REVIEW ARTICLE

# LOW BUDGET NATURAL WAY FARMING (AKA.VRIKSHAYURVEDIC FARMING) - TREES ARE THE NATURAL AGROCHEMICALS PRODUCERS FOR SUSTAINABLE FOOD PRODUCTION

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**Abstract:** Nowadays, people are looking for "organic" labels on food due to the harmful ill effects of indiscriminate agrochemical usage. Organic farming, natural farming, etc., to ensure eco-friendly foods. Here, a novel, yet traditional, way of food production using only trees and their parts and products to cultivate crops and maintain soil fertility is discussed. *vrikshayurvedic farming is* a traditional Indian system of farming to produce quality food. Here, indigenous and introduced leguminous tree leaves serve as soil fertility builders and leaf extracts serve as foliar nutrition for crops and protection from pests and diseases. This article extracts information from different sources (Fig. 1) and presents it in a nutshell to facilitate a paradigm shift in farming research.

**Keywords**: Biomass transfer technique, Green leaf manure, Leaf tea, LBNF, *Vrikshayurvedic farming*, Crop yields

## INTRODUCTION

At the global level, there is a general consensus on the need and necessity of gradually transforming modern farming practices into a more sustainable farming. And, people are also looking for 'organic' labels in food due to harmful ill effects of indiscriminate agrochemical usage. Hence, it's timely to reorient and adopt diverse strategies to move towards sustainable agriculture, which is facilitated by organic farming, natural farming *etc.* India has been the treasure land of biological wealth, intellectual knowledge and spiritual wisdom. In yesteryears, agricultural development mainly focused on short term productivity, ignoring the maintenance of soil health, based on external inputs and improper use of local resources with the sole objective of feeding the growing population in the world particularly in Indian Subcontinent. This has resulted in considerable and occasionally irreversible damage to the soil and environment. But, the major concern today is how to revitalize the damaged natural resources and reduce the pressure of modern agricultural technologies. At the same time there is also awareness among people on seeking for agrochemicals free, quality food produce to ensure healthier life. This key factor drives the farm researchers, peasants and farm policy makers to revisit the traditional farm and crop production practices and also forcing them to think of farming without synthetic agrochemicals, as it is a holistic approach, which takes care of all the components of the system for better sustainability of agriculture.


**Fig. 1.** Pictorial representation of *vrikshayurvedic Farming*

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Many traditional practises that have been practised in India for a long period of time have relevance to different organic agriculture practises adopted in many countries. In the early and mid-1900s, we observed different farming types adopted in countries like Germany, Austria, Japan, and also India. Biodynamic agriculture, a system of organic agriculture, was spawned by the late Austrian anthroposophist Rudolf Steiner and its development began in 1924**.** This method of agriculture was introduced to a large group of farmers in Germany. It emphasises and focuses exclusively on organic methods with spiritual and mystical perspectives (John 2010 and Abbott *et al*. 2007). In 1940, Albert Howard and Gabrielle Howard applied traditional farming methods in India to develop sustainability. They developed protocols for crop rotation, erosion prevention, and systemic use of compost and manure using these methods, which they eventually dubbed "organic farming." Later, in 1975, Masanobu Fukuoka, a Japanese farmer, established the approach of "natural farming". He described his way of farming in Japan as the "natural way of farming" (or) do-nothing farming. But when we look into the literature, a typical system of using herbal preparations from trees and plants for crop production known as *Vrikshayurveda* was traditionally practised for centuries in India from 400 BCE. Raychaudhuri *et al*. (1964) reported that *Vriksha* meaning trees*; Ayurveda* meaning the traditional Hindu system of medicine (incorporated in *Atharvaveda*, the last of the four Vedas), which is based on the idea of balance in living bodily systems; and treatment. *Vrikshayurveda*, a Sanskrit word literally (Indian plant science) means "Ayurveda for plants" and is used to denote knowledge of plant life. For centuries, such traditional practises of using trees and plants-based extracts and foods have been used in crop production and farming. *Vrikshayurveda* provides ample scope to produce quality food products by adopting traditional methods, which are also eco-friendly. It needs an organised attempt of traditional Indian plant science with systemic inquiry, which deals with various tree species and ensures healthy growth and productivity. Furthermore, it offers a relatively painless and smooth transition from chemical agriculture to organic agriculture within a few months. During the 1990's, the leaf extracts of several tree species were found to promote the growth and development of plants, which in turn was termed "*Vrikshayurvedic farming"*. Low Budget Naturalway Farming, aka. *vrikshayurvedic* farming is defined as "a scientific reorientation of the eco-friendly system of Indian agriculture by utilising the traditional and natural ways of food production and adopting those indigenous practises for cultivation of crops by utilising trees, plants, and animal products, with the objective of enhancing quality"(Swaminathan and Nandakumar 2012). A comprehensive way of using various trees and their parts and products for crop production needs to be scientifically experimented with. For experimentation in detail, this review paper will throw light on various aspects of this novel type of farming. Here, tree leaves are used as green leaf manure and leaf extracts as foliar spray for crops. The tree leaf extracts would be used as growth stimulants as well as pest and disease control agents, reducing the need for inorganic chemicals and fertilizers. When the present scenario of agriculture is analysed in India, it is clear that in an attempt to grow more food, soil health and ecological balance are lost. So *vrikshayurveda* has a solution to the food problems faced by mankind in a sustainable way.

