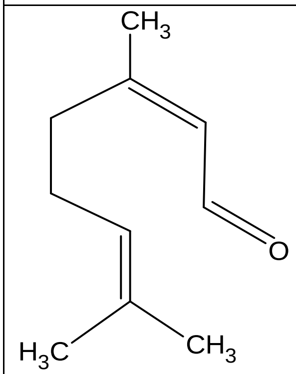
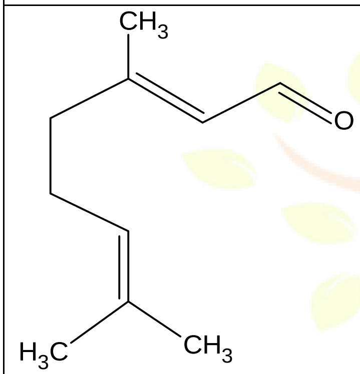
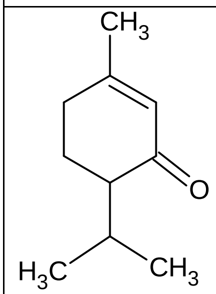
	Aldehyde		
			
			
	Ketone		

Table 1: Important components of C. nardus essential oil and their chemical structures

Countries	**Hydrocarbon**	**Aldehyde/Ketone**	**Alcohol**
Malaysia[3,21]	6.1	39.25	54.35
China[4]	17.86	26.23	40.53
India[19,22]	-	29.7	33.4
Morocco[23]	7.2	16.9	20.3
Brazil[24-25,4]	-	42.41	45.83
Africa[26]	4.1	29.2	47
Bangladesh[27]	9	0.9	80.1

Table 2: Oxygenated monoterpenes' percentage contribution to the essential oil of C. nardus.

Common methods for extraction of essential from citronella grass

Because the quality of citronella grass essential oil is largely depending on its biochemical constituents, the extraction techniques have been proven to significantly influence the yield and quality of citronella grass essential oil[28-29] so, the techniques involved are: -

a) **Solvent extraction**: The Soxhlet device is typically used in the solvent extraction process to extract essential oil from citronella grass[15]. This device makes it easier for plant material and refluxing liquid solvent to come into constant contact, increasing the effectiveness of the extraction process. Unfortunately, it requires a lengthy heating time at high temperatures (often close to the solvent's boiling point), which might cause thermally sensitive ingredients to degrade. The extraction of essential oil from fresh and dry citronella grass leaves using n-hexane as a solvent produced 1.85% and 4.5% oil yield, respectively. This is because solvent extraction, whether by maceration or Soxhlet extraction, requires a suitable solvent to achieve a high extraction yield and to prevent the loss of volatiles.[30]

b) **Ultrasound-assisted extraction:** Its main emphasis is on using innovative technologies to reduce greenhouse gas emissions. These technologies must fulfil legal environmental criteria, have minimal energy consumption, cheap investment and running costs, and great product/process safety and control to produce high-quality products.[31] Due to these disadvantages, automated sophisticated and effective extraction techniques have increased. One example is ultrasound-assisted extraction (UAE), which has reduced organic solvent use and energy consumption along with faster extraction timeframes. Soxhlet extraction, Clevenger hydro distillation, continuous packed bed extraction systems, and various ultrasonic hybrids with other extraction techniques including microwave, extrusive, and supercritical fluid extractions are examples of advancements.[32]

c) **Steam distillation:** It is a cost-effective technique[33] in which there is continuous flow of steam over fresh and dried plant material because of which oil-bearing cells of parenchyma tissue softens and thus it leads to the drifting of essential oil in vapor state. Now the condenser is used to cool and collect the steam which contain the essential oil. Moreover, it should also be noted that the process of vaporization should be continued with appropriate elevation in the steam temperature because excessive elevation may lead to the loss of crucial constituent of the essential oil because of decomposition. The extraction process is performed by the continual flow of steam which is having a temperature of 100^{o}C under an atmospheric condition in which steam temperature should be lower than the boiling point of an specific constituent i.e. 200^{o}C.[34] However distillation of aromatic grass is mainly done during their fresh or wilted state because during the process of distillation especially in case of wilted herbaceous materials moisture constitute should be lessened which leads to an increase in the yield of the oil content.[35] Furthermore it has also been found that essential oil constituent which has been produced by the steam distillation of citronella grass is 0.24%[36],0.3%[37],0.6%[38] and 0.71%[39]

