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Selective comparison of repellent activity with Contact toxicity of certain essential oils against different insect orders

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ABSTRACT

Elletaria cardamom, *Merremia vitifolia* and *Peperomia pellucida* Essential oils were tested against insects of 6 orders viz. Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera and Lepidoptera. And were found to be effective contact toxins. For the test, a slightly modified Impregnated paper assay was used in which Absolute lethal surface concentration and duration of the test was recorded. Based on this and other parameters the toxicity potential and insect strength were compared using new indices. It was found that *Merremia vitifolia* essential oil was the most powerful contact toxin. Among tested Insects, Coleoptera pests of stored products was the strongest followed by larvae of Lepidoptera. While Pyrrhocoridae family was the weakest one. The contact toxicity of *Peperomia pellucida* essential oil was slightly lower than that of the positive control, *Elletaria cardamom* essential oil. Comparing contact toxicity with the potential of chemical sensitivity using certain indices, it was found that there was a huge increase in the insecticidal potential of the essential oils, when used as a repellent.

Keywords: *Elletaria cardamom*, *Merremia vitifolia*, *Peperomia pellucida*, Absolute lethal concentration, Chemical sensitivity, Comparative Insecticidal activity.

INTRODUCTION

Insects, who coexist with the humans constitutes about 50% of all species on earth (Mora *et. al*., 2011). They are essential for a healthy and vibrant ecosystem. Not all insects are pests. Also, human activities that altered the natural ecosystem and certain species that successfully adapt often become pests. Coming to insect orders, Coleoptera is the largest order in the animal kingdom comprising nearly 25% of all insects (Stork *et al.*, 2015). Even though there are many helpful decomposers and Predatory species in the order Coleoptera, many others are regarded as major pests of agricultural plants and stored products. Diptera is one of the largest insect order which includes many familiar insects such as mosquitoes, midges, sand flies, house flies blowflies and robber flies. Some of them are pollinators, predators and decomposers, but many species of Diptera are ectoparasites of mammals and important due to the role they play in disease transmission. Order Hemiptera or true-bugs contains serious agricultural pests, predators of pests, bed bugs, and also species used for the production of the dyestuff cochineal and for shellac. Hymenoptera is the order which contains beneficial insects like the honey and wax producer, pollinators and insect predators, while some species are regarded as pests. Isoptera is the order of the important decomposers of the world and are occasional pests. And Lepidoptera is the order which contain some of the most beautiful creations of nature and silkworm. But the larvae of these insects are notorious pests of agricultural crops (Entomology Resources:NCSU (2017)). Insect pests are less than 1% of all insect species and the remaining 99% are more integral to the maintenance of the ecosystem. And the benefits of insects far outweigh the losses created by them (Pedigo and Rice, 2009).

There are many research articles which confirm the effectiveness of botanicals against insect pests. T. castaneum, S. granarius and S. oryzae are major pests of stored grains and its flour. Essential oil of T. terniflora showed a LC95(μg cm^{-2}) of 476.60 and 434.31μg cm^{-2} against T. castaneum and S. oryzae respectively. While essential oils of E. muticus and *C. citratus* possesed LC95 of 533.15 and 1158.29 against S. *oryzae* (Stefanazzi *et al.*, 2011). Even the direct application of neem leaf powder gave 100% mortality of S. granarius at certain experimental conditions (Bohinc and Trdan, 2017). And there are more than 28 major research papers, which proves the contact toxicity of botanicals against Callosobruchus spp alone (Kedia *et al.*, 2015). While 449.05 μg/adult of L. angustifolia essential oil gave 100% mortality against S. granaries (Germinara *et al.* 2017). But Diptera, B. cucurbitae is the pest of over 81 plant species, especially of the family Cucurbitaceae (Dhillon *et al.*, 2005). It was found that bark extracts from Acacia nilotica adversely affected the larval period and total developmental period of B. cucurbitae (Arti *et al*. 2015). At the same time, Ranganath *et al*. (2015) reported that neem soap is better than or equal to certain synthetic insecticides against B. cucurbitae by providing better/comparable yields. In case of Pyrrhocoridae family, some of its members are major pests of plants and grains. In another study on 28 essential oils, more than 42% gave 100% mortality and 75% gave 90 or more percent mortality against Hemiptera pests (Choi *et al.*, 2003). Pheidole, an ant genus is now the most species-diverse group of New World organisms after beetles (Zara and Fowler, 2005). Some Pheidole genus are minor pests. Baits with synthetic chemicals were popularly used for controlling Pheidole pests. Termites are occasional pests of wooden structures and agriculture. Regarding termicidal activity, Methanolic extract of J. curcas root, prosopis juliflora seed oil and 6 essential oils showed 100% mortality against Odontotermes obesus (Sharad *et al*., 2016), (Tura and Bezuneh, 2015), (Gupta *et al*., 2011). Botanical Fractions and compounds from cheaply available Punica granatum fruit rind also possessed respectable termicidal activity against Microcerotermes beesoni (Mishra *et al*., 2017). Anadevidia peponis F. is a serious Lepidopteran pest of snake gourd, while *Psara basalis* is a minor pest of Brinjal and Amaranthus. Essential oils are effective against lepidoptera pests of stored products (Ayvaz *et al*., 2010), vegetables (Dadang *et al*. 2009) and even trees (Badreddine *et al*. 2015). While Amoabeng *et al*., 2014 reported that the cost:benefit ratio of certain botanical insecticides were comparable to synthetic insecticides in cabbage.

