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Assessment of indigenous technical knowledge on uses of *Alliums* in plant protection

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Traditional indigenous pest and disease management practices followed by Indian farmers were environment friendly, economical and largely non-hazardous to human health. Nevertheless, indiscriminate use of chemical pesticides in today's modern agriculture has resulted in health hazards, development of insecticide resistance in pests and environmental pollution. Among the traditional practices, the extracts of onion and garlic were effective in indigenous pest management practices. Therefore, the present study was undertaken to document and validate the Indigenous Technical Knowledge (ITK) on ethnobotanical uses of onion and garlic in crop protection practices. The validation of the ITKs was done with 30 experts from the relevant scientific field. Present study revealed that among 36 formulations which were measured on 150 validity score, 30.56% had the validity score above 120, whereas 61.11% scored between 100 to 120. These results showed their wider applicability as pesticide and fungicide to protect various vegetables, cereals, pulses and commercial crops from biological stresses. *In vitro* standardization of formulation is necessary for effective application on targeted pest. Popularization and commercialization of these ITKs can be a boost for residue free food production.

Keywords: Ethnobotanical, Garlic, Indigenous Technical Knowledge, Onion, Validation

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Modern agriculture has no doubt enhanced food supplies to meet the demand of huge population, but simultaneously introduced several ecological, environmental and health issues. The use of synthetic agrochemicals became an essential practice for increasing farm production by preventing crop losses to meet the ever-increasing demand for food. But, despite of their efficiency, indiscriminate use of pesticides has resulted in various environmental complications that include development of insecticide resistance in pests and higher levels of residual toxicity caused health hazards to human, domestic and wild animals including birds[1]. Nowadays, with the growing awareness and concern about the ill effects of pesticides on human health, there is a need to look for ecofriendly and effective organic methods of plant protection as an alternative to the available methods. Increasing global demand for pesticide residue-free food has necessitated the need to look at pest control using botanicals/bio-pesticides, as an alternative ecofriendly option to the devastating synthetic chemicals for pest control[2].

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Over the centuries, farmers have innovated several agricultural practices which were based on need through curiosity, observations and continuous up-gradation by informal experimentation to solve the immediate situational problems. This traditional knowledge was transferred orally from one generation to another. Lack of documentation and validation of such informal knowledge systems and advent of modern technology and agrochemicals led to widening the gap in bridging traditional farming with techno-intensive agricultural practices including plant protection. Systematic use of plant extracts for insect pest management is called as ethnobotanical crop protection. These botanical pesticides possess broad spectrum properties like toxic, repellent, antifeedant, insect growth retardant, *etc.* against the pests of agriculturally important crops. They are less expensive and easily available due to their adequate natural occurrence; without much effect on environment and human health.

Members of the genus *Allium*, garlic (*Allium sativum* L.) and onion (*Allium cepa* L.) are widely used for culinary preparation. However, these *allium* crops

also played significant role in indigenous practices of agricultural pest and disease management. Onion and garlic contain allicin or alliin, diallyl disulphide, diallyl trisulphide and diallylsulfide. These compounds are known for antagonistic activities against many economically important pests[3]. Easy availability at home and insecticidal properties of the extracts from bulbs of these crops demonstrate wider use in indigenous plant protection measures practiced by farmers since ancient times. In the scenario of demand of residue free food, benefits of this indigenous traditional knowledge can be harnessed effectively to replace the indiscriminate use of chemical pesticide. In this context, proper documentation, compilation and scientific validation of ITKs are very important.

Methodology

The present study was conducted to document and validate the available scattered knowledge about the ethno-botanical use of major alliums *i.e.,* onion and garlic to effectively control pest and diseases of agricultural crops. The documented uses of onion as well as garlic in Indigenous Technical Knowledge (ITK) for prevention or control of pest and diseases of various crops among the traditional farming communities were screened from various published articles, research studies, books and thesis. The selected uses of onion and garlic in ITKs were sent to 100 plant protection experts for confirming their scientific validity. Further, two reminders were sent after the gap of a week between two reminders. Out of them, 30 experts provided their response on validity of ITKs for their relevance in scientific scenario of plant protection. Validity refers to the degree to which the data are realistic. The experts were asked to provide response on 3-point validity continuum and the responses were scored 5, 3 and 1 for scientifically valid, uncertain and not valid, respectively[4]. Thus, one ITK could get a maximum score of 150 and a minimum of 30. The rationale was provided for the use of onion and garlic in the plant protection.

