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Fumigation of Plants in Vrikshayurveda

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Abstract

The practice of exposing plants, bushes, and trees to smoke (fumigation) in combination with other practices has been mentioned frequently in different treatises of Vrikshayurveda. Ingredients of smoke, produced by burning materials obtained from plants and animals, are organic chemicals that could be growth promoters and/or antimicrobials. This paper quotes 53 verses from different treatises of Vrikshayurveda in which smoking of plants is recommended. Analysis, based on published literature, reveals several different kinds of antimicrobials and some growth promoters such as karrikins. The significance and relevance of this information to present-day agriculture is elaborated and discussed. The author believes that there is scope to validate these past practices, and if found suitable, recommend them for adoption by farmers.

Exposing plants to smoke (fumigation) produced by burning various materials is recommended in different texts of Vrikshayurveda, which is offshoot of Ayurveda, for managing plant health (Sadhale, 1996, 2004, 2011; Ayangarya, 2006). Ayurveda recommends inhaling herbal smoke especially for treating respiratory (*vata* and *kafa*) disorders in humans; it is therefore natural that smoking or fumigation was recommended in Vrikshayurveda for treatment of certain disorders of plants. Folk medicine in different parts of India includes herbal smoking even today. In his treatise, Charaka Samhita, Charaka (c. 700 BC), the immortal physician of India, has prescribed inhaling smoke for various illnesses of head and neck, such as heaviness, pain in the ear and eyes, hiccups, discharge from ear, eye, and nose, toothache, spasm in jaw and neck, voice disorders, hair loss, and so on. Treatment materials included 32 different plants such as *harenuka (Vitex angus-castus), kesara (Croccus sativus), chandana (Santalum album), ela (Elettaria cardamomum),* and *guggulu (Commiphora wightii)* (Valianathan, 2003).

What is smoke?

Smoke is a collection of airborne solid and liquid particulates and gases emitted when a material undergoes combustion or pyrolysis, together with the quantity of air that is entrained or otherwise mixed into the mass. Smoke can be used for pest control. Smoke is also used in rituals, when incense, sage (*Sylvia* spp.), or resin is burned to produce a smell for spiritual purposes. Sometimes smoke is used as a flavoring agent, and preservative for various foodstuffs (http://en.wikipedia.org/wiki/Smoke).

Smoke contains germination-promoting compound and growth regulator

Fire and smoke have been used in indigenous agricultural systems for centuries. In recent years, biologically active compounds have been isolated from smoke with potential uses in agriculture and horticulture. Slash-and-burn techniques are practiced by many indigenous communities around the world for converting forests into crop fields. In Arunachal Pradesh of India, the ethnic Nocte tribe has maintained an age-old traditional slash-and-burn farming system on hill slopes (Kulkarni *et al.*, 2011). Flematti *et al.* (2004) reported for the first time a germination-promoting compound in plant- and cellulose-derived smoke. The structure of this compound, deduced from spectroscopic analysis and confirmed by synthesis, was shown to be that of the butenolide 3-methyl-2*H*-furo [2, 3-*c*] pyran-2-one. Water containing the smoke promoted germination. Light *et al.* (2005) further demonstrated that heating proteins with amino acids and sugars at 180ºC for 30 minutes produces water soluble extracts that promote germination and the chemical is the same butenolide.

This discovery of the smoke-derived butenolide 3-methyl-*2H*-furo [2, 3-*c*] pyran-2-one, termed "karrikinolide" excited many scientists because of smoke's potential application in the cultivation of agricultural and horticultural crops (Kulkarni *et al.,* 2011). Karrikins are a chemically defined family of plant growth regulators discovered in smoke from burning plant material, one of which is the karrikinolide (Chiwocha *et al.,* 2009). Karrikins are potent in breaking dormancy of seeds of many species adapted to environments that regularly experience fire and smoke. The recent discovery that karrikins trigger seed germination and control seedling growth in taxa that would rarely experience fire indicates that their significance could extend far beyond fire ecology. This is exemplified by the recent studies showing that seeds of *Arabidopsis thaliana* respond sensitively and specifically to karrikins in smoke.

Fatty materials are also burnt during smoke production. Acrolein (systematic name: propenal) is the simplest unsaturated aldehyde. It is a colorless liquid with a piercing, disagreeable, acrid smell. The smell of burnt fat (as when cooking oil is heated to its smoke point) is caused by glycerol in the burning fat breaking down into acrolein. It is produced industrially from propylene and mainly used as a biocide and a building block to other chemical compounds, such as the amino acid, methionine. Acrolein is a registered pesticide in California as an antimicrobial and is used to control fungi and bacteria in secondary oil recovery injection systems. Acrolein is also registered as an algicide and herbicide for control of algae and water borne weeds in lakes, ponds, reservoirs, and other aquatic areas (http://www.pesticideinfo.org/ Detail_Chemical.jsp?Rec_Id=PC35753).

With all the information that we have today on the antimicrobial and growth regulating properties of herbal and other kinds of smokes, we should acknowledge the wisdom gained through ages by our

ancestral sages, scholars, and innovative farmers. Fumigation with smokes was frequently recommended to manage insect pests, diseases, and growth, flowering, and fruiting of plants. Knowledge contained in Vrikshayurveda was ignored by us during the last two centuries. However, lately there is palpable interest in utilizing our ancient knowledge wherever possible (Nautiyal *et al.,* 2007). Nautiyal and colleagues demonstrated that fumigation of a chamber with odoriferous and medicinal herbs, called the "*Havan Samagri",* which has been used for centuries for "*yagnas*" ('yagna' – ritual of the sacred fire), reduced bacterial count by 94 percent and kept the chamber free from pathogenic bacteria for 30 days. The author firmly believes that the time has come to carry out in-depth research on fumigation procedures, which have been recommended in different treatises of Vrikshayurveda. Similarly, information on "smoking" planting pits and plant nurseries, which has been recommended in our ancient texts, needs validation for present-day use.