Consistent and injudicious applications of pesticides lead to the development of resistance in insects, destruction of beneficial organisms and increases in residual problems, thereby posing a threat to human health and its ecological partners in the living biome.(Singh, 2014) Hence Pesticides are responsible for an estimated 200,000 acute poisoning deaths each year and destruction of the ecosystem. But this anti-life challenge of chemical pesticides has been exacerbated by a systematic denial fueled by the pesticide and agro-industry (UN General Assembly, 2017). Therefore, benefits of the synthetic pesticides has eclipsed by its risks. (Pedigo and Rice, 2009). On the contrary to chemical pesticides, the botanical pesticides have reduced toxicity to non-target organisms, reduced persistence in the environment, usable in organic agriculture, Low mammalian toxicity and Safe for farm workers and nearby residents (Seiber et al., 2014). Insecticides can be derived from leaf, bark and seed extracts of plants. Even the compost made out of plants can contribute to insect pest control (Singh, 2014). The ancient References to botanicals, which can be used for plant protection were found in Vedas, Sangam literature of Tamil, Krishiparashara, Brhat Samhita, Agnipurana, Vrikshayurveda etc., (Nene, 2003) and dates back to Rigvedic era(Matthews and Matthews, 2010).

It is well known that essential oil of many plants are effective pesticides. Insecticidal property of cardamom essential oil was made known through many published articles. Hence, this essential oil was considered as a positive control to compare other essential oils. Essential oil of *Elletaria cardamomum* (L.) Maton seeds showed contact toxicity with a LD95(µg/mg) value of 86 and 137 against the adults of S. zeamais and T. castaneum respectively. (Huang *et al*., 2000). Essential oil of *Peperomia pellucida* is well known for its medicinal and antimicrobial property(Wei *et al*. 2011). While essential oils of *E. cardamomum*, *P. pellucida* and *Merremia vitifolia* exhibited very strong insect repellent activity.(Aravind and Benny, 2018)

MATERIAL AND METHODS

2.1 Collection of plant materials and Essential oil extraction

Merremia vitifolia and *Peperomia pellucida* were collected from accessible barren uncultivated lands, and land near sacred groves(Kavu) in the Kottayam, Ernakulam and Pathanamthitta districts of Kerala. Dried *Elletaria cardamom* fruits were purchased from the market.

Fresh Buds with tender leafs and stem of *Merremia vitifolia* and fresh shoot of *Peperomia pellucida* were used for extraction. They were cut in to small pieces using knife or scissor. While *Elletaria cardamom* seeds were crushed with mortar and pistil. Essential oil was extracted by hydro-distillation using clevenger apparatus. 300gm of cut plant pieces or 100gm of crushed seed and 300ml of distilled water were added to 1000ml flat/round Bottom flask and distilled (Drew *et al*., 2012).

2.2 Insects

Anadevidia peponis larvae were collected from infested snake gourd plant and *Psara basalis* Larvae were collected from infested Amaranthus plant, Bactrocera cucurbitae larvae were collected from infested bitter-gourd, Adults of Pyrrhocoridae family were collected from infested seed-head of matured Sorghum plants, Adults of aulocophora lewisi were collected from Cucurbita maxima leaves. *Cetonia aurata* adults were collected from rose flowers. Workers of Pheidole genus, which had an average length of 3mm were collected from a piece of coconut shell with kernel placed near to the nest. While the workers of Odontotermes Genus with about 4mm length were collected from agricultural farm. All insect rearing/collecting plants were grown in the agricultural land or garden with-out any pesticide application.

Sitophilus granarius, *Sitophilus oryzae* and *Tribolium castaneum* were reared in the laboratory according to the procedure similar to that described by Aravind and Benny (2018). Details of the insects are shown in Table-1.

2.3 Contact Toxicity assay

For determining contact toxicity, a slightly modified Impregnated paper assay was used. The contact toxicity of essential oils was done in 9cm glass petridish.