d) **Microwave-assisted hydro distillation**: The working principle of microwave-assisted hydro distillation (MAHD) is probably same as of conventional HD. But MAHD is mainly associated with the involvement of microwave that heat the solvent. In a boiling state flask contain the solvent i.e. water with plant material i.e. slowly delivered to the controlled microwave oven (operated at 2.45 GHz). Microwave power speed is mainly used to enhance the rate of essential oil extraction. However this method is widely used because extraction time is less and can effectively implemented in both the scale whether it is industrial or laboratory .Moreover it is an eco-friendly technique which rapidly transfer mass followed by the involvement of energy because of which it is having excellent heating ability .It is also reported that MAHD and HD yield 0.35%-0.2% of essential oi.[40] However it's an alternative technique of the conventional method because it is potential enough to extract essential oil without altering the chemical composition of gerania, neral, myrecene and so due to this reason it exhibit superiority over conventional HD technique.[41]Additionally it is also found that MAHD yield 93.2% citral as essential oil.

e) **Supercritical fluid extraction(SFE):** It is an environment friendly technique used for extracting essential oils.[42] It is assosiated with high-pressure pump, an extraction vessel, a water bath heater or oven, ball valves, a back pressure regulator, a cold trap, a volumetric gas quantifier, and a vent. An additional high-pressure pump and mixer have to be added to the SFE unit when cosolvent is needed.[43] along with it Temperature and pressure adjustments are also needed for the solvation characteristics of the supercritical fluid shown in Figure:1. This first affects the fluid's density and then enables selective extraction. Because of its exceptional physicochemical qualities, which are mostly connected to its comparatively low critical temperature and pressure (23–50ºC and 8–12 MPa, respectively), carbon dioxide is the most widely used supercritical fluid.The pristine composition and qualities of the essential oil can be preserved by performing [44] SFE with CO2 at temperatures of around 30ºC. Unfortunately, one of this method's primary limitations that limits its implementation is the high cost of equipment investment. Additionally, supercritical CO2 is used in the extraction of citronellagrass essential oil. This approach often entails optimizing the extraction process by adjusting temperature and pressure, solvent flow rate, composition of the solvent mixture, and particle size of the input material. The maximum extraction rates and yields, 1.7% and 1.51%, respectively, were measured at 9 MPa & 23ºC and 12 MPa & 40ºC.The predominant constituents found in the extracted essential oil were neral and geranial, which had respective compositions ranging from 26.7% to 31.9% and 44.6% to 53.0%. In order to increase the citral content in the extracted essential oil, pressure (9, 10, 11, and 12 MPa) also affects the supercritical extraction of citronellagrass at 50°C for 360 minutes.[45] At 9 MPa, they found that the essential oil had the maximum yield (0.65%) and citral content (68%), whereas HD made it possible to achieve a process yield of 0.43% and a citral content of 73%.Because larger molecular mass components were also extracted throughout the process, the essential oil's colour changed from yellow to yellowish semi-solid at increasing solvent densities. The response surface approach is used to determine the ideal operating parameters for the supercritical CO2 extraction of lemongrass essential oil.[46]