Smoke can be antimicrobial

It is well known that leaves of plants and trees are known to absorb many volatiles. Thus we could logically state that the volatile antimicrobials, released in the smoke after herbals and other non-herbal materials are burnt, act in controlling insect pests and microbial pathogens.

Material used for fumigation

In different Vrikshayurveda texts, we find mention of herbs, animal wastes, cow products, natural products, and others used for smoking plants. A summary of the materials recommended for fumigation in different texts of Vrikshayurveda has been made in Table 1.

Cow products

Milk and curd contain proteins, fats, and carbohydrates; ghee contains mainly the fats. Therefore, smoking with milk or curd should release mainly karrikins with possibly some acrolein; burning ghee will produce mainly acrolein. While karrikins will favor growth, acrolein will kill microbes.

Animal wastes

Flesh contains mainly proteins with some fats. It contains collagen, which contains specific amino acids – glycine, proline, hydroxyproline, and arginine. Collagen makes up approximately 30% of the proteins within the body. These are tough and strong structures found all over the body: in bones, tendons, and ligaments. The amino acids glycine and proline are important for providing immunity to plants to abiotic stresses. The eight essential amino acids are

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Table 1. Vrikshayurveda: Materials used for fumigation.

Item	Details
Cow products	Ghee, milk water, curd
Animal wastes	Flesh: Hare, human, pig, fish, horned animal Bones: Hog, cow, dog Shell: Crab Excreta (dung): Cat, hare, cow, hog Horn: Buffalo Shellac: Lac Urine: Goat, cow Fish: *Shafari*
Herbs and trees	White mustard seeds, flowers of *arjuna* tree, *bidanga* (*Embelia ribes*), turmeric powder, *triphala*, *amlaki* (*Emblica officinalis*), *haritaki* (*Terminalia chebula*), *bibhitaka* (*Terminalia bellirica*), sesame, barley, *ramatha* (*Ferula assafoetida*), *vacha* (*Acorus calamus*), *usana* or *krishna* (*Piper nigrum*), plantain leaf, Indian bdellium (*guggula*; *Commiphora wightii*), long pepper (*Piper longum*), aconite (*Aconitum napellus*), *bhallataka* (*Semecarpus anacardium*), costus root (*Saussurea lappa*), *koshataki* leaves (*Luffa acutangula*), *shipha* (*haldi*; *Curcuma domestica*), *indrabeeja* (*Citrullus colocynthis*), leaves of *kadali* (*Musa paradisiaca*), *unmatta* (*Datura metel*), *vatarika* (garlic), *mallika* (*Jasminum sambac*), *sinduvara* (*Vitex negundo*), *masha* (black gram), *yava* (barley), husk of a cereal, *nirgundika* (*Vitex negundo*), *sarpi* (*Sansevieria roxburghiana*), *kubera* (*Ficus microcarpa*), *netra* (*Opuntia elatior*), seed of *asana* (*Pterocarpus marsupium*), *sita* (*Pueraria tuberosa*), *nimbu* (*Citrus aurantifolia*), *musta* (*Cyperus rotundus*)
Natural products	Honey, soil
Prepared products	*Kunapajala*, fermented herbals, incense

phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, leucine, and lysine. They are called essential amino acids not because they are more important than other substances but because it is essential that they are included in the daily diet since they are not produced naturally by the body. These essential amino acids are present in dairy, fish, pulses, and whole grains.

Herbs and trees

The antimicrobial constituents present in herbs and trees recommended for fumigation in Vrikshayurvedas are listed in Table 2.

Flematti* et al. *(2004) reported for the first time a germination-promoting compound in plant- and cellulose-derived smoke.

This discovery of the smoke-derived butenolide 3-methyl-2H-furo [2, 3-c] pyran-2-one, termed "karrikinolide" excited many scientists because of smoke's potential application in the cultivation of agricultural and horticultural crops.

The chemical metabolites mentioned are: alkaloids, benzoquinones, diferuloylmethane, diosgenins, fatty acids (esters), flavonoids, glycosides, isothiocyanates, oleoresin gums, phenols, saponins, steroids, tannins, terpenoids, and thymoquinone. All these metabolites, which include essential oils, are carried in smoke and plants could be fumigated. All these also have antimicrobial properties.

Natural products

Honey caramelizes at high temperatures. Caramelization reactions also result in the formation of flavors (vapors). Diacetyl is an important flavor compound, produced during the first stages of caramelization. Besides diacetyl, hundreds of other flavor compounds are produced for instance furans, esters, and maltols. Hydroxymethylfurfural (HMF) is found in honey, juices, and milk. Hydroxyacetylfuran (HAF) has a sweet aroma and a low odor threshold. Diacetyl, HMF, and HAF have antimicrobial properties.

In one of the verses of Vrikshayurveda smoking of a growing sapling by burning ghee mixed with soil is mentioned. The import of mixing soil is not clear unless we conjecture that the organic matter in the soil produced karrikins.

Prepared products

As pointed out earlier, *kunapajala* contains disintegrated proteins, carbohydrates and fats; therefore it is logical to expect release of karrikins (growth regulator) and acrolein (antimicrobial) in the smoke. Fermented herbals, when burnt, could be expected to

Fatty materials are also burnt during smoke production. Acrolein (systematic name: propenal) is the simplest unsaturated aldehyde.