Table 1: Insect details.

Order	Insect	Acronym used	Average Insect Weight(mg)
Coleoptera	*Aulocophora lewisi*	AL	14.01
	Sitophilus oryzae	SO	1.17
	Cetonia aurata	CA	103.33
	Tribolium castaneum	TC	1.89
	Sitophilus granarius	SG	1.35
Diptera	*Bactrocera cucurbitae* Larva	BCL	4.83
Hemiptera	*Pyrrhocoridae* family	PF	53
Hymenoptera	*Pheidole* genus	PG	0.65
Isoptera	*Odontotermes* Genus	OG	1.98
Lepidoptera	*Psara basalis* Larva	PBL	26.13
	Anadevidia peponis Larva	APL	81.51

Active Insects for each test were collected in a collecting vessel, just before the test. Where *Sitophilus granarius*, *Sitophilus oryzae* and *Tribolium castaneum* were collected in the Insect Collection Tube (IcT) (Aravind and Benny, 2018). While others are collected in petridishes. Five *Cetonia aurata* adults were used for each test. For all others, 10 insects/larvae were used for each test.

Essential oil was impregnated to a Circular grade 1 filter paper with 9cm diameter placed inside the petridish. Direct application of pure essential oil avoids the chances of losing highly volatile compounds during the drying of solvent. Therefore, pure essential oil was applied to different optimally spaced spots in the filter paper for uniform spreading of the oil. Spots very near to the edges were avoided. After applying, waited for 10 seconds, so that the essential oil spreads more evenly. Thereafter insects were gently added from the collecting vessel to the petridish and the lid was closed tightly and then the edge was sealed with transparent adhesive tape to prevent disturbances from diffusion of gases from inside and outside.

The assay was engineered to find the Absolute lethal concentration (LC 100) (IUPAC, 2014). To avoid the confusion with fumigant toxicity it was assumed that the toxicity is due to the direct contact of the insect with the essential oil impregnated in the filter paper only and all the applied oil spreads evenly in the filter paper. And therefore, surface concentration was used for mathematical analysis. Hence, Absolute lethal surface concentration was used instead of Absolute lethal concentration. The identification of exact absolute lethal surface concentration was done by screening a range. For that the methodology used was the same as described by Aravind and Benny (2018), but instead of repellent activity, mortality was analysed and with a different range of essential oil surface concentration. The maximum value of essential oil applied was limited to 150µl(2.359µl/cm^2) and the test duration was limited to be around 1hr in all possible tests. The insects were considered dead if they were immobile in strong white light and when tickled with a soft feather. The insect were visibly tested under strong white light after 30min, 45 min, 1 hr, 2hr, 3hr, 4hr, 6hr, 8hr, 10hr, 12hr, 16hr, 20hr and 24hr. If that test showed 100% mortality, petridish was opened and the insect were tickled with soft feather. If that also fails to give 100% mortality, that experiment was repeated with the next time interval(duration) or next higher dose of essential oil. All experiments with 100% mortality were repeated for three times to confirm the results.

$$Mortality(\%) = \frac{\text{Number of Dead Insects}}{\text{Total number of Insects used in the test}} \times 100$$

2.4 Repellent activity data

Repellent activity data for comparing with contact toxicity was taken from Aravind and Benny (2018).

2.5 Statistical analysis

LibreOffice (Writer, Calc, Math and Draw) was used for documentation, charts and statistical analysis. Because of the low duration of the tests, the mortality in the control is below 5%(Actually 0%). So percentage mortality is calculated directly without Abbott's corrected formula. Abbott's corrected formula will also give the same value as control mortality is 0 (WHO, 2013). The formula used to calculate percentage mortality is,

After finding the mortality, the mortality was made comparable by taking into account the time taken to get specific mortality. As time duration increases, the possibility of the insect to escape from the toxin increases in field condition. For that an Index called Mortality Index (Mi) was used, for that mortality, which is directly proportional and more important, but duration is inversely proportional. So it was calculated by dividing square of Percentage Mortality (M) by duration of the test in hour (D). so,

$$\mathbf{Mi = M*M/D}$$

Therefore, same mortality achieved at different period can be differentiated.

