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Indigenous approaches for pest management in vegetables with special reference to coriander in Southern Rajasthan, India

Narottam Kumar Meena[a,*], Ram Swaroop Meena[a], Yogesh Kanojia[b], Bapu Lal Roat[c] & Narayan Lal Dangi[d]

[a]ICAR-National Research Centre on Seed Spices, Ajmer 305 206, Rajasthan, India

[b]Krishi Vigyan Kendra (MPUA&T), Pratapgarh 312 605, Rajasthan, India

[c]Krishi Vigyan Kendra (MPUA&T), Dungarpur 314 001, Rajasthan, India

[d]Department of Entomology, Rajasthan College of Agriculture, MPUA&T, Udaipur 313 001, Rajasthan

E-mail: narottammeena@gmail.com

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The present survey-based study was conducted to record the indigenous pest management practices which were based on the use of various ethnobotanical plant parts, animal bi-products etc., for vegetable pest control by the farmers of tribal communities in four tribal districts of Southern Rajasthan. Data revealed that nowadays, indigenous knowledge of insect-pest management is being kept alive in age-old people of few communities and tribes of Southern Rajasthan are amongst the communities in which some farmers are still practicing indigenous methods for controlling pests on vegetables. 28 indigenous practices constituted by locally available wild plants constituents, animal by products, natural resource and few spiritual means were applied with age-old knowledge of farmers recorded effective management of various insect-pests infesting vegetables including coriander. The highest F_{ic} value was recorded for aphids followed by thrips and jassids. The use value was recorded in the range of 0.09 to 0.69 for all locations. The highest UV 0.69 secured for indigenous practices of *Neem* leaf extract; cow butter milk + cow dung ash + chilli seed powder; Neem seed kernel extract and ker plant + neem leaf + negadi leaf extract. These practices were easy in preparation, cost-effective, eco-friendly and widely acceptable by the community in region need to be documented for future reference.

Keywords: Coriander, Indigenous Traditional Knowledge, Pest Management, Southern Rajasthan, Vegetables

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Southern Rajasthan is dominated by tribal community since ancient time and mainly depends on agriculture and animal rearing. In this region, tribal people grow vegetables like brinjal, cabbage, cauliflowers, beans, chilli, tomato, okra, gourds, ginger, cassava and coriander etc. in a small area for their household use as well as for selling in local market for their livelihood. They inhabit the interiors of forest, foot hills, hillocks and flat terrains, little connected with roads for transport toward cities. These tribal people are known for their rich indigenous knowledge for insect-pests and disease management. Vegetables are a rich source of nutrients viz., vitamins, minerals, protein, carbohydrates, fat etc. and are essential for human growth and development for healthy life. Coriander's green leaves have wide range of healing properties as antioxidant, diuretic, ant-diabetic, anti-microbial, anti-convulsant, anthelmintic and anti-mutagenic[1,2]. It is also used in gastrointestinal complaints: anorexia, dyspepsia, vomiting and diarrhea[3]. Its leaves and seeds contain essential oil, create aroma[4] and lemony flavour in seeds due to linalool, terpenes, pinene and limonene[5]. Vegetables including coriander receive pest's complex load during different plant growth and fruiting period. It includes a number of insect-pests like aphids (*Hyadaphis coriandri* Das, *Myzus persicae* Sulzer and *Aphis gossypii* Glover)[6,7], thrips (*Thrips tabaci* Gen., *Frankliniella schultzei* Tryb.), jassid (*Empoasca* sp.), seed wasp (*Systole albipennis* Walker)[8], whitefly (*Bemisia tabaci* Genn.)[9], mites (*Tetranychus* sp.), brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.), shoot and fruit borer (*Earias insulana* Boisd. & *E. vittella* Feb.), *Heliothis armigera* Hub., *Pieris brassicae* Lin., *Plutella xylostella* Lin., cut worm (*Agrotis* spp.), tobacco caterpillar (*Spodoptera litura* Fab.), grasshoppers etc., right from germination to harvesting of the crops, cause significant loss in yield

*Corresponding author

and quality. Vegetables are consumed by people in raw and fresh condition, if any pests are controlled by chemical pesticides, it will be more dangerous to human beings due to its toxicity.

Indigenous pest management approaches have almost vanished from the developed countries worldwide and now it has confined to some isolated tribal dominated regions in the developing countries. Over 2000 plants belonging to some 60 families known to exhibit insecticidal activities[10,11] are used in pest management since ancient times. Farmers from tribal communities in four districts of Southern Rajasthan are still adopting age-old practices for insect-pests management in vegetables including coriander and other field crops. The older people of tribal communities know about this indigenous knowledge for pest management at their own fields and interested people of new generations are adopting these practices. In this perspective, a survey-based study was undertaken in different hamlets of tribal districts of Southern Rajasthan to document and conserve the knowledge of indigenous practices adopted by tribal farming communities for pest management in vegetables with special reference to coriander.