With all the information that we have today on the antimicrobial and growth regulating properties of herbal and other kinds of smokes, we should acknowledge the wisdom gained through ages by our ancestral sages, scholars, and innovative farmers. Fumigation with smokes was frequently recommended to manage insect pests, diseases, and growth, flowering, and fruiting of plants.

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Table 2. Antimicrobial constituents in plants recommended for fumigation.

Plant (or product)	Latin name	Antimicrobial chemical constituents present
Aconite/*Ativisha*	*Aconitum heterophyllum*	Several alkaloids and flavonoids; antimicrobial
Arjuna	*Terminalia arjuna*	Arjunolic acid, tannins, glycosides; antimicrobial
Asafetida/*Hingu*	*Ferula assafoetida*	Oleoresin gum; antimicrobial
Asana	*Pterocarpus marsupium*	Bark: alkaloids, glycosides, flavonoids, phenols, and terpenoids; antifungal, antibacterial, and antiviral
Bhallataka	*Semecarpus anacardium*	Biflavonoids, phenolic compounds, bhilawanols; antimicrobial, anti-termites
Bidanga, vidanga	*Embelia ribes*	Benzoquinone derivative embelin; anthelmintic, antibacterial, and antifungal
Canda, kebuka	*Costus speciosus*	Diosgenins, benzoquinones; antimicrobial
Datura, unmatta	*Datura metel*	Steroidal with ametelin; antifungal, antibacterial; dried leaves smoked in cigar for asthma
Guggula	*Commiphora wightii*	Alkaloids, glycosides, steroids, terpenoids, flavonoids, and oleo gum resin; antibacterial
Haridra	*Curcuma domestica*	Diferuloylmethane (curcumin) and several curcuminoids; antibacterial, antifungal, and antiviral
Indrabeeja	*Citrullus colocynthis*	Flavonoids, tannins, terpenoids; antimicrobial
Ingudi	*Balanitis aegyptiaca*	Saponins, glycosides, fatty acids; antimicrobial and anthelmintic
Kalajaji, upakunchika	*Nigella sativa*	Thymoquinone; antibacterial
Karanja	*Pongamia pinnata*	Flavonoids; antibacterial
Kosataki	*Luffa acutangula*	Terpenoids, steroids, flavonoids, and glycosides; antifungal and antibacterial
Kubera, plaksah	*Ficus microcarpa*	Aerial roots rich in phenolics; antibacterial and latex antifungal
Lasuna, rasona	*Allium sativum*	Allicin (organosulfur compound) works against fungi, bacteria, nematodes, and viruses; insect repellent
Mallika	*Jasminum sambac*	Alkaloids, glycoside, flavonoid, triterpenes, saponins, tannin, resin, and salicylic acids; antifungal, antibacterial, and anthelmintic
Maricha	*Piper nigrum*	Volatile oils; antibacterial
Masha	*Vigna mungo*	Mucilage; suspending and binding agent

continued

Table 2. *continued*

Plant (or product)	Latin name	Antimicrobial chemical constituents present
Musta	*Cyperus rotundus*	Oil contains 16 compounds [oxo-isolongi folene, α-gurjunene, (z)-valerenyl acetate, α-salinene, etc.]; antibacterial and antifungal
Nagaphana	*Opuntia* spp.	Alkaloids (3-methoxytyramine, candicine, and hordenine)
Neem	*Azadirachta indica*	Neem oil contains limnoids (triterpenoids) such as nimbine, nimbinine, nimbidine; insecticidal and antibacterial
Nirgundi	*Vitex negundo*	Alkaloids (nishindin and hydrocotylene)
Pippali	*Piper longum*	Resin, alkaloids – piperine, piper longuminine, one terpenoid; antibacerial and anthelmintic
Rajika	*Brassica nigra*	Isothiocyanates; antimicrobial
Sarjah	*Vataria indica*	Phenols and flavonoids; antibacterial
Sarpi	*Sansevieria roxburghiana*	Saponins, flavonoids, phenols, alkaloid, glycosides, etc.; antibacterial and antifungal
Tilah	*Sesamum indicum*	Antioxidants and phenols (sesamol, sesamolin, and sesamin); antifungal and antibacterial

release antimicrobial ingredients present in such herbals. Burning incense will release volatile essential oils that usually possess antimicrobial properties.

Vrikshayurveda texts

Verses on fumigation from different Vrikshayurveda texts are given below. (Few verses have not been included to avoid repetition.)

Surapala's Vrikshayurveda

1. "An expert should treat the plant by coating with sesame oil cake and *bidanga (Embelia ribes)* – the insecticide – by sprinkling mixture of milk and water and the liquid fertilizer (*kunapambu)* and by **smoking with ghee.**" (V.100)

2. "The trees give extreme satisfaction by their fruits and flowers when rendered free even from the suspicion of impurity by subjecting them to the **treatment of smoking by the mixture of white mustard seeds, flowers of the *arjuna (Terminalia arjuna)* tree, and flesh of the hare added**

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Kunapajala ***contains disintegrated proteins, carbohydrates and fats; therefore it is logical to expect release of karrikins (growth regulator) and acrolein (antimicrobial) in the smoke.***

to a combination of antiseptic (*bidanga*) and turmeric powder." (V.116)

3. "The trees yield rich reward in the form of flowers and fruits in a short period when smoked with the mixture of plantain leaves, white mustard seeds, and a small shining variety of fish." (V.117)

4. "Trees which are smoked heavily by a mixture of ghee, milk-water, and honey become full of flowers and fruits in a short time." (V.119)

5. "When its trunk is smeared with honey fully dissolved in fresh ghee and *safari* fish and **when smoked with the powder of *triphala* mixed with ghee** the pomegranate tree bears fruits of bigger size." (V.130)