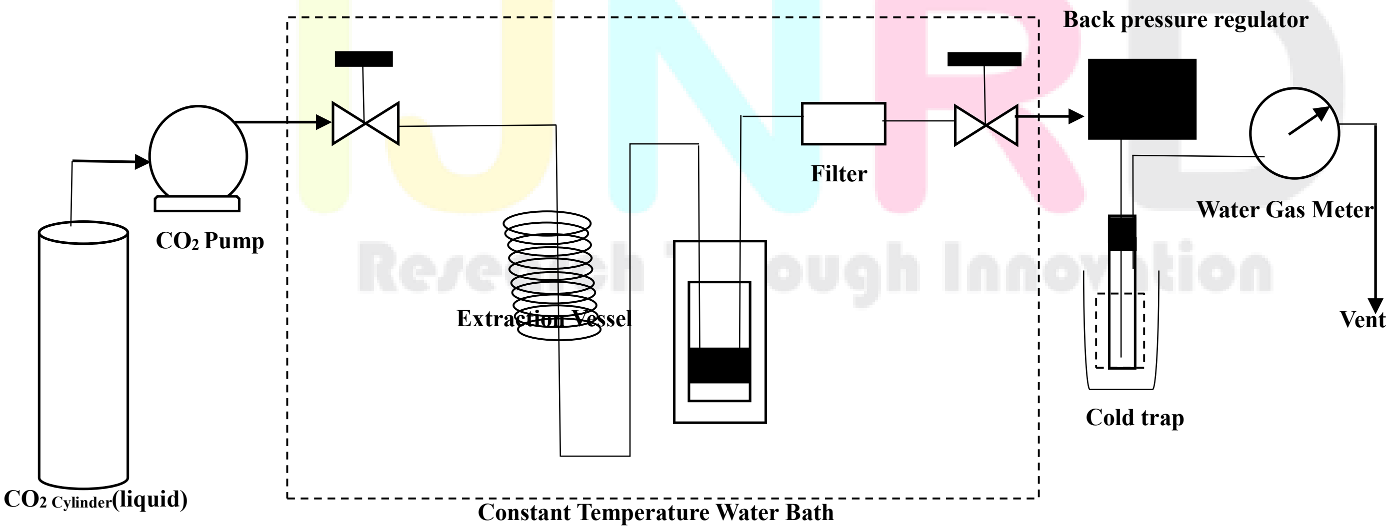


Figure 1: Supercritical fluid extraction apparatus

5. Biological activities

The biological properties exhibited by citronella essential oil are categorized into various types depending upon the target organism as follows: -

- a Anti-fungal
- b Anti-bacterial
- c Anti-oxidant
- d Insecticidal
- e Anti-parasitic
- f Staple preservation

a) **Anti-fungal activity**: C.nardus contain monoterpenoids which have natural fungicidal property with high efficacy and safety and so due to this reason it is highly potential against a broad range of fungi of multiple genus. Moreover, at a high conc of 400mg/l, it effectively inhibits the growth of Aspergillus niger and Penicillium putida and it is also potential at low conc. of 4 mg/ml against P. putida [47] along with it effectivity is also found against P. grisea, Aspergillus species and Colletotrichum musae. In the case of P. grisea, Aspergillus species and C. musae effectivity is conc.-dependent and so at appropriate conc it inhibits their spore production.[48] Potential inhibition toward Alternaria alternata (fungus that spoils fruits and vegetables, especially cherry tomato) is found at a dose of 1.5 µl/m and with a minimum inhibitory concentration of 1.5 µl/ml it is effective against PDA (Potato dextrose agar).[49] Moreover, it is highly effective against the fungi contaminating fungi belonging to Penicillium and Mucor genera (A. flavus, A. niger and A. fumigates).[50] Cost-effective nano-emulsion formulation with essential oil formulation is also highly effective[51] and for this cavitation assisted techniques[52,53] is implemented. The mixture of Nano emulsions of neem oil and citronella oil mixture is also having potential antifungal activity against phyt0pathogenic fungi (Sclerotium rolfsii and Rhizoctonia solani) followed by the reduction in the diseases caused by S. rolfsii and R. solani.

b) **Anti-Bacterial act**: Potency with Bacteriocidal action is also found with C. nardus essential oil especially against human pathogens such as Acinet0bacter baumanii, Escherichia coli, Enterococcus faecalis, Pseudomonas aeruginosa, Klebsiella pneum0niae, Serratia marcescens, Salm0nella typhemurium and Staphylococcus aureus at concentration range of 1200–20,000 µg/ml. Pronicity with High MIC value is found with human pathogens moreover inhibiting activity is shown for both Gram-p0sitive and Gram-negative bacterial.[54] High antibacterial potency of 0il was due to the existence 0f the comp0nents like elem0l (9.1%), citr0nell0l (10.4%), citronellal (16.9%) and ner0l (8%).[55]

c) **Anti-oxidant**: Anti-oxidant activity is also shown by Citronella 0il with IC_{50} value of 206 µg/ml.[56] Low antioxidant activity is found because they are devoid of phenolic compounds.[57] Citronella oil with high anti-oxidant properties is mainly possessed by the phytoconstituent like citronella having IC_{50} value of 49 µg/ml and limonene which is extracted by ohmic-heated hydrodistillation.[58] Moreover, it is a thermosensitive method so precautions must be taken otherwise the extract material's potency can deteriorate [59] and it's mechanism of action is shown effectively in figure:1

