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Bioefficacy of *Chromolaena odorata* against *Oligonychus coffeae* Nietner (Acarina: Tetranychidae) and *Helopeltis theivora* Waterhouse (Hemiptera: Miridae) in tea

Priyanka Borbaruah and Surajit Kalita

Abstract
Laboratory experiments were conducted at Department of Entomology, Assam Agricultural University, Jorhat during 2016-18 to evaluate the bioefficacy of different solvent extracts of *Chromolaena odorata* (L.) King & Robinson (Family: Asteraceae) against *Oligonychus coffeae* Nietner (Acarina: Tetranychidae) and *Helopeltis theivora* Waterhouse (Hemiptera: Miridae) of tea by taking Neem seed kernel extract (NSKE) 0.15% EC, fenpyroximate 5 EC and deltamethrin 2.8 EC as check for comparison. The results revealed that the methanolic leaf extract of *C. odorata* was found to be superior recording 100.0% adult mortality of *H. theivora* at 48 hours after treatment (HAT) as compared to petroleum ether and water extract recording 86.67% and 33.33% adult mortality, respectively. Likewise, application of methanolic leaf extract of *C. odorata* was also found to be the most effectual recording the highest of 98.33% adult mortality of *O. coffeae*, as against 58.33% and 25.00% mortality in case of petroleum ether and water extract, respectively. The bioefficacy of methanolic leaf extract of *C. odorata* is comparable and *at par* with the toxicity of deltamethrin 2.8 EC @ 1ml/Land Fenpyroximate 5 EC@1ml/L recording 100.0% adult mortality of the both the insects at 48 HAT. The order of toxicity of different solvent extracts of *C. odorata* with respect to LC_{50} values against *H. theivora* and *O. coffeae* was found to be methanol (0.056% and 0.603%) >petroleum ether (1.481% and 4.593%) >water (22.995% and 330.093%).

Keywords: Bioefficacy, *Chromolaena odorata*, *Oligonychus coffeae*, *Helopeltis theivora*, LC_{50}

Introduction
Tea, *Camellia sinensis* (L.) O. Kuntze (Family: Theaceae; Tribe: Gordonaceae) is a commercial evergreen perennial crop [23] covering 566.66 thousand hectares of area with annual production of 1239.15 million kilogram and productivity 2186.76 kg/ha in India [21]. Insect and mite pests (arthropods) are the most damaging factors with about 5% to 55% yield loss in tea [13]. Amongst the biotic pest complex, mirids are the major insect pests of tea in Asian countries causing about 11 to 100% crop loss [13]. Both nymphs and adults of tea mosquito bug (TMB), *Helopeltis theivora* Waterhouse (Hemiptera: Miridae) suck the cell sap of the young leaves, buds and tender stems, as a result discoloured necrotic area formed around the point of entry of the labial style [10]. Other than mirids, mites are also the most serious and persistent pests of tea resulting a crop losses ranging from 17% to 46% in almost all tea producing countries including India, of which the red spider mite (RSM), *Oligonychus coffeae* Nietner (Acarina: Tetranychidae) is the most widely distributed and devastating one in tea. Infestation of RSM in tea often creates minute reddish brown marks on the upper surface of mature leaves develops, which in turn seriously affects the plant growth and leaf productivity [17].
To defend the tea crop from the attack of these pests, chemical pesticides, more particularly organ synthetics are found to be the most extensively used ones, which resulted in several ill effects including resurgence of primary pests, secondary pest outbreak, resistance development, and environmental contamination, including undesirable residues on made tea in recent pasts [13, 19]. In this context, botanicals are proved to be an important and suitable alternative to synthetic pesticides since they possess toxic, repellency, deterrency, antifeedant and growth regulatory properties.