In order to differentiate the toxic potential of different essential oils, another index called Toxicity Index (Ti) was used, which incorporates the inverse proportionality of Absolute lethal surface concentration. That is, the essential oil that has the highest mortality with less dosage or concentration in the least possible time is considered as most powerful toxin. So Toxicity Index (Ti) is calculated by the division of Mortality Index (Mi) by Absolute lethal surface concentration (C). Therefore,

$$\mathbf{Ti = Mi/C = (M*M)/(D*C)}$$

Then finally different insects had to be compared for their anti-toxin strength. The strength of the insect is considered better if the insect with less weight has less mortality even at higher duration of toxin exposure at higher dosage or concentration. For that another Index called Insect strength Index (ISi) was used. Its inversely proportional to the Mortality (%), and average weight of the insect used for the test (W). And directly proportional to the duration of the test in hour (D) and Absolute lethal surface concentration (C). To make the result, a recognizable value, it is multiplied by 1000. Therefore,

$$\textbf{ISi} = ((D*C)/(M*W))*1000$$

For comparing potentials of contact toxicity and chemical sensitivity, identical indexes were used. To compare the potential of contact toxicity, Toxicity Index was used. To compare it with the potential repellent capacity, a similar index called Chemical Sensitivity (Surface) Index (CSUi) which consider surface concentration was used. To study the actual condition, that is spatial repellency, another index called Chemical Sensitivity (Spatial) Index (CSPi) was also used. If R is the repellent activity (%), D is the duration/time in hours for achieving the repellent activity. C_s and C_v are surface concentration and volume concentration respectively. Then the equations are,

$$\text{CSUi} = (R*R)/(D*C_s)$$

$$\text{CSPi} = (R*R)/(D*C_v)$$

Similarly for comparing the insect strength against the repellents, indexes similar to ISi were used. One with C_s and another with C_v, they were Anti-Chemical Sensitivity (Surface) Index (Anti-CSUi) and Anti-Chemical Sensitivity (Spatial) Index (Anti-CSPi). So,

$$\text{Anti-CSUi} = ((D*C_s)/(R*W))*1000$$

$$\text{Anti-CSPi} = ((D*C_v)/(R*W))*1000$$

The duration for getting repellent activity was assumed as 2min, the maximum time required for the test. Actually it was much below 2min. For calculating the volume, the minimum distance the insect reached during the test(repellent distance) in the test side was measured from the test end. For convenience 5cm was assumed as the repellent distance, But in many experimental or field situations it may be larger than 5cm.

3.1 Yield and Biochemical Composition of Essential oils

Yield and Biochemical Composition of the essential oils were the same and as reported in Aravind and Benny(2018).

3.2 Contact toxicity assay

The parameters recorded while evaluating 100% Contact Toxicity was Absolute lethal surface concentration (μl/cm^2) and the duration(in hours) to achieve the required result. The results are shown in Table 2 and Figure 1. Same Absolute lethal surface concentration(ALSC) for all the essential oils were obtained for Bactrocera cucurbitae Larva, Odontotermes Genus and Pheidole genus. *Sitophilus granarius* got the highest ALSC of *Merremia vitifolia* essential oil. Anadevidia peponis Larva, *Cetonia aurata* and *Tribolium castaneum* had the highest ALSC of *Elletaria cardamom* and Peperomia pellucida essential oil, while *Sitophilus granarius* also had the same highest ALSC for Peperomia pellucida essential oil. When Odontotermes Genus got the lowest ALSC, Lepidopteran insects and Coleopteran insects except Aulocophora lewisi possessed comparatively higher ALSC. Lepidopteran pests had the highest time duration with all essential oils. *Merremia vitifolia* essential oil has the lowest ALSC. Except for *Sitophilus granarius*, *Elletaria cardamom* and Peperomia pellucida essential oil has identical ALSC. While duration was generally different for various essential oils and insects.

3.3 Contact toxicity comparison

If two or more essential oils have the same ALSC doesn't always mean that the essential oils have equal potential. For getting a realistic comparison, the duration of the test had to be considered. Similarly average weight of the insect was also considered for comparing two or more insects. Odontotermes Genus which had the minimum ALSC in the test had the highest Toxicity index, so tested essential oils are more effective on Odontotermes Genus. But this is not the case with Pheidole genus which came second least ALSC is the fourth susceptible insect to MV essential oil. Due to the shorter duration of test, Aulocophora lewisi is equally susceptible to MV like the Odontotermes Genus. Where as, Anadevidia peponis Larva is the least susceptible species in the test.

RESULTS AND DISCUSSION

Table 2: Absolute lethal surface concentration and test Duration of essentials of *Elletaria cardamom*(EC), *Merremia vitifolia*(MV) and Peperomia pellucida(PP) against Insects.

