A Systematic Review of Ethnobotanical and Traditional Knowledge on Plant Extracts Reported to Repel Wild Boars

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ABSTRACT

The Indian Wild Boar (*Sus scrofa cristatus*) has become one of the most economically damaging vertebrate agricultural pests in South Asia. Farmer surveys in Himachal Pradesh report yield losses of 60-80% in badly affected fields, while national estimates place average multi-crop damage at 15-20% across maize, jowar, rice, *Brassica spp.* and vegetables, with the species consistently ranked among the top crop-raiding animals in household-perception studies. Because wild boar retain an IUCN "Least Concern" status and are currently listed under Schedule II of the Wildlife (Protection) Act, 1972 (as restructured by the 2022 amendment; formerly Schedule III under the original six-schedule framework), lethal control remains legally constrained, which positions non-lethal, farmer-adoptable repellents as the primary management pathway for smallholders who cannot afford solar or electric fencing (₹10,000-₹3,00,000 per acre). Wild boar relies predominantly on an exceptionally developed olfactory system (over 1,300 olfactory receptor genes, active from the prenatal stage) and possess comparatively weak, dichromatic vision, a combination that supplies a physiological rationale for odour- and taste-based botanical deterrents such as capsaicinoids and organosulfur compounds. However, the field evidence for such repellents is markedly inconsistent. This review synthesises the background of the conflict – including India's 2025 policy shift adding wild-animal crop loss as a Pradhan Mantri Fasal Bima Yojana (PMFBY) add-on cover, and Kerala's unresolved vermin-declaration dispute – alongside the sensory and behavioural biology that governs repellent design, and the primary field literature on ethnobotanical and botanical repellent efficacy. The review concludes that ethnobotanical repellents hold genuine but presently unproven promise for Indian smallholder agriculture, contingent on the development of controlled-release delivery systems, standardised efficacy protocols, and their integration within a broader Integrated Pest Management (IPM) framework rather than deployment as a stand-alone solution.

KEYWORDS: *Sus scrofa cristatus*; ethnobotanical repellents; human-wildlife conflict; crop protection; olfactory system; Economic Threshold Level; Economic Injury Level; VNO

INTRODUCTION AND BACKGROUND

Species status and the legal basis for non-lethal management

The Wild Boar (*Sus scrofa*) is classified as "Least Concern" by the IUCN, and the Indian form, *Sus scrofa cristatus*, is currently listed under Schedule II of the Wildlife (Protection) Act, 1972. This is a post-2022 designation: the Wildlife (Protection) Amendment Act, 2022, which came into force on 1 April 2023, consolidated the Act's original six schedules into four, and species that previously carried the lower-penalty protection of the old Schedule III – which included wild boar – were absorbed into the restructured Schedule II, a category of "other protected animals" that still carries significant legal protection [Government of India, Wildlife (Protection) Act, 1972; Wildlife (Protection) Amendment Act, 2022]. In practical terms, this means indiscriminate lethal control of wild boar remains illegal across most of India, and killing is permitted only through tightly regulated exceptions – principally Section 11 permits issued by a Chief Wildlife Warden, or the vermin-declaration mechanism under Section 62, which applies only where the Union government (or, under proposed state legislation, a state government) formally notifies a species as vermin in a defined area and period. This legal architecture is the central reason non-lethal, low-cost, farmer-adoptable repellents – including ethnobotanical formulations – occupy such an important place in India's crop-protection literature.