In recent years, several bioeffeicacy tests of *Chromolaena odorata* (L.) King & Robinson (Family: Asteraceae) leaf extract revealed insecticidal properties against several major agriculturally important insect pests including rice hispa, *Dicladispa armigera* (Chrysomelidae: Coleoptera) causing 77.5% adult mortality aft 48 hours after treatment [14]. The LC_{50} value of *C. odorata* leaf extract against 4th instar of *Aedes aegypti* was reported to be as low as 101.49 ppm [18]. Sukhthankar *et al*. (2014) [20] have also reported lower LC_{50} values of 43 ppm, 138 ppm and 1613 ppm against *Culex quinquefasciatus*, *Aedes aegypti* and *Anopheles stephensi*, respectively. Keeping in view all these facts in mind, the present investigation was considered to evaluate the bioefficacy of *C. odorata* leaf extracts against two most serious pests of tea *viz*., *Helopeltis theivora* and *Oligonychus coffeae*.

Materials and Methods

Collection and preparation of leaf extracts

Matured leaves of *C. odorata* were collected from their natural habitats from Borbheta and Lichubari areas of Jorhat district (26.746^{0} N latitude and 94.2026 ^{0}E longitudes) of Assam during September- October, 2017. The leaves were shade-dried, powdered using electric grinder and extracted separately with methanol and petroleum ether using Soxhlet extraction apparatus (Make: Labotech, Model No.B.O.I.78) as described by Bora *et al*. (1999) [5]. Each extract was dried with rotary vacuum evaporator (Make: JSGW, Model No. DOA-VI30-BN) and dissolved in acetone by w/v basis to make 100% stock solution and stored in an air tight sealed glass bottle at 4ºC in refrigerator. Similarly, the aqueous extract was prepared by grinding the fresh leaves of *C. odorata* using double distilled water with an electric grinder in weight by volume (w/v) basis. The grounded leaf paste was sieved using muslin cloth, squeezed further to extract all its content and kept in sealed air tight glass bottle, which were further diluted with water following serial dilution method to obtain desired concentration *viz.,* 10.00%, 5.00%, 1.00%, 0.50%, 0.10%, 0.05% for subsequent use in the different experiments.

Maintenance of test insect culture

Adults of *O. coffeae* and *H. theivora* were collected from the Experimental Garden for Plantation Crops (EGPC), Assam Agricultural University, Jorhat and were cultured on detached leaf technique proposed by Das *et al.* (2012) [9] and Das *et al*. (2017) [8] in the Physiology Laboratory, Department of Entomology, Assam Agricultural University, Jorhat.

Bioassay against test insect

From the stock culture of *O. coffeae*, twenty numbers of one-day-old adults were allowed to settle for 24 hours on a TV1 clone leaf disc of 2.5 cm^2 and sprayed with plant extracts at different desired concentrations by hand atomizer (Make: Axiva, Capacity: 50 ml). In case of *H. theivora*, three numbers of freshly detached shoots of TV1 clone with three leaves and a bud were wrapped with absorbent cotton and placed in a glass vial (Make: Borosil, Size: 3.5 cm diameter, 7 cm length) and partially filled with sterilized double distilled water to keep the shoots afresh. On each of tea shoots composite placed on glass vial, five newly emerged adults were released, caged with hurricane lantern glass chimney and sprayed with plant extracts at different concentrations with the help of hand atomizer**.** The top of the glass chimney were covered with muslin cloth to nullify any escape of the insect. Each treatment was replicated for three times and the data on adult mortality were recorded at 6, 12, 24 and 48 HAT, which were again converted to the per cent mortality. Moreover, as per the plant protection code of tea, Neem seed kernel extract (NSKE) 0.15% EC, fenpyroximate 5 EC and deltamethrin 2.8 EC were selected for comparison to the bioefficacy of *C. odorata* at the recommended rates along with a control.

Statistical analysis

The data on laboratory experiments are subjected to Completely Randomized Design (CRD) and differences on mortality rate of both the insect were studied using analysis of variance (ANOVA) after suitable conversion to angular transformation of the per cent mortality values. The data on mortality were subjected Abbot’s correction (Abbot, 1925) before angular transformation, whenever mortality in the control is obtained. Corrected percent mortality was calculated using Abbott’s formula as mentioned below.

$$\text{Corrected mortality (\%)} = [(S - K)/(100 - K)] \times 100$$

Where

S: Percent mortality in the treated group

K: Percent mortality of the control group

Further, data on per cent mortality were subjected to probit analysis for calculation of LC_{50} values by using SPSS computer software package (ver. 12.0).