Insect	*Absolute lethal surface concentration (µl/cm²)*			*Duration (Hour)*		
	EC	*MV*	*PP*	*EC*	*MV*	*PP*
Aulocophora lewisi	0.1573	0.0629	0.1573	1	0.5	1
Sitophilus oryzae	1.5727	0.4718	1.5727	16	1	20
Cetonia aurata	2.3590	0.7863	2.3590	5	0.5	24
Tribolium castaneum	2.3590	0.7863	2.3590	16	1	20
Sitophilus granarius	1.5727	0.9436	2.3590	16	0.75	20
Bactrocera cucurbitae Larva	0.1573	0.1573	0.1573	4	1	6
Pyrrhocoridae family	0.1573	0.1101	0.1573	2	0.5	2
Pheidole genus	0.0472	0.0472	0.0472	2	2	2
Odontotermes Genus	0.0315	0.0315	0.0315	2	1	2
Psara basalis Larva	0.6291	0.3145	0.6291	24	24	24
Anadevidia peponis Larva	2.3590	0.7077	2.3590	20	24	24

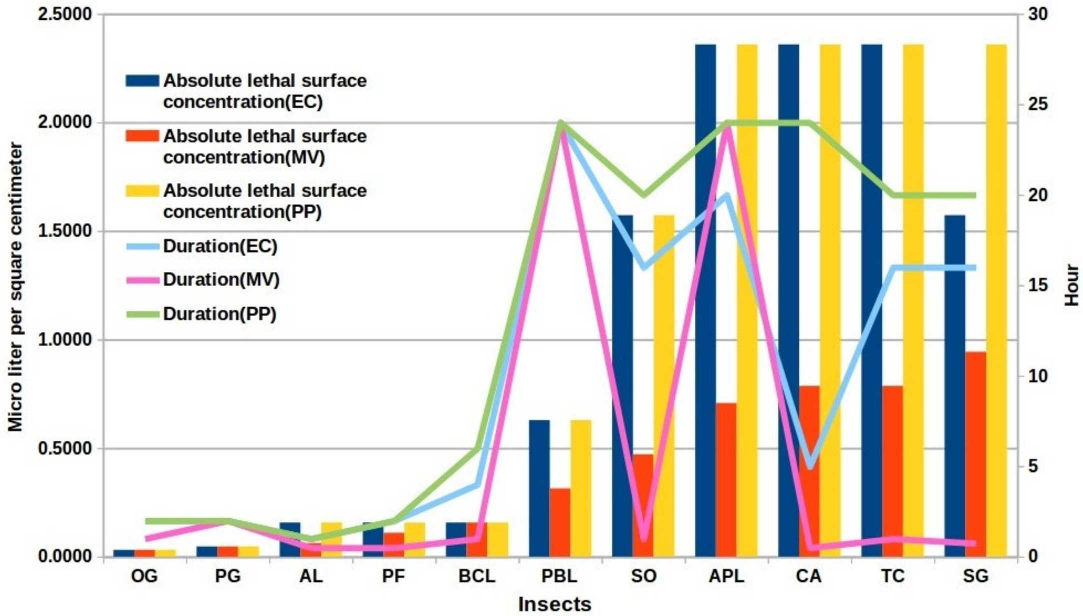

Figure 1: Absolute Lethal Surface Concentration and its duration against different Insects.

Higher toxicity index means higher potential of the essential oil or toxin. While higher Insect Strength Index shows the higher strength of the insect to withstand or escape the toxicity.

In the case of essential oils, MV was more than twice as effective as other essentials used in the test with toxicity indexes having an average of 96588.26. The PP essential oil was marginally less effective than the EC essential oil. *Cetonia aurata* was the heaviest insect and workers of Pheidole genus was the lightest insect used in the test. The difference between the average weight of the two differs by about 159 times (Table 1).

Table 3: Comparison of the toxic potential of essential oils and capacity or strength of insects.

Insect	*Toxicity Index (μl/cm²Hr)*			*Insect Strength Index (μlHr/mgcm²)*		
	EC	*MV*	*PP*	*EC*	*MV*	*PP*
Anadevidia peponis Larva	211.95	588.75	176.63	5.7884	2.0838	6.9460
Psara basalis Larva	662.34	1324.69	662.34	5.7780	2.8890	5.7780
Tribolium castaneum	264.94	12717.00	211.95	199.708	4.1606	249.635
Sitophilus granarius	397.41	14130.00	211.95	186.394	5.2423	349.488
Sitophilus oryzae	397.41	21195.00	317.93	215.070	4.0326	268.837
Cetonia aurata	847.80	25434.00	176.63	1.1415	0.0381	5.4793
Bactrocera cucurbitae Larva	15896.25	63585.00	10597.50	1.3024	0.3256	1.9537
Pheidole genus	105975.00	105975.00	105975.00	1.4517	1.4517	1.4517
Pyrrhocoridae family	31792.50	181671.43	31792.50	0.0593	0.0104	0.0593
Aulocophora lewisi	63585.00	317925.00	63585.00	0.1123	0.0225	0.1123
Odontotermes Genus	158962.50	317925.00	158962.50	0.3177	0.1589	0.3177
Average	34453.92	96588.26	33879.08			