Methodology

Study area

A survey-based study was conducted for two consecutive years during 2018-19 and 2019-20 with TSP project of ICAR-NRCSS, Ajmer in collaboration with KVKs of four tribal districts and state department of agriculture, Udaipur in Southern Rajasthan. These most tribal populated four districts (Udaipur, Dungarpur, Banswara and Pratapgarh) of Southern Rajasthan cover 24465 sq km area contribute 7.15% of total gross geographical area of Rajasthan (Fig. 1). The study area is lying between 23° 32' 26" to 24° 80' 0" N and 73°28'83″ to 74°80'0″E on the globe, possess annual temperature range between 15^0 to 45^0 Celsius and annual rainfall of 600 to 900 mm (Table 1). The study area is covered with Aravalli hill range in different elevations consisting of evergreen forest, restrain with huge wild plants diversity. Bhil, Garasia, Damor, Ninoma, Patelia, Charpota are the major groups of tribes situated in remote hilly terrain in the scattered manner. The accessibility of their hamlets to road transportation and market availability of chemical pesticides are still far behind. The primary occupation of this community is agriculture with marginal land holdings, growing maize, rice, vegetables etc., to fulfill their domestic need as well as for selling in local markets for livelihood. A total of 14 locations (tribal hamlets) were identified for the study from four districts having about 90% tribal populations (Table 1). The selected tribal farmers were informed in advance for their consent by officials of respective KVKs and agriculture department of tribal districts to interact with the scientists and provided the information as asked.

Data collection

In the study period, several field visits, scientist-farmer interactions were performed during various awareness programmes: farmers training, frontline demonstrations, and surveys conducted in tribal hamlets of the region and consulted with the age-old people to gather the information about various traditional practices followed for the management of insect-pests and diseases in vegetables including coriander. With the advancement in modern agriculture and way of communication, young generation of tribal community is also initiating to adopt chemical pesticides as one of the management options on crops. The age-old farmers of tribal community who have good experience of using local treatments of insect-pests management on different crops were considered as a source of data for this study. A total of 110 experienced farmers of tribal community from 14 locations were interviewed. In each location, 5 to 15 farmers of both genders with 50 to 70 years old age groups were taken into consideration for the interview (Table 1). The location wise interviews of selected farmers were performed on different dates during the study period and the information was collected and prepared used reports (UR). On the basis of interview and discussion, all relevant information i.e., local name of ethnobotanical plants, parts used, animal bi-products, methodology of preparations and use and other spiritual activities used as indigenous approaches of pest management were collected and data reservoir was generated and then the data was by triangulation between different stakeholders and institutions. The plants were identified with the literature available and correct nomenclature of species was also checked with The Plant list[12]. Ten valuable indigenous practices of pest management which was most privileged in the region were revalidated in institute level at Amlikheda,

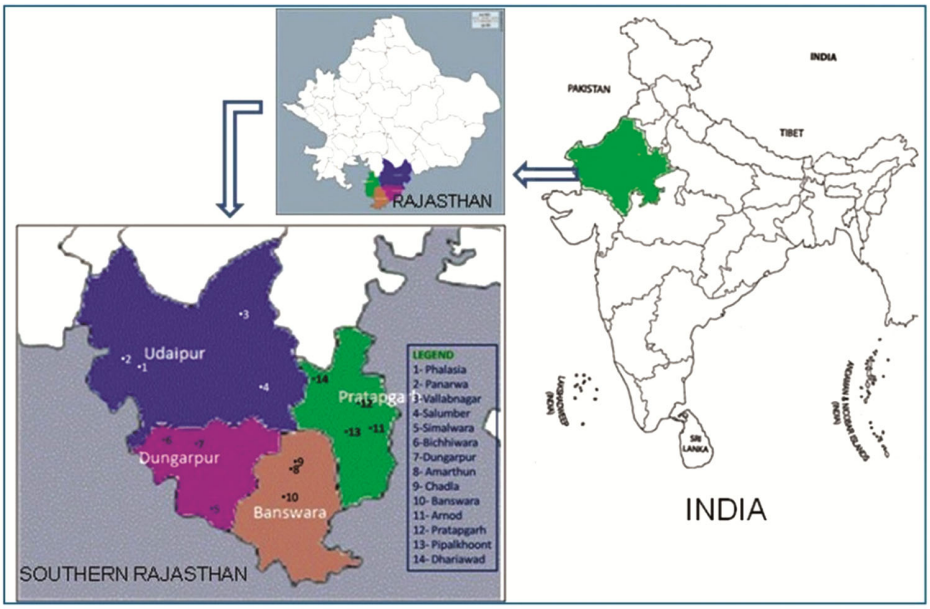

Fig. 1 — Map of four tribal districts of Southern Rajasthan indicating location of studied areas

Table 1 — Geographical information about locations surveyed in tribal districts of Southern Rajasthan, India

Name of location	District	Approximate coordinates (latitude, longitude)	No. of participant farmers with their gender	Age group (in year)
Phalasia, Jhadol	Udaipur	24°21′12″N & 73°31′48″E	10 M	60-65
Panrwa, Jhadol	Udaipur	24°23’83″N & 73°28’83″ E	4 M, 1 F	55-65
Vallabhnagar, Udaipur	Udaipur	24° 34' 16″N & 73° 41' 29" E	5 M	55-65
Morila, Salumber	Udaipur	24° 80' 0" N & 74° 30' 0" E	10 M	60-65
Kanba, Simbalwara	Dungarpur	23.5676° N & 73.7537° E	7 M, 3 F	50-70
Mada, Bichhiwara	Dungarpur	23° 50' 0" N & 73° 43' 0" E	5 M	50-65
Majhola, Dungarpur	Dungarpur	23°50′59″N & 73°43′05″E	5 M	60-65
Amarthun, Ghatol	Banswara	23° 45' 24"N & 74° 24' 42" E	11 M, 4 F	50-65
Chadla, Ghatol	Banswara	23° 45' 24"N & 74° 24' 42" E	9 M, 1 F	50-65
Kanpura, Banswara	Banswara	23° 32' 26" N & 74° 26' 32" E	4 M, 1 F	60-65
Nagdeda, Arnod	Pratapgarh	23°88'0" N & 74°80'0″E	10 M	50-65
Amlikhera, Pratapgarh	Pratapgarh	24°01′48″N & 74°46′48″E	6 M, 2 F	50-55
Motikheri, Pipalkhoont	Pratapgarh	23.80°N & 74.56°E	5 M	50-60
Jawahar nagar, Dhariawad	Pratapgarh	24°20′16″N & 74°27′50”E	7 M	50-60
Total locations-14			110	50-70 Years