Results and Discussion

The indigenous knowledge practiced by farmers should have a scientific basis for its successful results to consider it as valid. Farmers may not be able to explain the scientific rationale behind indigenous practices; therefore, scientists or experts in the relevant field can judge its rationality and validity. The profile of the experts who were asked to validate the ITKs is depicted in Table 1. Most of the experts (43.33%) were from middle age group. Majority of them (76.67%) possessed highest educational qualification as PhD in the relevant area. These experts belonged to Indian Council of Agricultural Research (ICAR) institutions, agricultural universities and private companies holding the designation ranging from scientist or assistant professor to principal scientist or professor equivalent. Experts were selected form plant protection fields like entomology, plant pathology, microbiology, biological control *etc.*

Allium species, particularly; onion and garlic are being traditionally used by ethnic farming communities either independently or in combination with other natural ingredients as plant protection measures for variable crops like vegetables, plantation crops, cereals including stored grains. The important documented pesticidal and fungicidal uses of onion and garlic for crop protection with their validity score and rationale are presented in Table 2. A total of 36 formulations of onion and garlic with other herbal additives have been shown with the validity scores calculated from 150 score scale. Among these formulations 30.56% were claimed to have the validity score above 120, whereas 61.11% were scored between 100 and 120, which strongly emphasize their wider applicability as pesticide and fungicide in crop protection practices.

*SV-Scientifically Valid, U-uncertain, NV- Not Valid and VS-Validity Score

Table 1 — Profile of experts

Parameters	Categories	Frequency	Percentage
Age	Young (<35)	12	40.00
	Middle (35-50)	13	43.33
	Old (>50)	05	16.67
Educational	MSc	07	23.33
Qualification	PhD	23	76.67
Designation	Scientist/ Asst. Professor	18	60.00
	Senior Scientist/ Associate Professor	03	10.00
	Principal Scientist/ Professor	07	23.33
	Manager equivalent	02	6.67
Subject	Entomology	14	46.67
	Integrated Pest Management	03	10.00
	Biological control	02	6.67
	Plant Pathology	06	20.00
	Microbiology	02	6.67
	Agrochemical	01	3.33
	Plant Biotechnology	01	3.33
	Plant Toxicology	01	3.33
Organization	ICAR Institutes	09	30.00
	Agricultural Universities	19	63.33
	Private Organizations	02	6.67

Table 2 — Validity and rational of indigenous use of onion and garlic in plant protection by experts