Result and Discussion

Chromolaena odorata has been tested most extensively against mosquitoes [4, 18, 20] and revealed presence of phytochemicals like alkaloids, Cyanogenic glycosides, flavonoids (Aurone, Chalcone, flavone and Flavonol), Phytate saponins and tannins that could bring the bioefficacy against several insect pests. Table1 represents the data on effect of different solvent extracts of *C. odorata* against *H. theivora* and the data revealed that amongst the solvent extracts, methanolic leaf extract was the most effective one recording the highest of 100.00% adult mortality of *H. theivora* upto 0.50% concentration after 48 hours of treatment as compared to the lowest of 26.67% mortality at 0.05% concentration after 6 hours of treatment. The mortality of *H. theivora* was found increased with an increase in concentration and exposure time. While comparing the results with standard check, it was found that deltamethrin 2.8 EC @ 1ml/L, the recommended insecticide under plant protection code for tea caused 100.00% mortality of *H. theivora*, which was found to be at par with bioefficacy of methanolic leaf extract of *C. odorata* (100.00% mortality) at 0.50% concentration at 48 HAT. Application of NSKE 0.15% EC @ 5 ml/L recorded as high as 60.00% mortality at 24 and 48HAT, which is at par with the methanolic leaf extract of *C. odorata* at 0.10% concentration recording 66.67% and 73.33% adult mortality, respectively. Next to methanolic leaf extract, petroleum ether leaf extract of *C. odorata* was found to generate the highest mortality of *H. theivora* (93.33%) after 48 HAT at 10.00% concentration, while water extract of *C. odorata* recorded only 33.33% adult mortality of *H. theivora* after 48 HAT at 10.00% concentration revealing negligible efficacy against *H. theivora*. The insecticidal properties of *C. odorata* was also earlier reported by Ezena *et al*. (2016) [12], Agaba and Fawole (2016) [3], Lawal *et al.* (2015) [15], Udebuani *et al*. (2015) [22], Zoubiri *et al.* (2014) [24], Chakraborty *et al.* (2011) [7], Bouda *et al*. (2001) [6] which corroborates our present investigation.

Table 2 represents the data on different solvent extracts of *C. odorata* against *O. coffeae* and a time-and dose-dependent mortality was recorded. Lawal *et al.* (2015) [15] also reported a dose and time dependent mortality of *Sitophillus zeamais* on application of methanolic extract of *C. odorata.* Amongst the solvent extracts, methanolic leaf extract was the most effective one recording the highest of 98.33% mortality of adult *O. coffeae* at 10.00% concentration after48hours of treatment, followed by 86.67%, 55.00%, 43.33%, 20.00% and 8.33% mortality with a concentration of 5.00%, 1.00%, 0.50%, 0.10% and 0.05%, respectively as against 96.67%, 85.00%, 51.67%, 41.67%, 18.33% and 8.33% mortality at 6 HAT, respectively. Amongst the standard checks, NSKE 0.15% EC @ 5ml/L caused the highest of 91.67% adult RSM mortality, which was at par with 10.00% and 5.00% concentration of methanolic leaf of *C. odorata* recording 98.33% and 86.67% mortality, respectively at 48 HAT. While, fenpyroximate 5 EC @ 1ml/L, the recommended acarcide under plant protection code of tea recorded 100.00% adult RSM mortality, which was at par with the treatment with 10.00% concentration of methanolic leaf extract of *C. odorata* causing 98.33% adult mortality at 48 HAT. While petroleum ether and water extract of *C. odorata* were found to be having lower acaricidal properties as compared to methanolic leaf extract and found causing 58.33% and 25.00% mortality, respectively at 10.00% concentration and 48 HAT. In terms of bioefficacy, petroleum ether and water extract of *C. odorata* were found to be recording the least adult mortality and were not at all comparable with the standard checks. Devi *et al.* (2013) [11] found a lower mortality of *O. coffeae* by the water extract of *C. odorata* which corroborates our results.