Pratapgarh on farmer field nearby KVK. The field trial was conducted in randomized block design (RBD) with three replications, wherein ten ITKs were evaluated against pests on coriander. Revalidation trial was carried out under the supervision of scientists of Krishi Vigyan Kendra (MPUA&T), Pratapgarh and ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan for their effectiveness against particular pests on coriander crop under field conditions. The relevant data were obtained, statistically analyzed and described and documented as age-old tactics of pest management in vegetables including coriander which are going to be nearly vanished from the region.

Analysis of informant consensus

F_{ic} was calculated to know the uniformity of ethnobotanical plants and other local practices shared by all the informants in management of particular pest species. The Factor Informants Consensus (F_{ic}) formula developed by earlier worker[13] was used.

$F_{ic} = Nur\text{-}Nt / (Nur\text{-}1)$

Where *Nur* denotes number of used reports (URs) from informants for a particular pest category and *Nt* refers the number of species used for a specific pest by all informants. The calculated values of informant consensus are given in the range of 0 to 1, wherein the values close to 1 show that the plants or other local practices used for the management of particular pest are highly shared among the informants. Similarly, the values close to 0 show disagreement among the informants on the ground of plants or other local practices used for particular pest management.

Use value (*UV*)

The use value (*UV*) was calculated according to the number of local plants used and the number of informants[13] using following formula:

$$UV = U/N$$

Where *U* refers to the number of used reports for a particular plant/practice and *N* means number of informants interviewed.

Results

Survey-based study revealed that the people of tribal community of Southern Rajasthan were cultivating vegetables throughout the seasons and coriander in winter and summer season for seed production as well as leafy vegetable in a small area. In the region, most of the farmers were growing vegetables in a small area for their household use as well as for selling in local market for their livelihood. Vegetable crops including coriander are infested with eight major pest species, causing 30-80% yield loss in general. The study area has a reservoir of huge wild plant species. In this study, 29 plant species belonging to 18 families are included, which are common in all locations and are used for preparation of various indigenous practices of pest management in vegetables (Table 2). These marginal farmers in tribal hamlets constantly used various indigenous approaches of pest management to curtail the pest infestation. However, some of them were also using few chemical pesticides for insect-pests and disease control in crops. Some pest specific and effective indigenous approaches of pest management have been enlisted and described below:

Aphid [*H. coriandri* (Das), *M. persicae* (Sulzer) and *A. gossypii* Glover]

Neem leaf extract: Spraying the crop with manually prepared extract of old neem leaves give admissible protection against aphids in the field. In this approach of aphid control, farmers manually collect the old neem leaves from the vicinity and obtain extract through grinding of leaves with water in 2:1 ratio (leaves: water) and then the extract is filtered through the muslin cloth to obtain 100% leaf extract. On aphid initiation, the crop is sprayed with prepared 10% solution two times at 7-10 days interval to manage its infestation.

Custard apple seed extract: Spraying of custard apple (*Annona squamosa* Linn.) seed extract containing acetogenins act as antifeedent against a number of sucking pests including aphids. To prepare CASE, custard apple seeds are crushed and 250 g seed powder is boiled in 1 L of water for 30-45 min. Extract is diluted with 5 L of water and sprayed on infested crop early in the morning to control aphid and other sucking pests.

Cow butter milk + cow dung ash + chilli seed powder: A spray solution is prepared by taking 2 L cow butter milk, 100 g fresh cow dung ash and nearly 10 g chilli seed powder in an earthen pot, mixed thoroughly and covered its mouth with polythene bag to avoid evaporation of water and kept it inside cow dung/ FYM heap for 10 days for fermentation. The solution is filtered through muslin cloth to get the concentrate solution. Use of this solution in 1: 5 ratio by adding 200 mL solution in 1 L of water gave effective control of aphid and whitefly.

Mahua leaf and flower extract: Spraying of mahua (*Madhuca indica* (J.Konig) J.F. Macbr) leaves and flower extract containing saponin is useful for the management of sucking pests and borers. For this, farmers collect 1 kg fresh leaves and 500 g shaded flowers of mahua and they are soaked in 2 L water for 3-4 days and then completely crushed in water and filtered and spray solution is prepared by adding 2/3rd water for spraying on infested crop which gives effective management.

Jatropha leaf and fruit + datura leaf + Calotropis leaf extract: Spraying a mixed solution prepared from jatropha leaves (*Jatropha curcas* Linn.) containing tannin, leaves and fruits of datura (*Datura stramonium* Linn.) containing tropane alkaloids and desi aak [*Calotropis gigantia* (Linn.) R. Br.] leaves (saponins) mixed in equal part and soaked in water for 3-4 days and then crushed to get extract. Extracted material is dissolved in water in 1:4 (extract: water) ratio and sprayed on infested crop to curtail aphid population considerably.