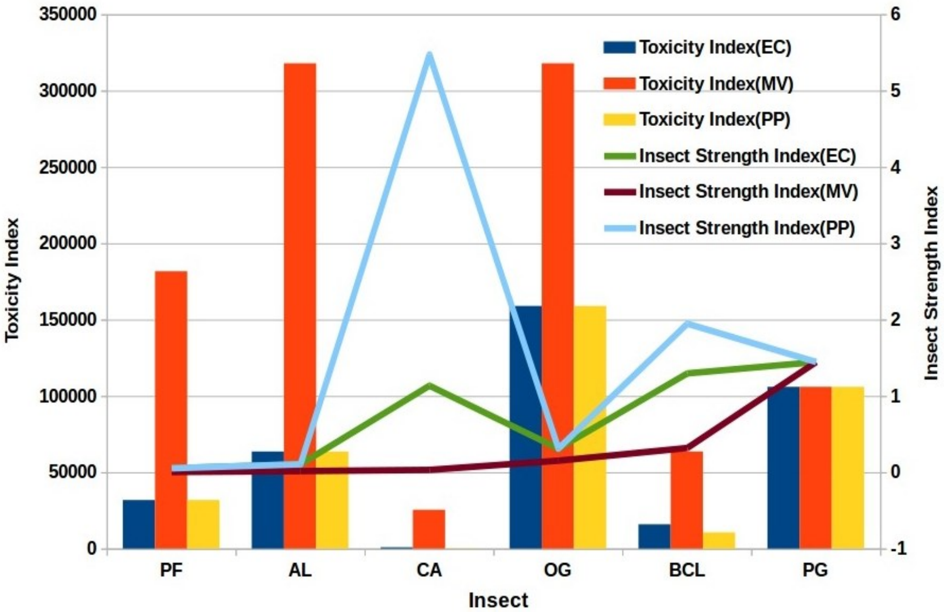

Figure 2: Toxicity Index and Insect Strength Index of weak insects.

Indexes that shows comparative strength of the insects like Insect Strength Index, Anti-Chemical Sensitivity (Surface) Index and Anti-Chemical Sensitivity (Spatial) Index shows whether the decrease in weight weaken the insect proportionately or not and vice versa. Coming to the strengths of the insects, stored pests of the order coleoptera occupy the top spots with *Sitophilus granarius* being the strongest. *Sitophilus granarius* was almost twice as strong than the Lepidopteran insects. Even though the Anadevidia peponis Larva was less susceptible than *Sitophilus granarius* against the most effective MV essential oil with with lesser ALSC and higher duration for achieving the result. But the *Sitophilus granarius* with less than 1/60 times the weight of Anadevidia peponis Larva possesses better strength. (Table 3, Figure 2 and Figure 3)

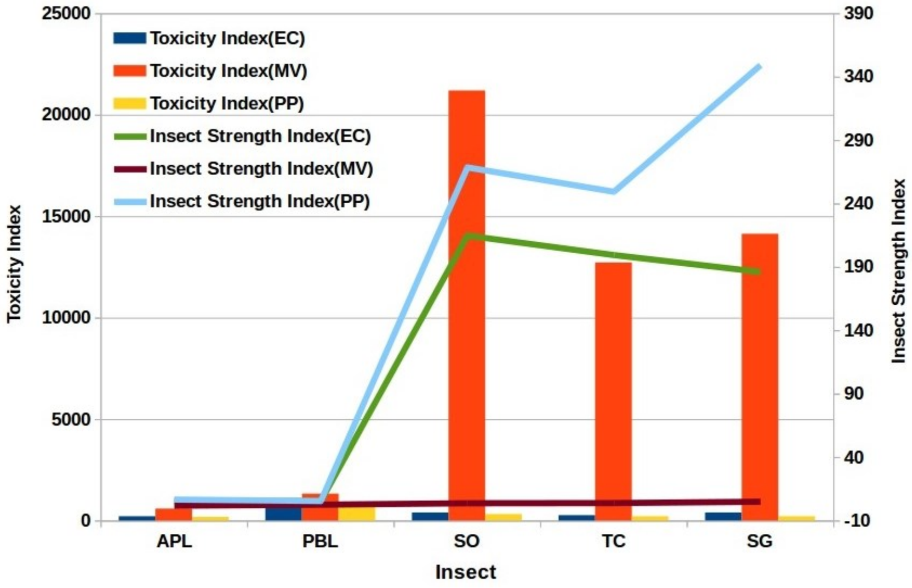

Figure 3: Toxicity Index and Insect Strength Index of strong insects.