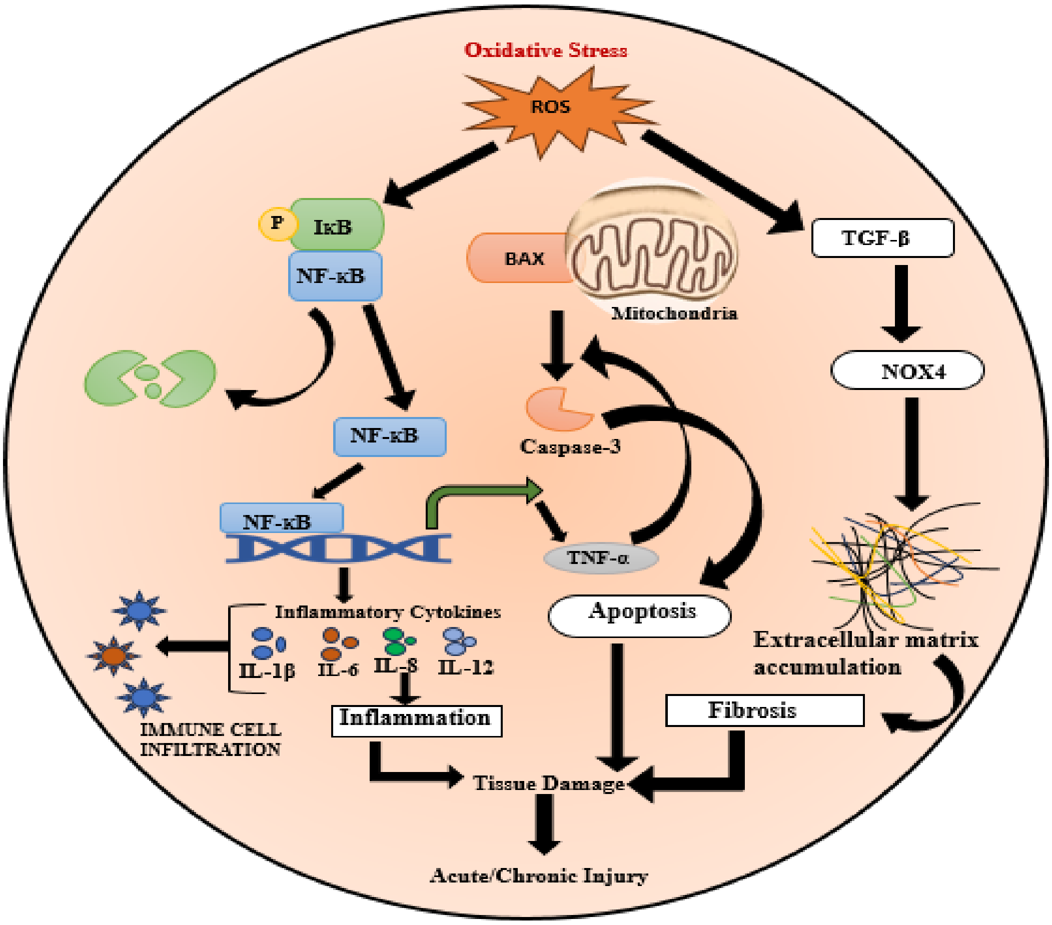


Figure 1: Citronella oil's mechanism of action with respect to its anti-oxidant property

d) Insecticidal: Prime activity of citronella essential oil is mosquito repellent activity.[60,61] For million yrs. they are used as insect repellent prior to the manufacture of synthetic insect repellent like DEET. Moreover citronella is also used as an antidote for snake bites and also play the role of antivenomous against the stings of venoumous insects moreover it can also be used as air purifier for warding off insects.[62] At a conc. of 12.5% citr0nella 0il is effective enough in killing tropical horse tick(Anocentor nitens)whereas at a conc of 0.006% it is used in pesticide product Bug Assassin[63], moreover combination of this citronella pesticidal product with peppermint, eugenol, Sodium lauryl sulfate is 90% effective in controlling of spotted spider mites (Tetranychus urticae).[64]