Sr. no	Crop, disease/pest and ITKs	Researcher, Year, Place	Validity				Rational behind use of ITK
			SV*	U	NV	VS	
1.	Paddy and vegetables (all diseases) Decomposed solution of cow dung, cow urine, chilli (*Capsicum annum*) and garlic at the ratio of 0.5:10:0.25:0.25 for three weeks[5]	Sinha (2004) Meghalaya	16	12	2	118	Allicin and diallylsulfide present in garlic extract, chilli extract contains capsaicin which have antifungal, repellent and deterrent activity against insect pests
2.	Chilli, (Wilt) Mixed cropping of chilli (*Capsicum frutescens*), coriander (*Coriandrum sativum*) and garlic[6]	Kant (2003) Himachal Pradesh	15	14	1	118	Garlic plants produce excretions of dimethyl disulfide, dipropyldisulfide and diallyldisulfide to inhibit fungal growth
3.	Coffee (Coffee rust) Garlic and papaya (*Carica papaya*) are used as fungicides[7]	Venkatesan (2012) Tamil Nadu	9	20	1	106	
4.	Coconut (Root wilt and nut fall) Apply crushed small onion (l Kg) and salt (2 Kg) in the basin of coconut trees[8]	Husain (2010) Kerala	7	19	4	96	
5.	Vegetables (Aphids) A mixture of extracts of garlic and neemcake[9]	http://agritech.tnau.ac.in/itk/IndigenousTechKnowledge_Oper.html	27	2	1	142	Garlic contain allicin and Neem contain azadirachtin act as insecticidal and repellent, antifeedant, pest growth inhibitor
6.	Vegetables (Fruit borers) Spraying of garlic extract and kerosene solution (2 Kg of garlic + 200 L of water + 400 mL of kerosene)[10]	http://agritech.tnau.ac.in/itk/Inde_techknowledge_dist.html	12	15	3	108	Kerosene acts as toxicant, garlic act as insecticidal and repellent against pest
7.	Vegetables (All pests) Application of neem cake 16.66%, dusting the ash 23.33%, spraying garlic and asafoetida (*Ferula asafoetida)* solution 10%, spraying of soap water 2.50%[11]	Jagdish (2007) Karnataka	22	6	2	130	Ash acts as a repellent, garlic and neem act as insecticidal and repellent against pests
8.	Vegetables (All pest) One Kg gulvel pieces (*Tinospora cordifolia*), 100 g onion pieces, 50 g chilli powder and 250-500 g turmeric (*Curcuma longa*) mixed with 1 L water. The mixture is thoroughly stirred, boiled and filtered. 2 L of the filtered extract is mixed in 100 L water and 100 g washing powder solution and used after 3 days for spraying[12].	Thakre (2003) Maharashtra	15	13	2	116	Garlic act as insecticidal and repellent against pest
9.	Vegetables (Lepidopteran pest and sucking pest) Three to four cloves of garlic, 2 handfuls of marigold (*Tagetes erecta*) leaves, 2-3 onions), 2-3 small peppers (*Capsicum*) and water boil the mixture. Dilute it with 4-5 times quantity of water. Stir constantly & spray[13].	Sankar and Akila (2017) Tamil Nadu	17	11	2	120	A major constituent of marigold tree essential oil, the monoterpenoid α-pinene, has insecticidal and repellent activities against pests
10.	Vegetables (leaf roller, stem/ fruit/ pod borer) Crush 1 Kg Ipomea (besaram) leaves, 500 g hot chilli, 500 g garlic and 5 Kg neem leaves in 10 L cow urine[14].	Rajput (2018) Odisha	20	9	1	128	

(*Contd*.)

Table 2 — Validity and rational of indigenous use of onion and garlic in plant protection by experts (…Contd.)

Sr. no	Crop, disease/pest and ITKs	Researcher, Year, Place	Validity				Rational behind use of ITK
			SV*	U	NV	VS	
11.	Brinjal (Fruit borer) Half Kg garlic and one Kg green chilli are taken and ground well. One Kg tobacco (*Nicotiana tabacum*) leaves and little water added to this mixture. Keep it for three days and add 1 L of this filtered mixture with 10 L of water[15].	Pradhan (2009) Orissa	15	13	2	116	Alkaline nature of tobacco, capsaicin active ingredient in green chillies and allicin in garlic act as antifeedant/ repellent to pests.
12.	Brinjal (All pest) Spray mixture of extract of garlic, kerosene and green chilli (*Capsicum frutescens*) and another mixture having garlic onion and chilli powder[16]	Narayansamy (2002) Tamil Nadu	9	19	2	104	
13.	Brinjal and sorghum (Shoot and fruit borer, Bihar hairy caterpillar and sorghum argot) Garlic 4 Kg + Kerosene 0.5 L + crushed onion 2 Kg + crushed green chilli 2 Kg + tobacco 1 Kg + Water 6 L stain it and add Asfoetida (*Ferula asafetida)*[17,18].	Arora *et al.* (2016) and Gonjari *et al*. (2016) Maharashtra	13	15	2	112	
14.	Brinjal, paddy (Borer and other pest) Ginger (*Zingiber officinale*) and garlic paste extract spray and repeated at an interval of once in 10 days[5,17].	Arora *et al.* (2016) and Sinha (2004) Meghalaya	13	16	1	114	Ginger and garlic act as insecticidal and repellent against pest,
15.	Tomato, Brinjal, Pumpkin, Groundnut (Fruit borer, Leaf beetle and Epilachna beetle, Caterpillar and Cutworm) Rui (*Calotropis gigantean*) + onion + garlic + chilli (*Capsicum frutescens*) powder spray[19]	Narayansamy (2006) Tamil Nadu	15	13	2	116	Garlic act as insecticidal and repellent against pest. Major mode of action rui is stomach poison against pest
16.	Tomato, Bhendi, Cowpea, Black gram, Pigeon pea Fruit borer and leaf caterpillar, Pod borer The filtered extract of 500 g of well crushed cloves of garlic mixed in kerosene and left for overnight, filtered solution of 50 g crushed chillies (*Capsicum frutescens*) in 1 L of water and 100 g of detergent powder dissolved in sufficient quantity of water is mixed. The mixture of these three solutions is used at the rate of 25 mL in 16 L of water and sprayed[9,16]	Narayansamy (2002) Tamil Nadu, and Husain (2010) Kerala	14	14	2	114	Kerosene acts as toxicant, chilli has repellent and insecticidal properties, It is found scientifically that garlic has volatile sulphur containing oil which is vaporized with raising temperature. Chillies contain capsaicin which irritates skin, detergent helps in spread of solution and adherence to crop.
17.	Tomato, Brinjal (Fruit borer attack) Raising garlic and onion as border crop in tomato and brinjal field[14,20]	Patidar (2013) Uttar Pradesh and Rajput (2018) Odisha	14	14	2	114	Onion and garlic act as a repellent against pest
18.	Tomato (Helicoverpa) Spraying of green chilli + garlic extract @ 7.5 Kg chilli extracted in water (4 Kg chilli should be drenched in 8 L of water for overnight) + 1.25 Kg garlic extracted in kerosene (750 g pounded garlic made to soak in 200 mL of kerosene for overnight) + 100 g dissolved detergent, for one hectare[21]	Srivastava (2016) Maharashtra	15	14	1	118	The mixture of solutionsact as insecticidal and repellent against pest