Table 2 — Ethnobotanical plant species recorded for pest management in tribal districts of Southern Rajasthan

Botanical name	Family	Local name	Habit	Used part	Pest managed
Azadirachta indica A. Juss.	Meliaceae	*Neem*	Tree	Leaf, seed, kernel	Aphid, thrips & mites
Annona squamosa L.	Annonaceae	*Sitaphal*	Shrub	Leaf, seed	Sucking pests
Allium sativum L.	Amaryllidaceae	*Lahsun*	Bulbs	Bulbs	Caterpillars
Argemone mexicana L.	Papaveraceae	*Kanteli*	Cripper	Whole plant	Lepidopteran caterpillar
Butea monosperma (Lam.) Taub.	Leguminosae	*Palash*	Tree	Leaf, bark	Aphid, whitefly, beetles
Calotropis gigantia (L.) R.Br	Apocynaceae	*Aak*	Shrub	Leaf	Aphid, whitefly
Capsicum annuum L.	Solanaceae	*Chili*	Herb	Leaf, fruit	Aphid, whitefly, borer
Capparis decidua (Forssk.) Edgew.	Capparaceae	*Ker*	Shrub	Whole plant	Aphid & other sucking pests
Cassia tora L.	Leguminosae	*Kuwandia*	Herb	Leaf	Leaf defoliator
Clerodendrum multiflorum (Burm.f.)	Lamiaceae	*Arni*	Shrub	Leaf, soft stems	Thrips
Datura stramonium L.	Solanaceae	*Datura*	Herb	Whole plant	Sucking pests
Euphorbia hirta L.	Euphorbiaceae	*Baridhudi*	Cripper	Whole plant	Grasshopper & caterpillar
Euphorbia neriifolia L.	Euphorbiaceae	*Danda thor*	Shrub	Stem	Caterpillars
Ipomoea fistulosa Mart. Ex Choisy	Convolvulaceae	*Besharam*	Shrub	Leaf	Leaf eating caterpillar & borers
Jatropha curcas L.	Euphorbiaceae	*Jaytropha*	Shrub	Leaf, fruit	Aphid, whitefly, beetles
Lantana camara L.	Verbenaceae	*Lantana*	Shrub	Leaf	Sucking pests
Madhuca indica (J. Konig) J.F. Macbr	Sapotaceae	*Mahua*	Tree	Leaf, flower	Aphids, jassids
Nicotiana tobacum	Solanaceae	*Tambaku*	Herb	Whole plant	Sucking pests
Ocimum sanctum L.	Lamiaceae	*Tulsi*	Herb	Whole plant	sucking pests
Pongamia pinnata L.	Leguminosae	*Karanj*	Tree	Leaf, seed	Mites
Ricinus cummunis L.	Euphorbiacea	*Castor*	Herb	Leaf	Spodoptera
Solanum xanthocarpum Schrad and Wendl	Solanaceae	*Ooth kateli*	Cripper	Whole plant	Grasshopper & caterpillar
Tephrosia purpurea L.	Leguminosae	*Dhamasa*	subshrub	Leaf	Caterpillars
Tribulus terrestris L.	Zygophyllaceae	Gokharu	Herb	Leaf	Caterpillars, beetles
Viscum articulatum BURM.F	Santalaceae	Keer cup	Shrub	Shoots	Lepidoptera pests
Vitex negundo L.	Lamiaceae	Negadi	Shrub	Leaf	Grasshopper
Vetiveria zizanioides L.	Poaceae	Vetiver	Herb	Whole plant	Caterpillars
Withania somnifera (L.) Dunal	Solanaceae	Ashwagandha	Herb	Whole plant	Whitefly
Xanthium strumarium L.	Asteraceae	Adashishi	Herb	Whole plant	Grasshopper & caterpillar

Jatropha seed + palash leaves + pig excreta + jhau rat hairs smoke: Farmers use a mixture of jatropha seed powder + palash [*Butea monosperma* (Lam.) Taub.] leaves containing linoleic and palmitic acid, pig excreta (dry) + jhau rat hairs for smoking on vegetables as well as coriander and this is found effective in management against sucking pests including aphid, white flies and beetles. Smoking was done in dark early in the morning for more effectiveness.

Lantana leaf + ker plant + wild tulsi leaf extract: Spraying of manually prepared extract of lantana (*Lantana camara* L.) leaves, ker [*Capparis decidua* Edgew (Forssk.)] plant and wild tulsi (*Ocimum sanctum* Linn) leaf was found effective in management of aphid and other sucking insects. In this method, farmers collect leaves of lantana, wild tulsi and one year old soft shoots of ker and chop them in small pieces then mix in equal ratio and grind by adding required water to extract plant juice and prepare spray solution by adding 100 mL/L of water for spraying on crops to minimize pests population.

Cow dung ash: Dusting of cow dung ash on infested crops during early morning gives good protection against aphids. It was observed by the farmers of tribal community of Rajasthan that 2-3 alternate dusting of cow dung ash at 10 days interval received less pest infestation on vegetable crops and also prevents fungal powdery mildew disease on coriander and chilli.

Thrips (*T. tabaci* Lindeman and *Frankliniella schultzei* Trybom)

Floating dirt of rainy ponds: Smoking of floating dirt of rainy ponds is used for the management of

thrips on coriander, chili and other vegetables. In this process, tribal farmers collect the floating dirt from rainy ponds located at their surrounding in the villages and then dry it and store in dry and cool place. Smoking of this dried dirt on crops during evening hours minimized the thrips infestation as the tribes' believed.