6. "*Karkandhu* (*Ziziphus nummularia*), *lakucha* (*Artocarpus lakoocha*), *badari* (*Ziziphus mauritiana*), *dhatri* (*Emblica officinalis*), and *jambu* (*Syzygium cumini*) trees when smeared with a mixture of ghee, honey, *krsara* (spiced food preparation with sesame, rice, and peas), and *lodhra* (*Symplocos racemosa*), enriched with the thick paste of barley or **when smeared and smoked well with sesame, honey, and barley for twelve days**, and watered with milk-water at the blossoming time bear good fruits." (V.135)

7. "Orange trees bend down with fruits when fed with plenty of water mixed with *bidanga (Embelia ribes)*, black gram (*Vigna mungo)*, sesame, mustard, and *bilva (Aegle marmelos)* along with water mixed with turmeric powder and flesh of rabbit, and when **smoked with the rabbit flesh.**" (V.142)

8. "The vegetables of the type of *birbhati (Vigna catjang), alambu (Lagenaria vulgaris), karkaru (Cucurbita pepo), trapusa (Cucumis melo),* etc. produce rich yields **when smoked in summer with the bones of hogs.**" (V.155)

9. "The worms accumulated on trees can be treated quickly by smoking the tree with the mixture of white mustard (*Brassica alba)*, *ramatha (Ferula assafoetida), vidanga (Embelia ribes), vaca (Acorus calamus), usana (Piper nigrum),* and water mixed with beef, horns of buffalo, flesh of pigeon, and the powder of *bhillata* (*bhallataka; Semecarpus anacardium*)." (V.195)

10. "If the branches are burnt they should be cut off and the particular spots should be sprinkled with water and milk and **smoked with the shells of crab**, etc. Thus treated the trees will put forth fresh sprouts." (V.204)

11. "If the drying is due to the lack of water, the trees should be watered with milk-water and properly **fomented by the smoke of crab shells.**" (V.209)

12. "Vegetables of cucumber types get cured of diseases when smoked around by the bones of cow and dog mixed with excreta of cat." (V.220)

13. "Trees produce flowers and fruits out of season undoubtedly if the following procedure is followed: *Varahi, jira* (cumin seed) and sugarcane juice should be kept for a month in a pot containing ghee prepared in the moonlight and when the mixture is well formed, roots of the trees should be smeared with it, and the basin should be filled with mud. Then sugarcane juice should be profusely sprinkled **and the trees should be smoked with honey and *kunapa*.**" (V.230–231)

14. "A tamarind plant is grown into an excellent creeper if fed with water, mixed with powder of *triphala,* sesame, barley, and black gram and then **smoked well with turmeric powder.**" (V.253)

15. "A pomegranate seed sprinkled several times with the blood of a cock and dried up in the sun and then sown immediately bears fruits, if watered and **smoked with human flesh and marrow.**" **(**V.280)

Sarangadhara's Upavanavinoda

16. "A fruit ripened in its natural season should be dried and seed should be extracted from the same. It should be drenched in milk and dried for five days and **then smoked with *sarpi* mixed with *bidanga.***" (V.51)

17. "Seed soaked with milk, besmeared with ashes of *brihat, tila,* and *sarpis*, rubbed with cow dung and sown, sprouts on the same day (soon) after **it is smoked with marrow.**" (V.52)

18. "*Dadima* tree smeared with the powder of *triphala* (*amlaka, haritaki,* and *bibhitaka*) mixed with ghee and *shafari* and **smoked liberally with *triphala* mentioned above, with mango fruits (?), yields fruits which surpass of *tala* in size.**" (V.152)

19. "All kinds of creepers are loaded with fruits (pods) if pierced with 'scorpion-sting' **smoked with ghee**, and sprinkled with the marrow of rat and hog." (V.160)

20. "Newly planted trees grow very well if they are **smoked with ghee mixed with soil**; are sprinkled with water in which *yava* is, or with mixture of milk and water, or with *kunapa;* and are smeared with paste of *bidanga* and *tila.*" (V.166)

21. "If new shoots and flowers of a tree droop down without any detectable morbidity and appearance is 'blown', there would be insects at its roots. They must be removed physically with effort. Roots should be smeared with a mixture of cow's urine, ghee, *vidanga*, mustard seeds and sesame, which will destroy insects. The tree should be sprinkled with water mixed with milk and then **smoked with incense.**" (V.183)

22. "To transform odorless flowers of trees into very fragrant ones, supply soil scented with fragrant flowers; sprinkle scented water of decoction of *dhava* and *khadira*; besmear with sandalwood powder and **smoke with the incense of ghee.**" (V.196)

23. "To make seeds of any tree grow and blossom amazingly fast, sprinkle them with milk mixed with marrow and flesh of fish and hog **and smoke it with the incense of the same.**" (V.207)

Chavundaraya's Lokopakara (Chapter VI; Vrikshayurveda)

24. "The seed treatment prior to sowing is as follows: Seeds of a naturally ripened fruit are to be collected, mixed well with cow dung and dried (in shade) for five nights (and days). This has to be soaked in milk for seven days. Afterwards, it has to be coated with the mixture of Indian nightshade (*Solanum indicum*) fruit juice and salt water. **This coated seed is to be fumigated with the powder of *vidanga* (*Embelia ribes*) seeds and ghee.**" (V.6)

25. "The plants should be sprinkled with curd-rice for protecting them against hailstones. Plants have to be fumigated (?) with the ash of a tree burnt by thunderbolt for protecting them from the frost. **Fumigation of the plants with fish meat, mustard, and plantain leaf helps them to grow vigorously and stoutly.**" (V.10)