LC_{50} value of botanical extracts

The order of toxicity with respect to LC_{50} was found to be *C. odorata* (methanol)>*C. odorata* (petroleum ether)>*C. odorata* (water). The LC_{50} values of *C. odorata* (methanol), *C. odorata* (petroleum ether) and *C. odorata* (water) against TMB were found to be 0.056%, 1.481% and 22.995% respectively at 48 HAT (Table 3). Similar kinds of results were also reported by Sukhthankar *et al.* (2014) [20] while testing *C. odorata* against *Aedes aegypti*. The LC_{50} values of *C. odorata* leaf extracts against RSM were found to be 0.603%, 4.593% and 330.093%, respectively at 48 HAT (Table3) which is in close conformity with results of Rajmohan and Logankumar (2011) [18], who also reported similar results against *Aedes aegypti.*

During the course of investigation, the leaves of *C. odorata* were found to bear insecticidal properties, which might because of presence of alkaloids [16] and flavonoids effecting body functioning [2]. The leaves of *C. odorata* were also reported to be rich in triglycerides, which were known for the growth inhibitory nature in animals. Our efforts in screening of some green chemicals or botanicals, could pave a way towards development of an ecologically sound integrated pest management strategy for successful control of will invertebrate limiting factors of tea ecosystem.

Table 1: Effect of *C. odorata* leaf extracts on adult mortality of *H. theivora*

Treatments	Conc. (%)/ dose (ml/L)	***C. odorata*(methanol)**				***C. odorata*(p. ether)**				***C. odorata*(water)**			
		6 HAT	**12 HAT**	**24 HAT**	**48 HAT**	**6 HAT**	**12 HAT**	**24 HAT**	**48 HAT**	**6 HAT**	**12 HAT**	**24 HAT**	**48 HAT**
C. odorata	10.00	100.00±0.00 (98.75)	100.00±0.00 (98.75)	100±0.00 (98.75)	100.00±0.00 (98.75)	86.67±6.67 (75.20)	86.67±6.67 (75.20)	86.67±6.67 (75.20)	93.33±6.67 (86.98)	26.67±6.67 (30.79)	26.67±6.67 (30.79)	26.67±6.67 (30.79)	33.33±6.67 (35.01)
C. odorata	5.00	100.00±0.00 (98.75)	100.00±0.00 (98.75)	100±0.00 (98.75)	100.00±0.00 (98.75)	53.33±13.33 (47.30)	53.33±13.33 (47.30)	53.33±13.33 (47.30)	60.00±11.55 (51.14)	20.00±0.00 (26.57)	20.00±0.00 (26.57)	20.00±0.00 (26.57)	26.67±6.67 (30.79)
C. odorata	1.00	100.00±0.00 (98.75)	100.00±0.00 (98.75)	100±0.00 (98.75)	100.00±0.00 (98.75)	46.67±6.67 (43.08)	46.67±6.67 (43.08)	46.67±6.67 (43.08)	46.67±6.67 (43.08)	13.33±6.67 (18.13)	13.33±6.67 (18.13)	13.33±6.67 (18.13)	20.00±0.00 (26.57)
C. odorata	0.50	100.00±0.00 (98.75)	100.00±0.00 (98.75)	100±0.00 (98.75)	100.00±0.00 (98.75)	20.00±0.00 (26.57)	20.00±0.00 (26.57)	20.00±0.00 (26.57)	20.00±0.00 (26.57)	0 (1.25)	0 (1.25)	0 (1.25)	6.67±6.67 (9.69)
C. odorata	0.10	66.67±6.67 (54.99)	66.67±6.67 (54.99)	66.67±6.67 (54.99)	73.33±6.67 (59.21)	13.33±6.67 (18.13)	13.33±6.67 (18.13)	13.33±6.67 (18.13)	13.33±6.67 (18.13)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)
C. odorata	0.05	26.67±6.67 (30.79)	26.67±6.67 (30.79)	46.67±6.67 (43.08)	46.67±6.67 (43.08)	6.67±6.67 (9.69)	6.67±6.67 (9.69)	6.67±6.67 (9.69)	6.67±6.67 (9.69)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)
NSKE 0.15% EC	5ml/L	46.67±6.67 (43.08)	53.33±6.67 (46.92)	60.00±0.00 (50.77)	60.00±0.00 (50.77)	46.67±6.67 (43.08)	56.33±6.67 (48.64)	60.00±0.00 (50.77)	63.33±6.67 (52.73)	46.67±6.67 (43.08)	53.33±6.67 (46.92)	62.33±6.67 (52.14)	62.33±6.67 (52.14)
Deltamethrin 2.8 EC	1ml/L	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)
Control	-	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)
S.Ed. (±)	-	3.35**	3.35**	2.69**	2.69**	9.14**	9.14**	8.96**	8.75**	4.80**	4.80**	4.45**	4.87**
C.D. $_{p=0.05}$	-	5.80	5.80	4.65	4.65	15.81	15.81	15.50	15.14	8.30	8.30	7.70	8.43
C.D. $_{p=0.01}$	-	8.54	8.54	6.86	6.86	23.31	23.31	22.85	22.31	12.24	12.24	11.35	12.42