Cow dung slurry + cow urine + virgin soil + neem leaves: Spraying of an extract obtained from cow dung slurry, cow urine, bund soil and neem leaves melt in water for a week managed sucking pests including thrips and whitefly on crop. To prepare a fermented extract, fresh 3 kg cow dung, 3 L cow urine, 250 g bund soil and 1 kg neem leaves are taken in a drum of 50 Ls capacity and then 30 L water is added and the drum is covered with a gunny sack. The contents are stirred for 7 days to ferment it completely. Fermented material is filtered through cotton cloth and spray solution is prepared by adding 1 L filtered material in 15 L of clean water and applied on infested crop plants as foliar spray for effective management of thrips and other sucking pests.

Arni leaf extract: Foliar spray application of arni [*Clarodendrum multiflorum* (Burm.f.) Kuntze non G.Don] leaf extract (terpeniods) at 10% was found effective for the management of thrips on coriander and other vegetables. For preparation of leaf extract, 1 kg arni leaves are collected, chopped and placed it in a pot with 2 L of water. The mouth is covered with cloth and kept as such for 2-3 days. The solution is filtered with cloth and the extract is diluted at 1:10 with water and 1ml/lit soap solution is added before spraying.

Whitefly (*B. tabaci* Genn.) and jassids (*Empoasca* spp.)

Smoking of cow dung and ashwagandha leaves: Farmers of tribal community practiced smoking of dried cow dung with ashwagandha [*Withania somnifera* (L.) Dunal] leaves (containing withanolides) in surrounding of vegetable field in morning hours twice a week to minimize whitefly infestation.

Tobacco leaf extract: Spraying of tobacco leaf decoction gives effective management of whitefly on vegetables. In this method, 250 g dry tobacco leaves are soaked in 1 L of water for 3-4 days and then the solution is filtered through muslin cloth following which spray solution in 1: 20 ratio is made and sprayed on infested crop to manage the whiteflies in okra, brinjal and chilli.

Mites (*Petrobia latens* Muller, *Tetranychus* spp.)

***Lantana camara* leaf and flower and karanj (*Pongamia pinnata* L.) leaf extract**: Use of *Lantana camara* leaf and flower and karanj leaf extract was found effective for the management of mites on vegetables like brinjal, okra, chilli and summer leafy coriander. For its use, equal quantity of leaves and flowers of both the plants taken and crushed with water to extract juice and diluted in water at 1:10 ratio for field application at inception of mites on plants and was found effective.

Cow urine: Spraying of desi cow urine with water at a ratio of 1:20 was reported effective for the management of mites on coriander, chilli and ladies' finger. Farmers also reported that foliar application of desi cow urine in a given ratio promote plant health and leaf colour.

Neem leaf extract: Tribal farmers of Southern Rajasthan use neem leaf extract for the management of sucking pests and mites on coriander and vegetable crops. In this method, farmers take 1 kg fresh neem leaves and crush it on stone slabs by rubbing round stone with required water, then the crushed material is placed in an earthen pot and 3 L of water is added and kept for 24 h. After that the extract is filtered and spray solution of 1:20 ratio is made for spraying on infested crop plants and is found to give good protection against mites.

Leaf eating caterpillars and borers

Leaf eating caterpillar or leaf defoliator (*Spodoptera litura* Fab., *Amsacta albistriga* Walk, *Hellula undalis* Fab.), cabbage caterpillar (*Pieris brassicae* Lin.), semi-loopers (*Thysanopulsia* sp.) and fruit borer (*Leucinodes orbonalis* Guen. and *Helicoverpa armigera* Hub.) mainly cause damage to many vegetables in the region. To manage these pests, tribal farmers apply certain age-old practices as described below.

Datura leaf + besharam leaf + green chilli + garlic extract: Fermented extract of datura, besharam leaves, green chilli and garlic clove was found effective for the management of leaf eating caterpillar and borers. For this, 1 kg datura (*Datura stramonium* L.) leaves, 500 g besharam (*Ipomoea fistulosa* Mart. ex Choisy) leaves which contain alkaloids and phenolic compounds was chopped and ground with 100 g green chilli (*Capsicum annuum* L) fruits of local cultivar and 100 g garlic (*Allium sativum* L.) clove (diallyl disulfide) separately and placed in a pot. The materials were mixed thoroughly and then 2 L normal water was

added and kept for 4-5 days for fermentation. On 5th day, the solution was filtered by squeezing of solid material in cotton cloth to get concentrated extract. Spray solution prepared by taking 500 mL extract/ tank (15 Ls) and spray on infested vegetable crops give good control of leaf eating caterpillar and fruit borers.

Kuwandia leaf + vetiver leaf extract: Aqueous leaf extract from kuwandia (*Cassia tora* Linn.) containing anthraquinones and vetiver (*Vetiveria zizanioides* Linn.) containing khusimol compound are used for the management of lepidopteran pests in tribal areas. For this, 1 kg fresh kuwandia leaves and 1 kg vetiver grass leaves are taken, chopped in small pieces and put in a pot. Then 2 L water is added and boiled for half an hour to soften the leaves. If required 1 L more water is added and kept for 3-4 days to get concentrated extract. One L extract is then taken and diluted in 15 L of water and sprayed on infested crops to get rid of leaf eating caterpillar and fruit borer on vegetables and coriander.

Satyanashi leaf and seed extract: For this, 1 kg green leaves of satyanashi or prickly poppy (*Argemone mexicana* Linn.) that contain sanguinarine and palmatine compounds are taken and cut into small pieces and also take 200 g of its seed, grind completely and place in earthen pot, add 2 Ls of normal water and keep it as such for one week. Filter the extract by squeezing in muslin cloth and prepare spray solution at 1: 20 ratio with clean water for spraying on infested crop which manages lepidopteran caterpillars effectively.