26. "**Fumigation of trees with mixture of the powders of the following ingredients** makes them disease-free. They also bear abundant fruits. The ingredients are *vidanga,* Indian bdellium, fish meat, turmeric, mustard, and *arjun* flowers." (V.12)

27. "For making a barren sweet orange tree to yield abundant fruits, the decoction of jaggery (from cane sugar), meat, and milk should be regularly applied to the basin. **Further the tree should be anointed or fumigated with hare dung.**" (V.33)

Someshvardeva's Manasollasa (Chapter on Vrikshayurveda-Bhudharakrida)

28. "A learned horticulturist should fumigate the trees and plants with the mixture of turmeric, *vidanga*, white mustard, flowers of *arjuna*, fish, and flesh of horned animals." (V.29)

29. "The above fumigation helps the trees and plants to bear increased flowers and fruits. It repels insects early and cures the diseases of trees." (V.30)

30. "*Vidanga*, *hinga*, and long pepper grown near a river, aconite, *vacha*, *bhallataka*, and buffalo horn should be (powdered) mixed in equal parts." (V.31)

31. "And **burnt in the garden**. This cures all types of plant diseases and kills the insects." (V.32)

32. "**Fumigation of the milky trees like banyan and cluster fig** with the mixture of lac and costus roots, enables them to fruit at all times. The mixture of costus roots, cow's milk, and –" (V.39)

33. "– goat's fat, if sprinkled over the climbers, yield fruits at all times." (V.40)

34. "**The fumigation of climbers** infested by insects with cow's ghee, or sprinkling them with the mixture of the fat of boar and rat, enables them to set pods all-round the year." (V.41)

Chakrapani Mishra's Vishvavallabha

Chapter VII (Nourishment and growth)

35. "Sprinkling with *kunapa* is always beneficial to all the trees for increasing the produce of fruits and flowers. Especially in the case of ***dadima* trees even fumigation with its vapors** results in growth of big-sized fruits." (V.6)

36. "When *dadima* tree is smeared with a mixture of fish, ghee, and *triphala* and then fumigated with ghee and *triphala*, its fruits ripen well besides being large in size." (V.7)

37. "*Madhuka* bears plenty of flowers when sprinkled with decoction of *koshitaki* leaves and *shipha* in combination with *krishna*. That the same result follows also when it is thoroughly fumigated by the same mixture is indeed a wonder." (V.19)

38. "A good sprinkling at the root of the basin with oil mixed with *bhillata* root, *yava*, milk, *bidanga*, and with water mixed with *indrabija* and depositing dried cow dung in the soil as **also a fumigation** with the same is conducive to growth of trees removing their impurities." (V.36)

39. "A powder of *siddhartha, kadali* leaves, *shafari* fish, and dung of hog and cat all taken in equal proportion mixed with ghee is beneficial for the growth of trees. **When used for fumigation and smearing of trees, it acts as strengthening medicine removing ailments and the bouncy tree, covered with blossoms looks healthy with branches and leaves so also with fruits.**" (V. 37) (Same as in Sarangadhara's Upavanavinoda.)

40. "Smearing with *bidanga, tila,* and honey, **fumigation with ghee,** good soil in the basin, and sprinkling with water mixed with *yava* and milk as also with *kunapa* will be very helpful for the growth of newly planted trees." (V.38)

41. "**Fumigation and smearing** with *unmatta, vatarika, mallika,* mixed with *sinduvara, tila,* and *masha* and with *yava,* ghee, and honey mixed with milk as also sprinkling with water with the same mixture is also helpful." (V.39)

42. "Equally beneficial is smearing with *sunthi,* ghee, honey, *bidanga, kushta,* **fumigation with husk and *bidanga***, and sprinkling with *kunapajala*, especially in the case of trees with milky juice." (V.40)

43. "Filling basins with good quality soil, **sprinkling at roots with urine of goats, fumigating thoroughly with its vapors** and sprinkling with water is immensely helpful to rid the trees of diseases and to make them grow healthy." (V.41)

Chapter VIII (Diseases and control)

44. "**Fumigation with a mixture of** *nirgundika, guggula, shepha, sarpi, kubera, netra*, seeds of *asana* as also filling goat dung and oil cake at the root yield favorable results in the treatment of wind disorders." (V.15)

45. "The bile imbalance can be cured if treated with *ushira, musta*, honey, milk, and *sarpis* or if the tree is smeared with *jambala*… or **fumigated with *sita*, honey, and large quantity of clarified butter.**" (V.18)

46. "Powdered leaves of *kankata* provided at the root and **fumigation and sprinkling with a mixture of honey and ghee** free the tree from indigestion." (V.30)

47. **"Fumigation by a mixture of** *sita*, clarified butter, and *guggula*, cures the disease of the tree and it becomes beautiful again with the growth of lovely foliage and healthy bark." (V.34)

48. "Fumigation by the mixture of cow's horn, *bhallataka, nimbu, musta*, *vacha, vidanga, ativisha, karanja, sarja, siddharthaka*, and *sinduvara* draws out insects from within the trees." (V.41)

49. "Applying paste of cat's dung, jackal, and hog mixed in *siddhartha*, and cow's urine draws out insects hidden inside the trees and **fumigation by the same mixture along with ghee wipes out the external ones.**" (V.42)

50. "**Fumigated with a mixture** of *nimba, siddhartha, vacha, vidanga, hingu*, and bark of *arjuna*, in combination with *tila*, milk, and water and sprinkled with a mixture of milk and water, a tree infested with insects (is freed from the pest and) once again becomes green with (a new growth of) branches and tender leaves." (V.43)