Moreover citronella essential oil was not effective enough against Homopteran pests and also shown poor effectivity against 3 species of kissing bugs,i.e. Triatoma pr0tracta, T. recurva and T. Rubida. Contact toxicity and repellency of essential oil of C. nardus against red imported fire ant (S0lenopus invicta) and argentine ant (Linepithema humile) was also studied.[65]

Citronella oil is capable enough to kill 50% of argentine ants in 34.3 minutes and 100% of all of them after 24 hours. However, once subjected to citronella oil for 24 hours, 50.6% of red imp0rted fire ants were killed, which resulted in a significant mortality rate. Head lice (Pediculus varcapitata) and body lice (Pediculus humanus var. humanus) were both repelled by the essential oil extracted fr0m C. nardus.[66]

Combination of Citronella essential oil with neem and coconut oil was successful in halting the propagation of head lice. Moreover, citronella's is having zero-toxic to humans and plants. Use of terpenes along with citronella essential oil is required to restrict insects' neural pathway, hindering their metabolizing ability. It was also found that 10–25% citronella oil derived from citronella might be doubled in its ability to repel Anopheles mosquitoes by adding 5% vanillin to it. At a concentration of 10% with 24-h exposure 100% of Anopheles dirusa and Culexquinque fasciatus and 97% of Aedes aegypti.

Greater protection is provided against A.aegypati by microencapsulated citronella oil-treated fabrics as compared to alcohol-treated citronella because microencapsulated citronella oil-treated fabrics is having an ability to repel mosquito for approximate 21 days whereas citronella oil show it's activity for approximate days of 5.[67]

Combination of citronella grass (Cymbopogon nardus) with other eight potential plants citronella grass (Cymbopogon nardus finger root (Boesenbergia pandurata), greater galangale (Alpiniaga langa), cardamom (Elettaria cardamomum), turmeric (Curcuma longa), Siamese cassia (Cassia siamea), neem (Azadirachta indica), eucalyptus (Eucalyptus citriodora), and siam weed (Eupatorium odoratum) and natural product show repelling property against 24 mosquit0es of Aedes, Anopheles, Armigeres, Culex and Monia genus.[68] Additionally, citronella's insect-repelling properties in conjunction with other binders like potato starch, neem powder, wood powder, cow dung, corn starch, and coconut shell powder showed that the combination of citronella leaf cake and neem powder produced the best results, burning for 21 minutes and leaving a 24.1% residual percentage.

e) Anti-parasitic: Citronella oil is highly effective against Ascardia galli is a parasite because this is responsible for inducing infection in livest0ck(boilers). This endo parasite hinders the growth and productivity of poultry. Moreover, it was also found that it produces a drastic loss followed by digestive disorders.

Citronella oil shows its effectivity by combining with ethanol extract and this combination was prepared by mixing an extract citronella oil extract with 0.25.0.5 and 1% distilled water 1ooml sol.[69]

f) Staple preservation: Citronella oil containing multiple number of chemical constituent like geraniol, myrcene, citral, eugenol, citronellol, citronellal which is having an ability reducing potato sprouts in storehouse and thus induce they undergo dormancy period of 6o days at a temperature of 10^{o} C.[70]

6. Industrial applications of citronella grass

Citronella grass is used as flavoring agent so due to this reason it’s leaves and stalks were used in tea to induce unique flavor moreover it is also for the preparation of food, drink, perfumery, soap, body and healthcare products and pharmaceutical products[71]. They are additionally also used for the treatment of orthopedics, muscular and skin problems. [72]

In Chinese medicine it’s leaves were used mainly for the treatment of rheumatism, fever, intestinal parasites, and digestive and menstrual problems. Moreover, they are also used as a diaphoretic, stimulant, and promoter of internal detoxification by encouraging sweating[73].

It is also used in the traditional medicine of Thailand as infusions which is used as blood tonic, diuretic and also used for flatulence, stomachaches, gastritis, intestinal cramps, irritable bowel syndrome, and indigestion along with analgesic pain.[74]

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