Scale and geography of the conflict

Crop-raiding by wild boar is severe and geographically widespread in India. Farmer surveys in Himachal Pradesh report yield losses of up to 60-80% in affected fields, while broader regional estimates place average damage across maize, jowar, rice, *Brassica spp.* and vegetables at 15-20% nationally, and household-perception studies from north India identify wild pig as one of the two most frequently cited crop-raiding species, alongside Nilgai (*Boselaphus tragocamelus*). Frequent crop damage has been documented in Kerala, Karnataka, Maharashtra, Himachal Pradesh, Uttarakhand, Gujarat, West Bengal, Odisha, Tamil Nadu and Andhra Pradesh. The conflict also carries a direct human-safety dimension: Kerala alone recorded 344 human deaths attributable to human-wildlife conflict between 2021 and 2025, with wild boar identified as a leading contributor to these encounters [Balakrishnan & Radhakrishna, 2025, as cited in Vidhi Legal Policy, 2026]. High-cost technical solutions such as solar or electric fencing, at an estimated ₹10,000-₹3,00,000 per acre, remain out of reach for small and marginal landholders, which is the principal economic argument for developing inexpensive, plant-derived repellent alternatives.

Recent policy developments

Two Indian policy developments from 2025-2026 directly frame the present review. First, on 18-19 November 2025 the Ministry of Agriculture and Farmers' Welfare approved a revision to the Pradhan Mantri Fasal Bima Yojana (PMFBY) recognising crop loss from wild-animal attack as a fifth "add-on cover" under the scheme's Localised Risk category, to be implemented nationwide from Kharif 2026. Under the revised framework, farmers must report losses within 72 hours through the Crop Insurance App and support claims with geotagged photographs, while states are tasked with notifying the list of locally responsible species and identifying vulnerable districts [Press Information Bureau, Government of India, 2025]. Second, Kerala's long-running request to have wild boar declared "vermin" under Section 62 of the central Act – which would permit unrestricted culling – has repeatedly been declined by the Centre; most recently, in July 2026 the Union Minister for Environment, Forest and Climate Change reaffirmed this refusal despite Kerala citing extensive crop losses and human casualties [The Federal, 2026)] In response, Kerala has pursued its own state-level Wildlife Protection (Kerala Amendment) Bill, 2025, which would transfer vermin-declaration authority to the state government and was forwarded to the President for assent in early 2026; the current interim mechanism instead relies on Local Self-Governments empanelling licensed shooters, who since 2025 receive a formal honorarium under strict monitoring, though the process is frequently slowed by its overlap with firearm-licensing procedures. This unresolved, administratively encumbered lethal-control pathway is precisely the context in which botanical and other non-lethal repellents continue to function as an active area of applied research.

Pest-Status Framework: Economic Injury and Economic Threshold Levels

Within Integrated Pest Management (IPM), organisms are classified according to their population dynamics and the severity of the damage they inflict. For a species to be classified specifically as a major pest, it typically must meet several ecological and economic criteria: the damage it causes must be substantial and consistently exceed the cost of control (conventionally, a yield loss of 10% or more if left unmanaged, which makes intervention financially justified); the damage must recur as a regular, seasonal occurrence tied to the standard agroclimatic conditions of the region, rather than flaring up only in unusual years; and the species' General Equilibrium Position – its average population density over time under natural regulation – must normally sit below the Economic Injury Level (EIL) even though its population curve regularly surges past the Economic Threshold Level (ETL) during the cropping season. Wild boar satisfies each of these criteria in the Indian context, given average multi-crop damage of 15-20% nationally (rising to 60-80% in badly affected Himachal Pradesh fields) and its consistent ranking among the country's principal crop-raiding species.

The standard bioeconomic model used to estimate the EIL is $EIL = C / (V \times I \times D \times K)$, where C is the management cost of implementing a control strategy per unit area, V is the market value or price per unit of crop yield, I is the injury caused by a single pest individual, D is the relationship between that injury and the resulting yield reduction, and K is the proportional reduction in pest damage achieved by the management action. The ETL is the lower, operational trigger point at which control measures should actually be deployed to prevent the population from climbing to the EIL; where it is set depends on subsidiary factors such as how rapidly the pest population is multiplying, the time lag between detecting the threshold and applying control, monitoring frequency, the crop's shifting physiological sensitivity (plants are typically most vulnerable during flowering or fruiting, which lowers the effective threshold), and the prevailing predator-prey or biotic-regulation balance.