51. "All trees can be relieved from insects by sprinkling water mixed with fruits and bark of *ingudi*, and raw sugar. By applying a paste of milk, ghee, raw sugar, and *ingudi* or by **fumigating with the same and by tying dog's bone on them, will rid the tree of insects.**" (V.44)

Chapter IX (Botanical wonders)

52. "Allow *varahi* to stay for 3 days in the mixture of ghee, *kunchika, bidanga, raji,* unclarified ghee (butter), and *triphala (amlaki, bibhitaka,* and *haritaki)* along with sugarcane juice. Smear the root of the tree with it. Fill fresh soil and **fumigate the tree thoroughly with the same mixture**. Sprinkle with sugarcane juice. The tree then produces flowers and fruits out of season." (V.18)

53. "Sprinkle a *draksha* creeper with sugarcane juice after mixing *yava* powder thoroughly in it. **Fumigate it with a mixture of ghee and *bidanga***. It will surely produce sweet fruits when it ripens in the season." (V.46)

Recommendations

Recommendations of smoking or fumigation, in all the 54 verses considered together, reveal the following.

1. Smoking is not carried out by itself; it is in combination with other treatments.

2. The smoking treatment is given to trees (and vegetables) specifically *Artocarpus lukoocha* (lakucha), *Citrus reticulata* (orange), *Cucumis melo* (*trapusa*), *Cucurbita pepo* (*kurkaru*), *Emblica officinalis* (*dhatri*), *Ficus benghalensis* (banyan), *Ficus glomerata* (cluster fig), *Lagenaria vulgaris* (*alambu*), *Madhuca indica* (mahua tree), *Punica granatum* (pomegranate), *Syzygium cumini* (*jambu*), *Tamarindus indica* (tamarind), *Vigna catjang* (*birbhati*), *Ziziphus mauritiana* (*badari*), and *Ziziphus nummularia* (*karkandhu*).

3. Smoking is prescribed for controlling different insect pests and diseases.

4. Smoking is also done to improve growth, hasten flowering and fruiting, produce large and sweet fruits, and keep plants healthy.

Farmers' practices

Farmers even today follow the practice of smoking crops. There are many farmers in India who burn different materials to

produce smoke for solving local problems (ICAR, 2003). Only a few examples are given below:

1. To avoid yield losses due to blister beetle in pear millet in Balaya village (Nagaur district) of Rajasthan, farmers use camel bones. The bones of a dead camel are sun-dried, crushed into coarse powder, and burnt along with trash around fields. Crushed camel bones contain a group of proteins called collagens and chondroitin sulfate, composed of a chain of alternating sugars (N-acetylgalactosamine and glucuronic acid). Presence of both proteins and sugars will lead to production of karrikins and insecticidal sulfur products.

2. In some districts (Dahod, Mehsana) of Gujarat, farmers effectively reduce occurrence of leaf curl in chili by producing smoke from *guggula (Commiphora wrighti)* mixed with dried cow dung cakes or maize flour and sugar. Materials to be burnt are placed in saucer-shaped earthen pots and carried around the fields of chili. *Guggula* contains antimicrobial substances (Table 2).

3. Trash consisting of fallen leaf and stems are used to produce smoke around orchards to repel fruit fly and fruit-sucking moths in the Aizowl area in Arunachal Pradesh. Biological smokes are usually insecticidal or insect repellents.

Antimicrobial properties of material used for smoking

If we look into the chemistry of the materials recommended in different treatises of Vrikshayurvedas, we see that the cow products as well as animal wastes mainly contain proteins, fats, carbohydrates, vitamins and minerals. Honey contains carbohydrates, proteins and amino acids, vitamins, minerals, and metabolites – antioxidants. Products such as *kunapajala* would contain chemicals that came from the basic materials used in fermentation. Herbs contain chemicals that need to be highlighted. Table 2 provides the information on herbs. The chemical metabolites, which are present in the herbs, have been mentioned earlier.

Rabbing (parching) for paddy disease management

The word *rab* in Marathi (possible origin: in Sanskrit *raksha* means ash, which is *raakh* in Marathi; *rab* may be the corrupt form of *raakh*) signifies burning. *Rabbing* (parching) paddy nursery soil controls most seedling and adult paddy plant diseases in the field. This is a practice of burning refuse to parch the soil reserved for raising nurseries before the advent of monsoon. The following steps were taken: (i) Elevated land for nursery was bunded to prevent surface washing; (ii) A thick layer 2.5 to 5 cm of broken cattle dung cakes (when plentifully available) was placed in the nursery; (iii) A layer of leaves or chopped loppings (preferably of *Terminalia tomentosa*) was placed to provide intense heat; (iv) A layer of dry grass was then placed; and (v) A layer of finely divided straw or husk was placed to close openings between the stems of the coarse grass and prevent the earth (final layer) falling through. To prolong burning, the fire was started on the lee side.

The system of *rabbing* is commonly practiced in Thane district of Maharashtra and was first documented in 1787 (Nene, 2005). A part of the ash provides nutrients (mainly calcium, potassium, zinc, boron, and silica) and the weeds are reduced. Rice seedlings grow vigorously. It is possible that the plants might be getting exposed to karrikins that could have been present in the nursery water after *rabbing.* Farmers also find the nuisance of weeds, pests, and diseases greatly reduced in the transplanted crop from the *rabbed* nurseries. It is claimed that yields double if the practice of *rabbing* is followed. It is intriguing why most rice researchers in the last 60 years have outrightly dismissed the practice of *rabbing* on the grounds of 'wasting' compostable organic matter. This argument does not hold ground because the organic matter thus burnt for *rabbing* is so little and the benefits are likely to exceed the loss of burnt organic matter. The author has reproduced below relevant paragraphs from http://www.agf.gov.bc.ca/range/publications/documents/fire2.htm.