Gokhru leaf and seed + mahua flower + neem leaf extract: About 1 kg gokhru (*Tribulus terrestris* Linn.) leaves (saponins), 500 g sadden mahua [*Madhuca indica* (J.Konig) J.F. Macbr] flowers and 1 kg neem (*Azadirachta indica* A. Juss) leaves were collected, chopped in small pieces and soaked in double quantity of water in an earthen pot for a week. After that the fermented material were filtered through cotton cloth and spray solution prepared by adding of 500 mL extract /tank (15 Ls of water) and applied as foliar spray on infested crop for successful management of *Spodoptera litura* Fab., *Amsacta albistriga* Walk and beetles.

Dhamasa leaf + danda thor + keer cup extract: About 1 kg dhamasa (*Tephrosia purpuria* Linn.) leaves (contain tephrorin A and B), 1 kg danda thor (*Euphorbia neriifolia*) stem and 500 g of keer cup (*Viscum articulatum* BURM.F.) shoots were taken, chopped in small pieces and then boiled with 3 Ls of water for 30-45 min. The boiled material is kept for three days in the same pot but stirred twice a day for 2-3 min. The concentrated solution is diluted ten times in water and used as a foliar spray given good control of *H. armigera* and other lepidopteran caterpillars.

Castor trap crop: Raising of castor on border area as trap crop helped main crops and vegetables (tomato, chili, coriander and okra) escape from the damage of *H. armigera* and *S. litura.*

Beetles (*Aulacophora foveicollis* Lucas and *Epilachna vigintioctopunctata* Fab.)

Deep ploughing: Summer deep ploughing of fields after crop harvesting in the month of May and June exposed immatures and adults of beetles and reduced its infestation on vegetables including coriander.

Trapping devices: Blue or bright yellow colour plastic containers of 500 g to 1 L capacity was taken and filled with water by 3/4 portion, added 1 tsp detergent powder and placed at different locations in the field to attract beetles and kill them to minimize their population.

Setting of light traps: Tribal farmers setup oil lamps and bonfires during early rainy season near crop fields to minimize beetles' population. In this procedure, tribal farmers make 5-6 bowl type earthen pots as lamps in mustard oil/acre and keep on small wooden tripod stand on another big swallowed parat/tray filled with kerosenized water. The adult beetles are attracted on lightning of lamp and fall down in the kerosenized water and are killed. Tribal farmers also used bonfires during late evening in early rainy days for the control of beetles in their field.

Grasshoppers

Ker plant + neem leaf + negadi leaf extract: Chopped 500 g ker [*Capparis decidua* Edgew (ForssK)] plant shoots, 1 kg neem leaves and 1 kg negadi (*Vitex negundo* L.) leaves and soaked in 5 Ls of water for 24 h. After that the mixture material was boiled for an hour and then filtered through muslin cloth to obtain aqueous extract. One L of aqueous extract was added in 15 Ls of water and 10 mL soap solution and sprayed on infested crop which gave good result for management of grasshopper and aphids.

Neem seed kernel extract: Spraying of neem seed kernel extract managed grasshoppers in vegetables. In this tactic, farmers grind collected dried neem seed,

soaked in water for 1-2 days and then boiled for half an hour and sprayed on crops by adding 50 m prepared extract/L water at the time of grasshoppers attack mainly during rainy season gives effective management.

Butter milk + cow dung ash + adashishi leaf + datura leaf + baridhudi leaf + oonth kateli extract: A tribal pest management practice consisted of taking of 5 L butter milk, 250 g cow dung ash, 1 kg adashishi (*Xanthium strumarium* L.) leaves, 1 kg datura leaves, 500 g baridhudi (*Euphorbia hirta* L.) and 1 kg oonth kateli (*Solanum xanthocarpum* Schrad and Wendl) plant (leaves, stem and fruits), chopping them in small pieces and putting in a plastic drum and adding 5 L of normal water and mixing thoroughly. Drum's mouth is covered with gunny material, kept it for 10 days but material is stirred regularly once a day, if required 1-2 L water is added. The cocktail material gets fermented completely in 10 days, then the solid matter is crushed and extract is filtered by squeezing in cotton cloth and spraying on infested crop plants in 1:10 ratio (extract: water) to effectively manage all types of insects including grasshoppers and caterpillars as reported by tribal farmers of the region.

Quantitative analysis

The recorded pest problems on vegetables with particular reference to coriander were enlisted in eight pest's species based on used reports (Table 3). In all locations, aphid, thrips and leaf eating caterpillars and borers were categorized as major pest problem recorded with large number of UR. The calculated F_{ic} values were found in the range of 0.3 to 1 with mean value of 0.64 for all the locations (Table 3). The highest number of F_{ic} value (F_{ic}=1) for all groves was recorded for aphid followed by thrips and jassids (F_{ic}=0.8) and leaf eating caterpillars & borers (F_{ic}=0.7). These insects i.e., aphids, thrips, jassids leaf eating caterpillar and borers are the common pest problems on vegetables in all the locations. The lowest number of F_{ic} value (F_{ic}=0.3) recorded for mite infestation in all locations, showed that the informants have disagreed on the use of these indigenous practices for its management.

The study also recorded the use value (UV) in ranged from 0.09 to 0.69 for all the locations. The highest use value (0.69) was secured for indigenous pest management approaches i.e., Neem leaf extract; cow butter milk + cow dung ash + chilli seed powder; Neem seed kernel extract and ker plant + neem leaf + negadi leaf extract, wherein the plant species *A. indica* and *C. decidua* were recorded as most culturally essential species in all locations. *A. mexicana* recorded lowest UV with 0.09 in all the locations, which was used as satyanashi leaf and seed extract for the management of leaf eating caterpillar.