It is worth noting however, that the EIL/ETL framework was developed primarily for arthropod pests with comparatively simple, density-dependent population dynamics, and its transposition to a wide-ranging, cognitively sophisticated vertebrate such as wild boar is imperfect. Recent reviews of wild-pig damage have specifically identified the absence of standardised, quantitative bioeconomic assessment – as opposed to farmer-perception-based damage estimates – as a major methodological gap limiting comparability across studies and regions [VerCauteren, Pepin, Cook et al., 2024].

Biology and Sensory Ecology Relevant to Repellent Design

Taxonomy, morphology and reproduction

Wild Boar belongs to the family Suidae, genus *Sus*, with up to 16 recognised subspecies across the species' Eurasian and North African native range; the form distributed across India, Nepal, Myanmar and Sri Lanka is *Sus scrofa cristatus*, the Indian boar. Adults measure roughly 0.6-1.9 m in length, stand 55-100 cm at the shoulder and weigh 50-200 kg, with pronounced sexual dimorphism in which males are larger and more robust and carry proportionally bigger tusks and skulls. Females reach sexual maturity at 5-10 months; gestation averages 115 days and litters average 4.2-5.7 piglets, rising to 10-12 under high food availability. Because breeding is not obligately seasonal, well-fed sounders can produce more than one litter annually, which is a principal driver of the species' high population density and rapid recovery from control efforts – a factor that limits how much any single repellent, however effective, can achieve on its own. Socially, females form stable, linear-hierarchy matriarchal groups ("sounders") of roughly 6-25 individuals, while adult males are largely solitary or form loose bachelor groups outside the rut. Wild boar is non-ruminant, hindgut-fermenting omnivores that, because hindgut fermentation extracts energy from fibrous material less efficiently than foregut fermentation, actively select easily digestible, low-fibre forage – which is precisely the profile of many cultivated grain, tuber and vegetable crops, and helps explain the intensity of crop-raiding behaviour.

Olfaction: the dominant sensory channel

The wild boar's primary sensory modality is olfaction. The porcine genome carries an estimated 1,301 olfactory-receptor (OR) related sequences, of which 1,113 are functional and 188 are pseudogenes – a repertoire substantially larger than that of cattle (970 OR genes) and even of dogs (811 OR genes), despite the latter's reputation as the benchmark olfactory mammal [Nguyen et al., 2012]. The olfactory bulb occupies roughly 7% of total brain volume, and detection relies on two parallel systems: the main olfactory epithelium for general odorant detection, and a fully functional vomeronasal organ for chemo-signal and pheromone detection linked to the flehmen response; unlike some domesticated lineages, wild boar shows no evidence of vomeronasal regression. This olfactory capacity develops unusually early: gene-expression activity in the olfactory mucosa is detectable before birth, preparing piglets for scent-driven foraging, predator avoidance and social recognition from the earliest stages of life [Fulgione et al., 2017]. Comparative transcriptomic work further shows that wild boar retains fuller olfactory-mucosa gene expression than domestic pigs, whose olfactory capacity shows signs of relaxed selection under domestication [Buglione et al., 2024] – an important caveat for repellent research, since it implies that behavioural findings obtained from domestic pigs may understate the olfactory acuity, and therefore the potential sensitivity to botanical volatiles, of free-ranging wild populations.

Vision: a comparatively weak, secondary channel

By contrast, wild boar vision is comparatively weak and dichromatic. Using electroretinogram flicker photometry, Eguchi, Tanida, Tanaka and Yoshimoto (1997) empirically demonstrated that wild boar possess two cone classes, meaning that blue wavelengths are readily perceptible while red and green are poorly discriminated from grey. Field of view is wide (roughly 310°, owing to laterally placed eyes) with a single blind spot directly behind the head, but overall visual acuity is low and the animals are functionally near-sighted relative to their olfactory and auditory senses. This sensory asymmetry has a direct, practical implication for repellent design: purely visual deterrents such as red reflectors, flashers or solar blinkers are mechanistically weaker cues than odour- or taste-based repellents, and where visual deterrents are used, colour choice matters – blue materials are more likely to register as salient than red ones.