"Numerous exchangeable cations including phosphorus, potassium, calcium, and magnesium typically increase following a fire. This results in an abrupt release of elements, which in the absence of fire, would only have become gradually available through the slow decay of plant litter. These cations are generally released during various combustion stages with the total amount released being dependant on fire severity, intensity and fuel type. Overall, in most cases, a fire increases the amount of nutrients available, and as a result nutrient cycling is increased."

"Nitrogen may be reintroduced back into an ecosystem via symbiotic and non-symbiotic fixation. Fixation, which is commonly more active following fires, can in some ecosystems actually restore lost nitrogen. This process is generally facilitated by both heterotrophic (cannot survive on its own) bacteria as well as symbiotic fixation taking place within nodulated plant roots. Nodulated plant roots occur in numerous plant species including alder, *Ceanothus* and various legumes. Depending on the site, bacterial fixation in decomposing wood may also provide an important post-fire nitrogen source. The process is enhanced by the ash and the blackened soil surface which acts as a black body (absorbs energy and warms quickly)."

"While various nutrients can become more available during and after a fire, others may be volatilized and thus lost during a fire. Volatilization, which is temperature dependant, most commonly affects nitrogen and to a lesser extent, sulphur, phosphorus and carbon. Even though volatilization removes nutrients from a system, it can also convert them to a more available form. For example, nitrogen is often converted to the more available form ammonium, during the volatilization process. Thus, even though the total amount of nitrogen on a site decreases, the amount of available nitrogen to plants may actually increase or decrease, depending on the site."

"Some nutrients may also be lost by other means including convection, runoff, or leaching. This loss while generally insignificant for prescribed burns, may,

depending on fire severity, be significant during or after intense wildfires."

"Silicon is not classified as an essential mineral for plants, except for certain algae and Equisetaceae (Division: Pteridophyta). Silica, which is released during *rabbing,* provides increased resistance to chemical (high levels of salt or toxic metals) and physical stresses (drought and high temperature). It also adds strength and stiffness of the stems and leaf blades thereby increasing light interception and also increases pest and fungal resistance. This has led to the utilization of silicon fertilizers for sugarcane and rice, which show decreased yields when silicon accumulation is low."

Rabbing is still practiced in India by small farmers. It is noteworthy that *rabbing* nursery soil was reported from Karimnagar and Warangal (Andhra Pradesh), Dang (Gujarat), Shimla (Himachal Pradesh), and Sindhudurg (Maharashtra) (ICAR, 2003). Burning of soil with agricultural wastes was practiced before taking up vegetable cultivation of amaranth and cucumber. This was the kind of disinfection practice for soil-borne problems. Burning of soil with huge quantity of agricultural wastes was being practiced and such soil was known as '*sudumannu*' in coastal Karnataka and was used for growing various crops (personal communication: M Gangadhara Nayak, Cashew-Puttur-574 202, Dakshin Karnataka). The author sincerely hopes that better sense would prevail on rice researchers, who would try to research *rabbing* in depth.

Methods of applying smoke

There is hardly any information available from Indian texts on how the smoke was applied to trees and plants. Some of the indigenous practices involved burning piles of dry plant material, dried cow dung, husk, and coconut coir spaced around fields or in orchards; recommended herbals or other materials were dropped in the burning piles.

Plastic tents

Sown seed trays or whole seed are placed on an open-mesh, two-tiered frame in a sealed, plastic tent approximately 2 m × 2 m and 1.4 m high. Smoke is generated by slow, controlled combustion, in a 200 liter drum, of a mixture of fresh and dry leaf and twig material from a range of plants or the materials mentioned above. The drum is fitted with an inlet through which air is pumped, and an outlet is connected to a 1.5-m long pipe. A 2-m length of flexible, steel exhaust piping approximately 50 mm in diameter is then connected to the plastic enclosure. This ensures that the smoke is injected towards the roof of the tent and is therefore spread throughout the tent (Dixon *et al.,* 1995).

After smoking for 60 minutes, trays are transferred to the pothouse and watered carefully for the first 6–10 days to ensure that the soluble promoter/antimicrobials in smoke come in contact with the seeds but is not washed through the mix before reacting with the seed. Watering is then continued as for normal germination.

Seeds can also be direct-smoked. In this instance, seed is laid out in a single layer in

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trays. The trays are smoked for 60 minutes in the fumigation tent (as described above) and the air-dried seed is then sown or stored dry until required. Unlike smoke applied to soil containing sown seeds, smoked seeds can be watered as would be normal practice.

Pots with holes

It is mentioned that earthen pots with holes are filled with prescribed materials and lit [personal communication: Centre for Indian Knowledge Systems (CIKS), Chennai]. These are then placed near trees or taken while walking in field crops. Other ways could be to hang small earthen pots on lower branches of trees or fix bamboo poles 2–5 m long with pots tied at the top of each pole. Since better resources are available today, we can follow some simple methods in practice elsewhere. Also there is an excellent opportunity to innovate some improved practices for smoking or fumigation of seeds, seedlings/saplings, young and adult plants or trees.

Discussion and conclusion

In the frost-prone areas of northern India, farmers commonly create a smoke cover over their vulnerable crops and irrigate the fields. Although these practices have been followed by farmers for past centuries, the author is not sure if these practices of farmers help in reducing losses if severe frost occurs. As pointed out earlier, agronomists always express vehement opposition to burning leaf and stem trash on the grounds that "valuable organic matter" is being destroyed. They ignore the fact that crop residues harbor dormant stages of pathogens and pests, as also weed seeds. Most small farmers of India continue the age-old practice of burning non-cattle-feed crop trash because they see the advantages mentioned above. Recent studies, as described above, on organic smoke have revealed that the smoke from carbohydrates, proteins, and fats are growth promoters as also antimicrobial.