(*Contd*.)

Table 2 — Validity and rational of indigenous use of onion and garlic in plant protection by experts (…Contd.)

Sr. no	Crop, disease/pest and ITKs	Researcher, Year, Place	Validity				Rational behind use of ITK
			SV*	U	NV	VS	
19.	Chili (Thrips or wood worms) Coriander or garlic is intercropped with chilies (*Capsicum frutescens)*[7]	Venkatesan (2012)[7] Tamil Nadu	15	13	2	116	Garlic plants produce excretions of dimethyl disulfide, dipropyldisulfide and diallyldisulfide to act as a repellent against pest
20.	Potato (Minimize pest attack) Intercropping garlic in potato (*Solanum tuberosum*)[22]	Indigenous Technical Knowledge (ITK). https://cststudy.blogspot.com /	17	12	1	122	
21.	Cabbage, cauliflower and other vegetables (Sucking insects, such as jassids and aphids and larva) Mixture of Cow urine 100 L + Neem leaves 40 -50 Kg + Garlic 5 Kg and Tobacco (finely grinded) 5 Kg is sealed in copper utensil and kept for a fortnight. Thereafter it is boiled in steel container to reduce it by 50-60%. After filtering ready to spray[23]	Gaushala (2003) Rajasthan	19	9	2	124	Neem act as insecticidal and antifeedent, Alkaline nature of tobacco acts as antifeedant/repellent to pests
22.	Vegetables, millets, pulses and oilseeds (Larvae of *Spodoptera litura*, Polyphagous pest) Mixture of fenugreek (*Trigonella foenum-graecum* L) + betel vine (*Piper betle*) + onion + buttermilk + castor (*Ricinus communis*) oil[19]	Narayansamy (2006) Tamil Nadu	10	18	2	106	Betel vine major mode of action is stomach poison against larvae
23.	Wheat (Insect-pest attack) Mixed cropping of wheat (*T. aestivum*), thymol, garlic and onion[24]	Verma (2004) Himachal Pradesh	12	14	4	106	Its act as insecticidal and repellent against pest
24.	Coconut (Mites) Apply garlic solution (Grind 20-30 g of garlic and take the extract in 1 L of water)[8]	Husain (2010) Kerala	5	23	2	96	Garlic diallyl disulphide has insecticidal properties that are effective against many pests including the red spider mite.
25.	Vegetables, Mustard, Rice, Cow pea, Cotton (Aphids and jassids, Rice earhead bug, sucking as well as other pests) Crush 100 g of bird eye chilli and 50 g garlic and take the juice. Dilute the juice with 10 L of water and spray[8,25]	Roy *et al.* (2015) West Bengal	10	18	2	106	Garlic has strong pungent repellant action on different insect pest. Chilli has repellent and insecticidal properties and stomach poison against pest
26.	Chick pea and pigeon pea (*Helicoverpa armigera*) Indigenous cow urine 15-20 L + crushed leaves of neem 1.5-2 Kg + *Nicotiana* spp. 500 g + crushed green chilli 500 g + garlic pest 250 g.[18]	Gonjari*et al* (2016) Maharashtra	21	8	1	130	Its act as insecticidal and repellent against pest
27.	Paddy (Gundhi bug) Extract 1 Kg of garlic 200 g of tobacco leaves, 200 g washing powder dissolved in 200 L water[28].	Jamal (2003) Jamia Nagar (New Delhi)	19	10	1	126	Alkaline nature of tobacco acts as antifeedant/repellent to pests