Effectiveness of selected indigenous practices of pest management at institute level

The effective indigenous pest management knowledge collected from age-old farmers of tribal hamlets in four districts of Southern Rajasthan. These practices were utilized for pest control in vegetables since long back, amongst them, ten selected indigenous tactics were evaluated at farmers field at nearby village Amlikheda of Pratapgarh district under the supervision of scientists of Krishi Vigyan Kendra (MPUA&T), Pratapgarh as well as ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan to validate their relative effectiveness against insect-pests on coriander under field conditions (Table 4). Study data revealed that a number of locally available wild plants posses several insecticidal properties i.e., antifeedant, repellent, oviposition disruptor, metamorphosis deterrent and toxicant action against a variety of pests. Amongst tested indigenous pest management approaches, per cent reductions in insect population were recorded in the range between 47.50 to 72.55%. The indigenous pest management practice consisted by ker plant + neem leaf + negadi leaf extract at 60 mL/L of water gave highest reduction (72.55%) in aphid population followed by the treatment consisted with cow butter milk + cow dung ash + chilli seed powder at 200 mL/L reduced 70.00% aphid and whitefly population and both the treatments were proved as most effective and significantly superior for the management sucking pests over the other treatments. *L. camara* leaves and flower + ker parts of plant + wild tulsi leaf extract at 10% and

Table 3 — Pest categories based on the information of used reports (UR)

Pests to be managed	F_{ic}
Aphid (*H. coriandri* Das, *M. persicae* Sulzer and *A. gossypii* Glover	1.0
Thrips (*T. tabaci* Lindeman and *F. schultzei* Trybom)	0.8
Whitefly (*B. tabaci* Gen.)	0.5
Jassids (*Empoasca* sp.)	0.8
Mites (*Patrobia lateens* Muller, *Tetranychus* spp.)	0.3
Leaf eating caterpillars and borers	0.7
Beetles (*A. foveicollis* Lucas; *E. vigintioctopunctata* Fab.)	0.5
Grasshoppers	0.5
Mean	0.64

Table 4 — Efficacy of some selected tribal pest management practices against pests on coriander crops

Treatment	Dose/ Cons.	Target pests	Population reduction (%)
T_1-Custard apple leaf and seed extract	10%	Aphid	47.50
T_2-Mahua leaf and flower extract	30%	Aphid	48.57
T_3-Kuwandia leaf + vetiver leaf extract	60 mL/lit.	Leaf eating caterpillar	53.84
T_4-Neem leaf extract	50 mL/lit.	Mites	61.37
T_5-Arni leaf extract	10%	Thrips	50.98
T_6-Cow butter milk + cow dung ash + chilli seed powder	200 mL/lit.	Aphid, whitefly	70.00
T_7-Dhamasa leaf + danda thor + keer cup extract	10%	Fruit borer	52.17
T_8-Lantana camara leaf and flower + ker plant + wild tulsi leaf extract	10%	Mites	66.52
T_9-Ker plant + neem leaf + negadi leaf extract	60 mL/lit.	Aphid	72.55
T_{10}-Untreated control	-	All insects	0.00
SEm ±			1.27
CD (p=0.05)			3.78

neem leaf extract at 20 mL/liter reduced 66.52 and 61.37% mites' population, respectively. Kuwandia leaf + vetiver leaf extract at 60 mL/L also found effective which gave 53.84% control of leaf eating caterpillars. Use of custard apple leaf and seed extract at 10% gave minimum per cent reduction (47.50%) in aphid population. Whereas, the other remaining treatments consisted with several plant products cocktailed with other bio-products, used as indigenous practice of pest management were also found effective against many pests under field conditions as compared to untreated control.

Traditional significance of study

In study region, most of the tribal farmers have marginal land holdings inside forest, foot hills and flat terrain; grow vegetables in a small area for their household use as well as for selling in the local market. Collected information shows that even now some tribal farmers use indigenous practices of pest management on vegetables including coriander. Because of inaccessible and far interior area and non-availability of specified chemical pesticides; these indigenous technologies become more imperative and feasible for insect-pest management particularly on vegetables which consume in fresh and raw conditions. These practices can be prepared easily at their own farm by using various material available naturally in the vicinity which are cheap, safe, eco-friendly and widely acceptable by the community. Validation of some selected tactics under the supervision of subject matter specialist prove that these are effective for controlling of insect-pests infesting vegetables under field conditions.

The information provided on various indigenous techniques i.e., plants, animal bi-products, local spiritual activities (exorcism) as well as cocktail preparations used as insect-pest management indigenously on crops are socially acceptable by the tribal community of the region. A number of wild plant species i.e., custard apple, jatropha, mahua, neem, arni, ashwagandha, ker, *Lantana*, *Ipomoea*, *Cassia*, *Vitex* etc., are tremendously available in the region having remarkable insecticidal properties against a number of vegetable pests. Documentation of such important indigenous practices of pest's management would carry forward among forthcoming generations and to be alive in future. It will also be beneficial to those farmers or vegetable growers who are not practicing these tactics even then crops being suffering pest attacks and causing measurable losses due to absence of effective chemical control. In the current agriculture era, indiscriminate use of chemical pesticides creates widespread hazard in available resources, health of living organisms and the environment. Similarly, some animal-based products like butter milk, cow urine, cow dung, pig excreta, hairs etc., can be utilized for preparation of several indigenous pest management practices. These tactics were found effective for controlling of various pests like aphid, thrips, whiteflies, beetles, mites and caterpillars on vegetables and other crops. They are cost effective, eco-friendly, sociologically acceptable and safe to predator and parasitoids. With this knowledge, researches may discover some potential bio-molecules from any utilized plant or animal byproducts for production of bio-pesticides that can do the marvel in the field of pest management.