Domestic smoke originating from the kitchens of poor people, where solid (wood, dry cow dung cakes, charcoal, etc.) fuels are

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used, is considered in general to be harmful to human health. We must remember, however, that ever since humans started cooking on fire, they have been exposed for millennia to the kitchen smokes. Thus humans have evolved facing all the time the challenges to their health due to smoke. This should have given them constitutional ability to survive the smoke challenge. Mishra (2004) has the following to state: "A review of evidence on health effects of indoor air pollution indicates that household use of unprocessed solid fuels for cooking and space heating has significant impact on human health. However, the quantity and quality of scientific literature on the health effects of smoke vary considerably by type of health outcome. There is compelling evidence linking smoke from biomass and coal use for cooking to acute respiratory infections in children and chronic bronchitis in women. Also, there is limited evidence linking indoor smoke and asthma, tuberculosis, lung cancer, and adverse pregnancy outcomes. But the evidence on cataract and blindness, otitis media, lung fibrosis, and cardiovascular disease is weak or nonexistent." Thus several presumed effects have yet to be proven. In addition, it should be remembered that the smoke that emanates from Indian kitchens contains karrikins and antimicrobials originating from spices (mustard, sesame, garlic, black pepper, asafetida, turmeric, and cooking fats). The author believes that we should worry less about smokes from kitchens than from the smokes originating from fossil fuels.

Agnihotra has been suggested by Koch (2004) and several others such as Vasant Paranjape (http://www.agnihotra.org/) and many of his disciples to increase crop yields. This is a modern usage because originally *Agnihotra* was described in detail in the *Yajurveda Samhita, Shatapatha Brahmana* (12:4:1), and the Atharvaveda (11:7:9). The Vedic form of the ritual is still performed by some Brahmins of India. It is a *vrata* that is performed for the welfare of one's own family. Etymologically, '*vrata*', a Sanskrit word, means 'to vow' or 'to promise'. In the context of Hinduism, the term *vrata* (pronunciation: *vrat* or *brat*) denotes a religious practice to carry out certain obligations with a view to achieve divine blessing for fulfillment of one or several desires. As stated above, modern versions of the *Agnihotra* are promoted by various individuals and groups as a non-sectarian ritual for the healing and purification of the atmosphere and as a primary source of *vibhuti* or sacred ash. To study effects on yield and quality of horticulture crops, experiments with *Agnihotra* and *Homa* therapy were conducted recently at Tamil Nadu Agricultural University, Ooty, Tamil Nadu in India. It is believed that when you perform *Agnihotra* and *Yajnya*, or other *Homas* in a garden, an atmosphere is created that is conducive to growing, and therefore attracts nutrients, insects, microorganisms, and animals that would be happy and thrive in that environment. This of course is because nature is so wonderful, it automatically benefits the soil and the plant, and the plant thrives. Same thing happens when you put the ash or use *Agnihotra* ash water but it works more for the plants individually – by putting the ash around the individual plants or in the beds or spraying the plants, those elements that

are best for that plant are attracted to it and it thrives.

The author was very skeptical of the hype to use *Agnihotra* in farming, because its original purpose was taking a vow to carry out the ritual of *Agnihotra* for the family's welfare. *Agnihotra* enthusiasts slowly reduced the use of the word *Agnihotra* in their writings and moved to a general word *"homa"*, which meant oblation to sacred fire. With the knowledge of "smoke" that has been gained in the last decade and elaborated in this paper, it is possible to conjecture beneficial effects of *homas*, where several herbals and ghee are offered to the sacred fire resulting in the smoke-carried production of antimicrobials and growth enhancers to plants and trees. Since one or two locations of *homas* in a garden would be insufficient to benefit all the plants, it is logical to suggest several *homas* to be carried out in gardens or farms of different sizes.

Different treatises of Vrikshayurveda have prescribed smoking or fumigation of seed, seedlings, saplings, and young and adult plants, bushes, and trees. Recommendation of smoking alone is rare; mostly it is in combination with treatments such as seed dressing, tree trunk dressing, sprinkling leaves, drenching at the base of soil with various materials of plant and animal origin. Smoke produced from materials recommended contains growth promoters as well as antimicrobials and thus contributes to efforts of managing plant health effectively. We thus have forgotten the knowledge of plant health practices that were relevant to small farmers of the past centuries. In many parts of India smoking by burning farm trash is practiced as a consequence of the experience of ancestors. This knowledge has to be studied again. Many practices need to be validated and, if found suitable, need to be recommended to farmers for adoption, especially to those farmers who have forgotten the ancestral knowledge. From this vast knowledge base, we could carry on innovations, with ample resources available today, to further simplify these practices. In short (i) smoke has the present-day potential to become an important tool in agriculture and horticulture; (ii) it is scientifically proven that smoke improves seed germination and seedling growth of many plant species; and (iii) smoke-technology may economize input of fertilizers, pesticides and herbicides and may thus improve their economy of production.

Domestic smoke originating from the kitchens of poor people, where solid (wood, dry cow dung cakes, charcoal, etc.) fuels are used, is considered in general to be harmful to human health. We must remember, however, that ever since humans started cooking on fire, they have been exposed for millennia to the kitchen smokes. Thus humans have evolved facing all the time the challenges to their health due to smoke. This should have given them constitutional ability to survive the smoke challenge.

It would be a pity if Indian agricultural scientists continue to ignore the ancient and medieval plant health management practices.

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