Repellent Factors and Field Efficacy

This section reviews the primary field literature on the factors that have been tested to repel wild boar from crops, organised by the principal sensory channel and delivery mechanism exploited. Because wild boars are macrosmatic and only weakly photopic, most repellent research has targeted olfaction and taste, with visual and combined cues used chiefly as adjuncts.

Olfactory and gustatory botanical (ethnobotanical) repellents

The strongest positive results for plant-derived repellents come from small-plot Indian field trials. Rao, Kumar and Sakthivel (2019) tested castor oil, ginger extract and garlic extract both individually and in combination against wild boar in field crops, and found that a botanical mixture of castor oil, ginger extract and 25% garlic extract, delivered by soaking coconut-coir rope strung around field boundaries, achieved a mean crop protection of 95.9% relative to untreated controls over a 30-day period, with a reported cost-to-benefit ratio of roughly 1:5; critically, the individual components performed markedly worse than the combination, and the coir-rope delivery method outperformed bund-spray or sand-mix application of the same mixture, implying that both compound synergy and slow-release delivery are material to efficacy. This built on earlier work by Rao, Rao and Reddy (2013), who evaluated a non-poisonous, castor-based repellent against wild boar in maize crops around Hyderabad.

By contrast, the most methodologically rigorous European field trials report negligible efficacy for comparable olfactory and gustatory approaches. Schlageter and Haag-Wackernagel (2012a) tested a commercial odour repellent at baited luring sites across three regions of Basel-Land, Switzerland, and recorded a deterrent effect of only 0.4%, which was not statistically significant; the authors concluded the product was not recommendable for crop protection and expressed general scepticism toward fear-inducing odour repellents for this species. A companion study by the same authors [Schlageter & Haag-Wackernagel, 2012b] tested a gustatory repellent in clover, meadow and wheat fields and likewise found only a slight, non-significant trend toward reduced damage, with no detectable area avoidance by the animals. Zamojska, Bandyk and Olejarski (2014) similarly monitored repellent effectiveness in Polish fields and did not find that any of the tested measures – diversionary feeding, fencing, gustatory or odour repellents, acoustic devices, or optical deterrents – significantly reduced the proportion of damaged farmland. Most decisively, Faltusová, Ježek, Ševčík, Silovský and Cukor (2024) fitted 18 wild boar with GPS collars and installed 12 linear odour-fence sections (the same "Wildschwein-Stopp" product family) across their home ranges in the Czech Republic: the animals crossed the fence lines with statistically indistinguishable frequency before and after installation (20.5 ± 9.2 versus 19.9 ± 8.4 crossings), and average home-range size was unchanged (377.9 ± 185.0 ha versus 378.1 ± 142.2 ha), leading the authors to conclude that odour fences should not be relied upon for crop protection or for restricting wild boar movement.

A partial exception comes from short-term pilot work in Germany: Denzin, Helmstädt, Probst and Conraths (2020) tested seven physical and chemical deterrents at carcass-substitute luring sites near Greifswald and found that certain combinations – LED blinkers and aluminium strips among physical measures, and the chemical products – reduced the odds of wild boar contact to roughly one-third over the short trial period, although the authors explicitly recommended further, more rigorous testing of these candidates before drawing firm conclusions. Predator-derived olfactory cues have also shown promise: in a multi-year comparison of countermeasures in cornfields at Hunchun, Jilin Province, China, Li, Burns, Cui, Song, Zhao, Zhang, Zhang and Liu (2025) found that Amur tiger (*Panthera tigris altaica*) faeces, used as an olfactory deterrent, and playback of predator vocalisations, used as an auditory deterrent, both measurably reduced wild boar visitation, though electric fencing still provided the most reliable protection, sustaining effectiveness for up to 29 days; the same review notes that predator-scent deterrents produced a sustained effect over roughly 30 days in an earlier South Korean study, and that wolf-howl playback reduced wild boar foraging activity in Swedish agricultural fields.