Data represented are the mean of three replications with 5 samples each *- Significant at p=0.05, **- Significant at p=0.01, NS-Non-significant
Data with mortality in the control are corrected with Abbot's formula Mean within parentheses are the angular transformed values
HAT- Hours after treatment

Table 2: Effect of *C. odorata* leaf extracts on adult mortality of *O. coffeae*

Treatments	Conc. (%)/Dose (ml/L)	*C. odorata*(Methanol)				*C. odorata*(Petroleum ether)				*C. odorata*(Water)			
		6 HAT	12 HAT	24 HAT	48 HAT	6 HAT	12 HAT	24 HAT	48 HAT	6 HAT	12 HAT	24 HAT	48 HAT
C. odorata	10.00	96.67±1.67 (84.30)	98.33±1.67 (91.53)	98.33±1.67 (91.53)	98.33±1.67 (91.53)	50.00±5.77 (45.00)	56.67±8.82 (48.93)	56.67±8.82 (48.93)	58.33±7.27 (49.90)	5.00±2.89 (10.87)	15.00±0.00 (22.79)	21.67±1.67 (27.71)	25.00±0.00 (30.00)
C. odorata	5.00	85.00±5.77 (68.10)	85.00±5.77 (68.10)	85.00±5.77 (68.10)	86.67±4.41 (69.24)	46.67±6.01 (43.05)	48.33±6.67 (44.00)	48.33±6.67 (44.00)	48.33±6.67 (44.00)	3.33±1.67 (9.03)	11.67±1.67 (19.89)	13.33±1.67 (21.34)	15.00±2.89 (22.60)
C. odorata	1.00	51.67±1.67 (45.96)	51.67±1.67 (45.96)	53.33±3.33 (46.92)	55.00±2.89 (47.88)	38.33±6.01 (38.16)	38.33±6.01 (38.16)	40.00±5.77 (39.15)	41.67±4.41 (40.17)	1.67±1.67 (5.14)	6.67±1.67 (14.76)	6.67±1.67 (14.76)	10.00±0.00 (18.43)
C. odorata	0.50	41.67±1.67 (40.20)	41.67±1.67 (40.20)	43.33±1.67 (41.16)	43.33±1.67 (41.16)	21.67±1.67 (27.71)	21.67±1.67 (27.71)	23.33±1.67 (28.86)	23.33±1.67 (28.86)	0 (1.25)	3.33±1.67 (9.03)	5.00±2.89 (10.87	8.33±1.67 (16.60
C. odorata	0.10	18.33±1.67 (25.31)	18.33±1.67 (25.31)	20.00±0.00 (26.57)	20.00±0.00 (26.57)	13.33±3.33 (21.14)	15.00±2.89 (22.60)	18.33±3.33 (25.19)	18.33±3.33 (25.19)	0 (1.25)	1.67±1.67 (5.14)	3.33±1.67 (9.03)	3.33±1.67 (9.03)
C. odorata	0.05	8.33±2.89 (16.59)	8.33±2.89 (16.59)	8.33±1.67 (16.59)	8.33±1.67 (16.59)	8.33±1.67 (16.60)	11.67±1.67 (19.89)	11.67±1.67 (19.89)	11.67±1.67 (19.89)	0 (1.25)	0 (1.25)	1.67±1.67 (5.14)	3.33±1.67 (9.03)
NSKE0. 15% EC	5ml/L	73.33±1.67 (58.93)	76.67±1.67 (61.14)	85.00±2.89 (67.40)	91.67±1.67 (73.41)	73.33±1.67 (58.93)	76.00±0.00 (60.67)	86.00±2.89 (68.02)	91.67±1.67 (73.41)	71.33±1.67 (57.63)	76.67±1.67 (61.14)	85.00±2.89 (67.40)	92.67±1.67 (74.29)
Fenpyroximate 5EC	1ml/L	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)	100±0.00 (98.75)
Control	-	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)	0 (1.25)
S.Ed. (±)		4.34**	4.34**	4.48**	4.20**	3.30**	5.15**	5.86**	4.83**	3.56**	2.87**	3.89**	3.08**
C.D. $_{p=0.05}$		7.51	7.51	8.37	7.27	5.71	8.90	10.14	8.36	6.16	4.97	6.72	5.33
C.D. $_{p=0.01}$		11.07	11.07	11.42	10.71	8.42	13.13	14.94	12.32	9.08	7.32	9.92	7.85