(*Contd*.)

Table 2 — Validity and rational of indigenous use of onion and garlic in plant protection by experts (…Contd.)

Sr. no	Crop, disease/pest and ITKs	Researcher, Year, Place	Validity				Rational behind use of ITK
			SV*	U	NV	VS	
28.	Paddy (Pests attack) Application of the dilution of Neem leaves, garlic and 'khaini' / tobacco leaves[29]	Ali *et al.* (2018) West Bengal	25	4	1	138	Generally farmers use this dilution to prevent paddy pests attack. This is a precautionary measure.
29.	Paddy (Pest and disease) One Kg garlic and notchi leaf are soaked in 5 L water for 5 days mixed with cow urine. The extract is mixed with water in the ratio of 1:1 and sprayed in the morning[30]	Tiruvannamalai (2003) Tamil Nadu	18	11	1	124	Its act as insecticidal and repellent against pest, also act contact poison and growth regulator
30.	Cotton, Maize (Bollworm, *Spodoptera litura*, grasshopper and other leaf inhabiting insect) Spraying of mixture of garlic extract and monocrotophos[31]	Shakrawar *et al.* (2018) Madhya Pradesh	13	10	7	102	Garlic act as a repellent against pest, Diallyldisulphide, diallyl tri-sulphide active molecule is responsible to control *Spodopteralitura* Garlic had reduced the population of grasshopper.
31.	Cotton (*Helicoverpa armigera*) Mixture of 20 L of cow urine + 2 Kg of neem leaves with twigs + 500 g of tobacco + 500 g crushed spicy green chilli + 250 g crushed garlic cloves is boiled for about 15 min and allowed to cool for 48 h. Mixture is stirred and filtered with cloth and it can be stored in shade for 3 months. Use 6-10 mL of the mixture in 20 L of the water for spray[32]	Patil (2016) Maharashtra	14	15	1	116	Cow urine and neem showed anti-feedent and anti-ovipositional effects against *Helicoverpaarmigera*, Alkaline nature of tobacco acts as antifeedant/repellent to pests, chilli has repellent and insecticidal properties
32.	Cotton (*Helicoverpa armigera*) 1.5 kg green chilli (*Capsicum frutescens*) and 500 g garlic extract is added with kerosene mixed water (100 mL kerosene in 5 L water). Soap Powder (75 g) and 100 L water are added in the extract and sprayed for control of American bollworm[33,34].	Das *et al.* (2003) Maharashtra and http://www.cicr.org.in/PDF/itk.pdf	11	17	2	108	Intolerable odour of kerosene and soap powder acts as an emulsifier, chilli has repellent and insecticidal properties
33.	Sugarcane (Shoot borer) Mixed cropping of onion+ sugarcane (*Saccharum officinarum*)[35]	http://vikaspedia.in/agriculture/best-practices/ sustainable-agriculture/crop-management/ indigenous-technologies-practiced-by-farmers Mau (U.P.)	10	17	3	104	Onion act as a repellent against pest
34.	Sugarcane (White fly) Sugarcane cuttings are coated with onion juice[36]	Patel (1997) Gujarat	5	22	2	93	Onion act as a repellent against pest

(*Contd*.)

Table 2 — Validity and rational of indigenous use of onion and garlic in plant protection by experts (…Contd.)