Table 4: Comparison of Toxicity and Chemical Sensitivity potential of essential oils and the Insect strength against it.

Indices	*Pyrrhocoridae family*			*Sitophilus granarius*		
	EC	*MV*	*PP*	*EC*	*MV*	*PP*
Toxicity Index	31792.50	181671.43	31792.50	397.41	14130.00	211.95
Chemical Sensitivity (Surface) Index	759751.88	1519503.75	1519503.75	379875.94	1519503.75	759751.88
Chemical Sensitivity (Spatial) Index	3798759.38	7597518.75	7597518.75	1899379.69	7597518.75	3798759.38
Insect Strength Index	0.059347	0.010386	0.059347	186.394	5.242	349.488
Anti-Chemical Sensitivity (Surface) Index	0.002483	0.001242	0.001242	0.194995	0.048749	0.097498
Anti-Chemical Sensitivity (Spatial) Index	0.000497	0.000248	0.000248	0.038999	0.009750	0.019500

3.4 Comparing Toxicity with Chemical sensitivity

The aim of ideal anti-insect strategies might be to protect the entity to be safeguarded from insects with minimum damage to the environment. Hundred percent insect removal can be achieved with both 100% mortality and 100% repellent activity. In this scenario repellent activity achieve that feet with least essential oil and time. (Table 4).

Potential of the tested essential oils increased many folds when used as a repellent. Repellent (Surface) Index of EC essential oil increases 23 fold and Repellent (Spatial) Index increases by 119 times with respect to Toxicity Index against Pyrrhocoridae family. While that of PP essential oil increased over 47 and 238 times in the respective indices. Here the *Merremia vitifolia* essential oil has the least difference when compared with EC and PP essential oil. (Figure 4).

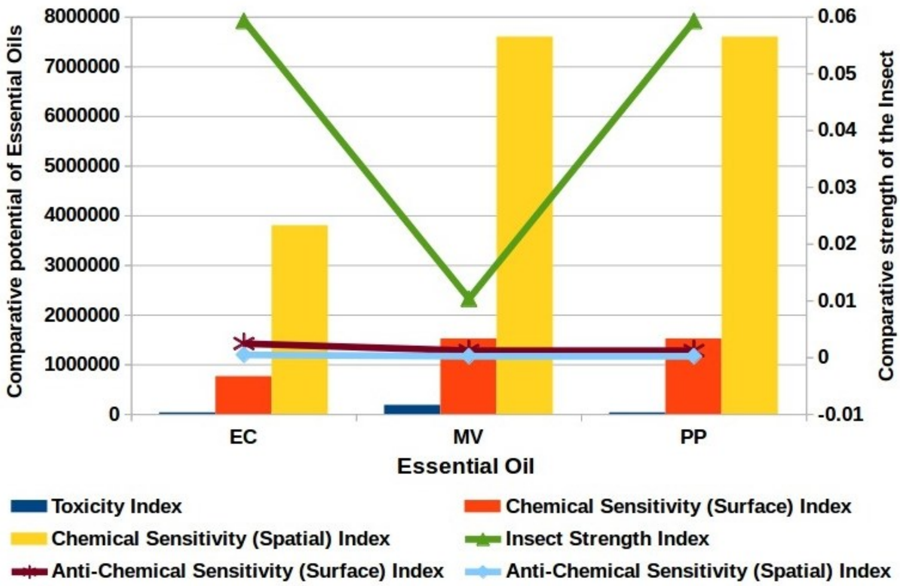

Fig. 4: Toxicity and Sensitivity potential of Essential oils against Pyrrhocoridae family.