Data represented are the mean of three replications with 20 samples each *- Significant at p=0.05, **- Significant at p=0.01, NS-Non-significant
Data with mortality in the control are corrected with Abbot's formula Mean within parentheses are the angular transformed values
HAT- Hours after treatment

Table 3: LC_{50} values of *C. odorataleaf* extracts after 48 hours of treatment

Treatment	Regression Equation	Standard error of Regression coefficient	Heterogeneity χ^2	LC_{50} (%)	95% Fiducial Limits		Order of toxicity
					Lower bound	Upper bound	
Oligonychus coffeae							
C. odorata (methanol)	Y=0.283+1.287 X	0.050	38.867	0.603	0.487	0.745	I
C. odorata (petroleum ether)	Y=-0.386+0.583 X	0.040	47.756	4.593	2.706	9.609	II
C. odorata (water)	Y=-1.265+0.502 X	0.054	20.316	330.093	122.468	1460.604	III
Helopeltis theivora							
C. odorata (methanol)	Y=3.483+2.799 X	0.249	28.236	0.056	0.047	0.063	I
C. odorata (petroleum ether)	Y=-0.188+1.105 X	0.047	222.927	1.481	0.835	2.899	II
C. odorata (water)	Y=-1.206+0.886 X	0.063	98.229	22.995	10.428	107.497	III

Y=Probit kill, X= log dose
Mortality based on 3 replications each with 20 individuals

Conclusion
Eco-friendly pest management practices using botanicals are always found to be an alternative to overcome the ill affects of synthetic chemical pesticides especially pesticide residues in tea. Thus, present investigation exploring bioefficacy of *C. odorata* against *H. theivora* and *O. coffeae* paved a path in their possible use in eco-friendly IPM programme with minimal pesticide residues in made tea.