Visual and combined visual–olfactory repellents

Given the wild boar's weak, dichromatic vision, purely visual deterrents have generally underperformed relative to olfactory measures, and their effectiveness appears to depend heavily on colour choice. Schlageter and Haag-Wackernagel (2011) evaluated solar-powered blinkers as a crop-protection measure and found them to provide only a modest, short-term reduction in wild boar visitation before efficacy declined, most likely because the animals rapidly habituated to a static light stimulus; a possible confound, noted in subsequent literature, is that the red LED units used may have been a poor choice of colour given that wild boar appear unable to reliably distinguish red from grey [Eguchi et al., 1997]. This is consistent with the Hunchun study, where red solar blinkers were judged a cost-effective but strictly short-term solution owing to rapid habituation (Li et al., 2025).

A well-documented case that combines both sensory channels comes from Japan: students at Gunma Prefectural Tone Technical High School constructed field-perimeter fences from suspended blue plastic pots together with red chilli peppers and reported that the combination excluded wild boar from a rice paddy for an entire growing season and remained effective for roughly 120 days in a separate wooded enclosure trial, whereas equivalent fences built with brown, black or red pots did not work [Nicol, 2016, reporting the students' project in The Japan Times]. This account is corroborated by subsequent Japanese agricultural-extension experience indicating that capsaicin applied alone tends to lose effectiveness quickly, whereas pairing capsaicin (a gustatory/olfactory irritant) with a blue visual cue – the one colour band wild boar can readily perceive – produces a more persistent deterrent effect than either stimulus alone. It should be emphasised that this is a well-publicised applied/extension case rather than a peer-reviewed, replicated field trial, and should be read as a suggestive proof-of-concept for combined visual–olfactory design rather than confirmatory evidence; a separate trial by Wakayama Prefecture's agricultural technology centre, testing red-pepper extract combined with pyroligneous (wood vinegar) acid without a blue visual component, reported no repellent effect, reinforcing that the colour pairing – not capsaicin alone – may be the operative variable.

Delivery format and persistence

Across the reviewed studies, how a repellent is delivered appears to matter as much as which compound is used. The Indian coir-rope trials show that slow-release delivery around field boundaries outperforms direct bund spraying or sand-mix application of the identical botanical mixture [Rao, Kumar & Sakthivel, 2019], while the negative European results are drawn overwhelmingly from single-application sprays, foam dispensers or static odour-fence products that are designed for periodic (weekly to bi-monthly) reapplication and are consequently exposed to volatilisation, rainfall, ultraviolet degradation and microbial breakdown between applications. The broader botanical-pesticide literature identifies exactly this short environmental persistence as the central obstacle to commercialising plant-derived repellents generally, and points to controlled-release technologies – silicone rubber dispensers, wax-based matrices, polymeric or microencapsulated carriers – as a means of extending active life (Isman, 2020); however, such delivery systems have been developed and validated mainly for insect pests and remain almost entirely untested specifically against wild boar, representing a clear translational gap between formulation science and vertebrate-repellent application.

Habituation and the split in the evidence base

A recurring theme across the literature is behavioural habituation: wild boar possesses strong spatial memory and rapid associative learning, and repeatedly encountering a static, unchanging deterrent – whether a light, a smell, or a taste – without a genuine negative consequence appears to erode its effectiveness over time [Li et al., 2025; Schlageter & Haag-Wackernagel, 2011, 2012a]. This helps explain why studies of short duration or small spatial scale (days to a few weeks, single fields) tend to report higher efficacy than studies using longer-duration, larger-scale, or GPS-telemetry-based designs, which are far better placed to detect whether an initial avoidance response persists. The clearest fault line in the literature is therefore not simply "botanical repellents work" versus "they do not," but rather a divide between (i) short-duration, small-plot trials using freshly applied, multi-compound mixtures with slow-release delivery, which report strong protection, and (ii) longer-duration, larger-scale, and instrumented (GPS-telemetry) trials of single-compound or commercial products, which consistently report negligible or statistically insignificant deterrence. Reconciling these two bodies of evidence, rather than treating either in isolation, is the central scientific challenge facing this field.