This indigenous knowledge of pest management in vegetables including coriander is confined to age-old tribal farmers reside in tribal hamlets and has not been documented so far for the region, hence, in this

document, an attempt has been made to document their knowledge after its authentication.

Discussion

Indigenous pest management approaches are developed from the cheaper, easy and locally available materials, which are easy to prepare and feasible ecologically[1,3,4]. Further, it is developed mostly based on botanicals and animal byproducts and few are by mechanical and other spiritual means. In current era, people of Indian tribal communities are still living in interior geographical locations[1,4,5] having these marvel information that needs to be documented. A large portion of southern Rajasthan is dominated by tribal communities who have conserved several potential plants with medicinal properties. It is evident from the questionnaires that the age-old tribal farmers of southern Rajasthan are the reservoir of information adopted for insect-pests management indigenously on different crops including vegetables. So far, no researchers systematically documented these indigenous practices of pest management, hence published information could not be discussed particularly from this region. However, several wild plants, weeds, animal byproducts alone or in combinations are documented for sustainable pest management in many crops. Neem leaf extract can be used for control of aphids[17,18], rice weevil[15,19] and sucking pests on different crops. Butter milk + cow dung ash were reported for control of aphid, jassids and whitefly[20], Jatropha leaf extract, Calotropis leaf extract + garlic + chilli powder against vegetable pests[15]. *L. camara* leaf + wild tulsi leaf extract was reported effective against rice pests on rice[15], two spotted mites, *Tetranychus urticae* of vegetable, ker plant extract against aphids on coriander[21]. Aqueous leaf extract of adashishi (*X. strumarium*) reported 72.6% insect mortality when applied at 4% extract[22]. The other products viz., neem seed kernel extract, cow urine, cow dung slurry, vetiver leaf extract, argemone leaf and fruit extract, vitex leaf extract have also been used for the control of many pests subjected to various crops[23-27]. Aqueous extract of *A. sativum* contains tannins and terpenoids phytochemicals[28] and both the compounds showed insecticidal activity against sucking pests and borers.

Several wild plants i.e., *M. indica, A. squamosa, B. monosperma, C. multiflorum*, *W. somnifera, D. stramonium, I. fistulosa, C. tora, T. terrestris, T. purpuria, V. articulatum, X. strumarium* and *Solanum xanthocarpum* etc., were utilized by tribal farmers for preparation of numerous indigenous tactics of pest management and were found effective in management of many pests damaging variety of vegetables. Due to lack of published literature, it could not be compared and discussed. However, leaf extract of *A. squamosa, W. somnifera* and *D. stramonium* were also found effective for the management of aphids on coriander as reported[21]. *W. somnifera* is a xerophytic plant, available in plenty at Udaipur area of Rajasthan contains withanolides compound[29] illustrated feeding deterrent effect against wide range of pests. *A. mexicana* plant restrains sanguinarine and palmatine chemical acts as antifeedant and repellent action on many pests[30] get support to the present findings. The other ethnobotanical plants also have several insecticidal properties due to various chemical compounds present in their plant parts i.e., *M. indica* (saponin), *J. curcas* (tannins), *D. stramonium* (tropane alkaloids), *C. multiflorum* (terpenoids) responsible for the management of insect-pests in vegetables.

In the study area, aphid, thrips, jassid, leaf eating caterpillars and borers were recorded as major pest problem on vegetables. The highest number of F_{ic} value (F_{ic}=1) for all groves was recorded for aphid followed by thrips and jassids (F_{ic}=0.8) and leaf eating caterpillars & borers (F_{ic}=0.7). However, no such study was carried out in this region, hence the results could not be compared and discussed. The lowest number of F_{ic} value (F_{ic}=0.3) was recorded for mite infestation in all locations, showing that the informants disagreed on the use of these indigenous practices for its management. Mite's infestation observed on okra, brinjal, round gourd and chilli throughout the year cause significant yield loss. Similarly, the highest used report was determined for the indigenous pest management approach of neem leaf extract followed by cow butter milk + cow dung ash + chilli seed powder; Neem seed kernel extract and ker plant + neem leaf + negadi leaf extract but the results could not be compared and discussed due to lack of literature available.

Conclusion

It could be concluded from this study that few age-old tribal people of southern Rajasthan have abundant traditional knowledge and apply for insect-pests management in vegetables and other crops but it has not been documented so far. In current era of agriculture, chemical pesticides are highly used in

vegetable production in the country which results in several health hazards, environmental pollution, mortality of natural enemies and pollinators and pest resistance to insecticides. Indigenous practices of insect-pests management are excellent alternatives of chemical pesticides for sustainable agriculture. These practices are cheap, easy to prepare and use and are also safe for living ones and environment. It is therefore suggested that extension agencies should intensify their efforts to takeover these wealthy indigenous approaches and widespread in farming communities through various extension activities. Further, these practices should be nurtured very well and widely adopted in vegetable production in view of health benefits and properly documented to make these endangered age-old knowledge alive among forthcoming generations in the country.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

NKM and RSM conducted surveys at tribal districts of Southern Rajasthan. YK, BLR and NLD facilitated in collection of data from tribal farmers of Pratapgarh, Dungarpur and Udaipur districts, respectively. All authors provided critical feedback and helped in preparation of manuscript. The authors read and approved the final manuscript.

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