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References
1. Abbott WS. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology. 1925; 18:265-267.
2. Acero LH. Dried Siam weed (*Chromolaena odorata*) as rice weevils (*Sitophilus oryzae*) eradicant. International Journal Chemical Engeneering Application. 2014; 5:363-366.
3. Agaba TA, Fawole B. Phytochemicals constituents of Siam weed and African custard apple. International Journal of Food, Agriculture and Veterinary Sciences. 2016; 6(1):35-42.
4. Ahiati J. A study of the insecticidal effects of *Chromolaena odorata* oil extracts on the larvae and adults of mosquitoes (Family: Culicidae). Online available, 2004. http://esa.confex.com/esa/2004/techprogram/paper_14489.htm.
5. Bora HR, Hazarika LK, Dutta N. Botanicals for forest and tea pest management. In: Green Pesticides Crop Production and Safety Evaluation. Agnihotri, NP; Waliga S. and Sajbhiye, (Eds.).V.T. Society of Pesticides Science, India, 1999.
6. Bouda H, Tapondjou AL, Fontem DA, Gumedzoe MYD. Effect of essential oils from leaves of Ageratum conyzoides, Lantana camara and Chromolaena odorata on the mortality of Sitophilu szeamais (Coleoptera: Curculionidae). Journal of Stored Products Research. 2001; 37(2):103-109.
7. Chakraborty AK, Rambhade S, Patil UK. *Chromolaena odorata* (L.): An overview. Journal of Pharmacy Research. 2011; 4(3):573-576.
8. Das P, Saikia S, Kalita S, Hazarika LK. Tea clonal preference by *Helopeltis theivora* (Hemiptera: Miridae). Journal of Entomology and Zoology Studies. 2017; 5(6):97-103.
9. Das P, Saikia S, Kalita S, Hazarika LK, Dutta SK. Effect of temperature on biology of red spider mite (*Oligonychus coffeae*) on three different TV clones. Indian Journal of Agricultural Science. 2012; 82(3):255-259.
10. Devasahayaman S, Nair CPR. The tea mosquito bug (*Helopeltis antonii* Signoret) on cashew in India. Journal of Plantation Crops. 1986; 14(1):1-10.
11. Devi OI, Dutta BK, Choudhury P. Control of red spider mite (*Oligonychus coffeae* Nietner) in tea plantation of Barak valley (Southern Assam) using allelopathic plant extracts. International Journal of Tea Science. 2013; 9(4):25-30.
12. Ezena GN, Akotsen-Mensah C, Fening KO. Exploiting the insecticidal potential of the invasive Siam weed, *Chromolaena odorata* L. (Asteraceae) in the management of the major pests of cabbage and their natural enemies in southern Ghana. Advanced Crop Science Technology. 2016; 4:230.
13. Hazarika LK, Bhuyan M, Hazarika BN. Insect pest of tea and their management. Annual Review of Entomology. 2009; 54:267-284.
14. Kalita S, Hazarika LK, Das P. Bio-efficacy and field test of *Chromolaena odorata* extract alone and with *Beauveria bassiana* against rice Hispa. *Dicladispa armigera*. Annals of Plant Protection Science. 2016; 24(2):295-299.
15. Lawal OA, Opoku AR, Ogunwande IA. Phytoconstituents and insecticidal activity of different solvent leaf extracts of *Chromolaena odorata* L. against *Sitophilus zeamais* (Coleoptera: Curculionidae). European Journal of Medicinal Plant. 2015; 5(3):237-247.
16. Man NC. Phytochemical analysis of leaves of *Chromolaena odorata*. International Journal of Scientific & Research Publication. 2013; 3:1-2.
17. Mukhopadhyay A, Gurusubramanian G, Somnath R. A preliminary toxicological study of commonly used acaricides of tea red spider mite (*Oligonychus coffeae* Neitner) of North Bengal. India Resistant Pest Management Newsletter. 2009; 18(1):7-10.
18. Rajmohan D, Logankumar K. Studies on the insecticidal properties of *Chromolaena odorata* (Asteraceae) against the life cycle of the mosquito, *Aedes aegypti* (Diptera: culicidae). Journal of Research in Biology. 2011; 1(4):253-257.
19. Sanigrahi S, Talukdar T. Pesticide use patterns in Dooars tea industry. Two and A Bud. 2003; 50:35-38.
20. Sukhthankar JH, Kumar H, Godinho MSH, Kumar A. Larvicidal activity of methanolic leaf extracts of plant, *Chromolaena odorata* L. (Asteraceae) against vector mosquitoes. International Journal of Mosquito Research. 2014; 1(3):33-38.
21. Talukdar U, Hazarika C. Production and export of value added tea in India and its global competitiveness. Economic Affairs. 2017; 62(4):705-710.
22. Udebuani AC, Abara PC, Obasi KO, Okuh SU. Studies on the insecticidal properties of *Chromolaena odorata* (Asteraceae) against adult stage of *Periplaneta americana*. Journal of Entomology and Zoology Studies. 2015; 3(1):318-321.
23. Wight W. Combiners for tea breeding. Two and A Bud. 1961; 8(3):19-21.
24. Zoubiri S, Baaliouamer A. Potentiality of plants as source of insecticide principles. Journal of Saudi Chemical Society. 2014; 18(6):925-938.