Reconciling Sensory Biology with Field Outcomes

The wild boar's sensory biology provides a coherent physiological rationale for pursuing olfactory and gustatory botanical repellents in preference to purely visual ones: an olfactory receptor repertoire exceeding that of cattle and dogs, a functional vomeronasal system, and prenatally active odour-processing machinery [Nguyen et al., 2012; Fulgione et al., 2017; Buglione et al., 2024] together imply that pungent, sulfur-rich or capsaicinoid-bearing plant compounds should, in principle, register strongly and aversively. Set against this mechanistic plausibility, however, the field record is genuinely mixed rather than uniformly supportive. The most parsimonious explanation is not that olfaction is an ineffective channel per se, but that (a) single, static, infrequently reapplied commercial products are readily habituated to and rarely maintain aversive intensity for more than a few weeks; (b) multi-compound botanical mixtures paired with slow-release delivery formats (such as coir rope) appear to outperform single compounds and simple sprays, though this evidence currently rests on a small number of Indian trials that have not been replicated at the scale or with the instrumentation (e.g., GPS telemetry) used in the negative European studies; and (c) combined visual–olfactory cues that respect the animal's actual colour sensitivity (blue rather than red) appear, in at least one well-documented case, to extend the deterrent duration considerably beyond that of either cue alone. None of the studies reviewed here, including the positive Indian trials, used the level of experimental control –blinding, randomised replication, GPS-verified boar presence, multi-season repetition – that would allow a confident, generalisable efficacy estimate to be stated for any single botanical formulation.

Research Gaps and Future Directions

- Standardised, replicated, and preferably blinded field protocols for measuring both crop damage and repellent efficacy, so that results from India, Europe and East Asia become directly comparable [VerCauteren et al., 2024; Nasiadka et al., 2025].
- Chemical identification of the specific bioactive volatiles responsible for avoidance behaviour in free-ranging wild boar specifically – as opposed to domestic pigs, whose olfactory gene expression differs measurably from that of wild populations [Buglione et al., 2024].
- Development and field validation of controlled-release delivery systems (wax matrices, microencapsulation, coir- or fibre-based slow-release carriers) purpose-built for wild-boar botanical repellents, translating principles already established in the botanical-insecticide literature [Isman, 2020].
- Longer-duration, larger-scale, and where possible GPS-telemetry-instrumented trials of the multi-compound botanical mixtures that have so far only been tested at small plot scale over 30-day periods.
- Systematic study of habituation dynamics and of rotation or synergy strategies (varying compound composition or pairing with visual/acoustic cues) that might delay the

decline in efficacy observed with static repellents.

- Integration of repellent evaluation with standardised bioeconomic assessment (EIL/ETL-type frameworks) and explicit cost–benefit analysis suited to smallholder adoption, an area that remains conspicuously under-studied relative to the volume of damage-documentation literature [Bengsen et al., 2014].
- Alignment of repellent research with India's evolving compensation and vermin-declaration policy landscape, including the new PMFBY wild-animal add-on cover and the unresolved Kerala vermin dispute, both of which shape farmers' practical incentives to adopt non-lethal measures.

Conclusion

Wild boar management in India sits at the intersection of a legally constrained lethal-control regime, severe and geographically widespread crop damage, and a sensory biology – dominant olfaction paired with weak, dichromatic vision – that offers a genuine physiological basis for ethnobotanical repellents. The available field literature, however, does not yet support unqualified confidence in any single botanical formulation: small-plot Indian trials of multi-compound, slow-release mixtures report near-complete crop protection, while larger, more rigorously instrumented European studies of commercial single-compound products report negligible effect, with habituation, delivery persistence and trial scale the most plausible sources of this discrepancy. Ethnobotanical repellents therefore remain a scientifically promising but methodologically unproven component of wild boar management – most defensible not as a stand-alone solution, but as one element within a broader Integrated Pest Management strategy that also draws on physical barriers, predator-derived cues, community-based monitoring, and the compensation and regulatory mechanisms that India's policy framework is now beginning to formalise.

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