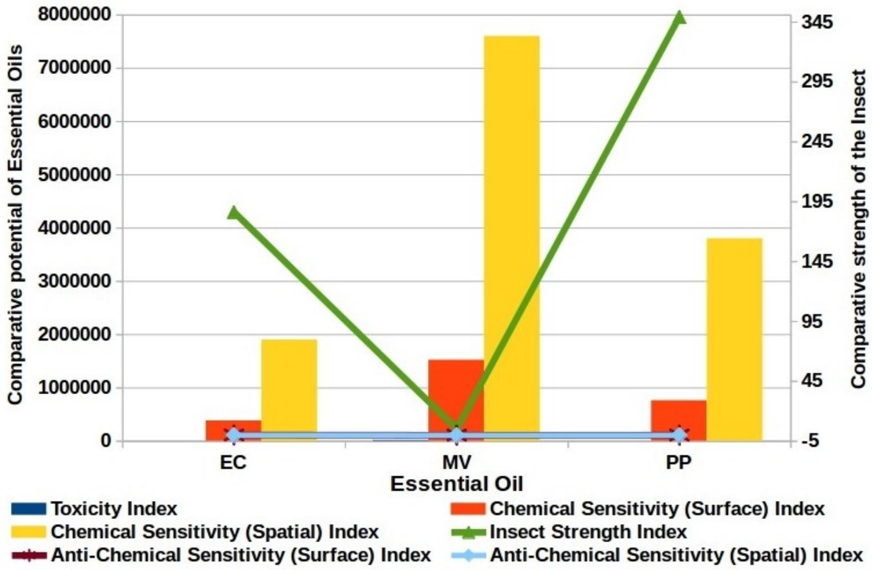

Figure 5: Toxicity and Sensitivity potential of Essential oils against *Sitophilus granarius*.

In the case of strong insect *Sitophilus granarius* the increase is huge for Peperomia pellucida and *Elletaria cardamom* essential oils than *Merremia vitifolia* essential oil. The Repellent (Surface) Index increased more than 955 times for EC essential oil, while for PP essential oil it was more than 3584 times than Toxicity Index. The Repellent (Spatial) Index was even higher. And it was 4779 and 17922 times for EC and PP essential oils. (Figure 5).

For both insects, PP essential oil had the highest differences between Repellent indices and Toxicity Index. In Toxicity index the potential of MV essential oil was nearly 5.7 times higher than that of other essential oils against Pyrrhocoridae family, whereas, that against *Sitophilus granarius* was nearly 35.55 times and 66.66 times of EC and PP essential oil respectively. But when it comes to Repellent Indices against *Sitophilus granarius*, the MV essential oil was only 4 and 2 times more powerful than EC and PP essential oils. At the same time, against Pyrrhocoridae family the difference was nearly half of that for *Sitophilus granarius*, that means PP essential oil equals the repellent potential of MV essential oil against Pyrrhocoridae family. So unlike toxicity potential, PP essential oil had better repellent potential than EC essential oil.

The toxic potential or Toxicity index differs by about 150 times for PP essential oil to nearly 12.86 times for MV essential oils between the weak insect Pyrrhocoridae family and the strong one *Sitophilus granarius*. Whereas, the repellent potential of MV essential oil was similar for both insects, while that of other essential oils only doubles against the weak insects.

Insect shows the maximum strength against contact toxins than repellents. The insect strength against surface repellent (Anti-Repellent (Surface) Index) was 5 times that of spatial repellent (Anti-Repellent (Spatial) Index) for all essential oils and insects. The Pyrrhocoridae family's strength against toxin (Insect Strength Index) was ranging from 41.8 times (MV essential oil) to 238.9 times (PP essential oil) of spatial repellent (Anti-Repellent(Spatial) Index). In the case of *Sitophilus granarius* that ranges from 537.7 times to 17922.9 times.

The Insect strength against MV essential oil was minimum in all cases. So, in this test, MV essential oil is the best toxin and the repellent. And the repellent activity was superior and had very high potential than contact toxicity.

CONCLUSION

The failure reports of synthetic insecticides in the form of insect resistance, surfaces within a few years of its introduction. And an example of this is neonicotinoid insecticide (Bass et al., 2015). Even the genetically modified crop plants also fail to fulfill the required goals, as it needs synthetic pesticides (Coupe and Capel, 2016) and also need the service of natural enemy to delay the resistance of pests against genetically modified crops (Liu, 2014). Its inefficiency couped with its catastrophic effects on environment and human health, these commercialized unnatural methods of pest control cause more problems than benefits. Reliance on hazardous pesticides is a short-term solution that undermines the rights to quality food and health for present and future generations (UN General Assembly, 2017). Being a natural product, botanical pesticides acts as a viable and safe substitution to a great extent.

The results here show that the botanical insecticides are toxic to all the tested insect orders. In that MV essential oil was the most effective contact toxin and repellent. While EC essential oil was a slightly better contact toxin than PP essential oil. But the repellent activity potential of PP essential oil was much better than EC essential oil. It seems that a repellent, especially a spacial repellent is the most eco-friendly alternative to safe guard the natural predators, non-target insects and especially the weak beneficial insects. Even crude extracts of potential plant parts can become helpful insect repellent and/or toxin especially in preinfestation period. Botanicals together with the natural responses to check pest population like natural predator population and host plant adaptability has to be further explored.

The study shows the comparative potential of essential oils, comparative strength of insects of different orders and comparison of contact toxicity and chemical sensitivity. The study and its methodologies paves the way for further research in these fields and also for comparing photo sensitivity having a measurable luminescence per square cm with contact toxicity and chemical sensitivity.

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