Sr. no	Crop, disease/pest and ITKs	Researcher, Year, Place	Validity				Rational behind use of ITK
			SV*	U	NV	VS	
35.	Food grains, pea seeds and pulses Neem leaves, onion and garlic are kept with stored grains to protect the grains from insect pests[8,25,26,37]	Husain (2010) Kerala Roy *et al.* (2015) West Bengal, Kumar (2016) Uttar Pradesh Prakash *et al.* (2016) Karnataka	25	4	1	138	Neem have natural compounds that repel insects and other pests, while providing medicinal value to the food grains, strong odour of neem would repel the storage pests. Garlic has repellent, insecticidal properties diallyl disulphide, diallyl trisulphide and diallylsulphide are the major compounds present in Garlic has anti-feedant, bactericidal, fungicidal, insecticidal, nematicidal and repellent properties.
36.	Rice grains Turmeric (*Curcuma longa*) and garlic are mixed with rice grains[38-39].	Nagnur *et al.* (2006) Karnataka Mujumdar *et al.* (2013) Assam and	19	9	2	124	Turmeric has natural compounds that repel insects and other pests. Smell of garlic repels insect. Garlic cloves are pungent in nature.

The results showed that onion and garlic either alone or in combination of other ingredients were found effective in controlling various pest and diseases in vegetables (chilli, brinjal, ginger, tomato, pumpkin, bhindi, potato cabbage, cauliflower); cereals (paddy, sorghum, wheat, maize); pulses (cowpea, black gram, pigeon pea, chick pea); oilseeds (groundnut and mustard); plantation crops (coffee and coconut) and commercial crops (cotton and sugarcane). The formulations of onion and garlic extract along with other ingredients were found be effective in control of important diseases such as wilt, coffee rust, root wilt and nut fall commonly found in vegetables and plantation crops. Further, formulations were also found effective in managing wide array of insect pests *viz.*, sucking pests like aphids, jassids, thrips, whitefly and mites; other lepidopteran pest, leaf roller, shoot and fruit borer, stem borer, pod borer, bihar hairy caterpillar, sorghum argot, leaf beetle and epilachnene beetle, caterpillar and cutworm, *Spodoptera litura*, rice earhead bug, *Helicoverpa armigera*, gandhi bug, bollworm, *etc*.

The onion or garlic have been used in combination with other natural ingredients for formulation of effective solutions against the various pest and diseases. Allicin compound found in *Alliums* has a distinctively pungent smell which reveals anti-bacterial and anti-fungal properties[40-42]. Various researchers reported the presence of flavonoids from the onion and garlic inhibit the growth of microorganisms such as *Aspergillus niger*, *Fusarium oxysporum* and *Colletotrichum*[43]. Onion and garlic are also highly useful in effective storage of the stored food grains and pulses because of repellent, insecticidal properties due to presence of diallyl disulphide, diallyl trisulphide and diallylsulphide compounds. These disulfides exhibit greater toxicity for insects than fungi[44]. Intercropping of onion and garlic in other crops also found effective in controlling the pest attack. Intercropping of onion with sugarcane was found effective to control borers effectively down to 72-85%[45]. Onion and garlic plants produce excretions and aromas which discourage insects, and are therefore regarded as insect repellent plants. Due to these biocidal properties of onion and garlic, these have been used in traditional crop protection measures for pest and disease management.

The formulations having high validation score, therefore, need to be further standardized for effective proportion of the ingredients as well as their effective applications at different life stages of insects. Further research is needed to study the efficacy during the life stages of insects which may differ in their response to these bio-pesticides. The effectiveness may also differ with the time of occurrence of the pest and the ecosystem in which it occurs. The farmer participatory experimental trials for validation of the ITK may be laid out with different treatments. It was

found that labour intensiveness and cumbersome process of extracts preparation are the limiting factors with the use of stated ITK. Therefore, steps may be initiated to commercialize the formulations which have best effect on control of selected pests. Agri-incubator start-ups can play an important role to bring these formulations in commercial scale for organic or residue free crop production.

Conclusion

Onion and garlic-based biopesticides can be better alternatives for the chemical plant protection measures in the scenario of the growing demand for residue free agriculture. This study provided an inventory of ethno-botanical use of onion and garlic extract against different pest and diseases. Validated ITKs can be further tested in laboratory and standardized for proper and effective application on targeted pests and insects. Popularization of these standardized ITKs among the farming community will be helpful for residue free food and cost reduction of farm production.

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Conflict of Interest

Authors declare no conflict of interest.

Authors' Contributions

R B K & S S G: Conceptualization, design, drafting; R B K & A O P: Survey and analysis; K J, S J G & M S: drafting, review & editing

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