## METHODOLOGY

A systematic and integrative review of work done elsewhere, including India, was done to screen the related and relevant literature that could be used for writing a review paper. About 2 months have been spent on writing the manuscript, and about 200 reviews and research papers were screened and shortlisted based on the subject relevance, and about 95 reviews were used to write this paper. A few papers were rejected as they had very limited or no scope for my area of research, and a few provided principle mechanisms which were included.

For initial searching of research papers, various data bases were used, and the top three were TNAU elibrary, Google scholar, Researchgate, and Scopus. Through TNAU elibrary, accessing of e-Books like CAB e-Books, Elsevier-Science direct-e-Books, Springer e-Books, Taylor & Francis, John Wiley, and Astral; e-Journals like CeRA (Consortium for e Resource in Agriculture), Indian Journals, Directory of Open Access Journals (DOAJ), Web of Science, and End Note; besides e-Databases like Indiastat, Delnet, and Commodity India and Library Web OPAC was done.

**Ancient texts and Genesis of *Vrikshayurveda***

The earliest references to this science are in the Rig-Veda and Atharvaveda. The other valuable information from Vrikshayurveda is Kautilya Arthasastra. *The Vrikshayurveda* was written by Salihotra around 400 B.C., consisting of twelve chapters, namely, *Bhuminirupana, Bijoptivithi, Padapavivaksa, Ropana vidhana, Nisecanavidhi, Posanavidhi, Drumaraksa, TaruCikitsa, Upavanakriya, Nivasasannataru, Subhasubha Laksana, Taru Mahima, and Citrikarana.* It gives information regarding various aspects of plant science like soil analysis, soil biota, genetic variability, seed testing, green manure, and liquid biofertilizers. *Amarsimhas, Amarkosha, Patanjali's Mahabhasya, Krishi-Parashara,* Varahamitra and *BirhatSamhita.* The three major ancient texts, inter alia, are in detail. 1) Varahamitra, 505 AD.,

BirhatSamhita, Vrikshayurveda Part I, Chapter 55 (edited by M. Ramakrishna Bhat, Motilal Banarasidas, Bangalore, India 1950) 2) Chaundarya,1025 A.D. Lokopakaran, Vrikshayurveda, chapter 6 (edited by H. Shesa Iyengar, Government central Manuscripts library, Chennai, India 1950) and 3) Sarangadhara, 1363 A.D. Vrkshayurveda (edited by S.K. Ramachandrarao, Kalpatharu Research Academy, P.O. Box 1857, Bangalore, 1993, India). The most detailed of all three seems to be that of Chaundarya, 1025 A.D.

Earlier, there was no independent text, only *Surapala vrikshayurveda* is a credible compendium, and it was translated into English and published for the first time by the Asian Agri-History Foundation in 1996 (Sadhale 1996); where there are references to holistic crop management systems, glorification of trees, composition of planting and cultivation aspects, and also animal production. Later in India, there are several prescriptions for enhancing the growth of crop plants that are both plant and animal based and have been compiled as a book called "Vrikshayurveda" (Jugnu 2004). It has been used since ancient times, from the time of Kautilya (296–321) BC) to the thirteenth century A.D. Since then, it has been re-interpreted and compiled by different authors (Nene 2012). Surapala (1000 A.D), Sarangadhara (1283–1301 A.D) and Chakrapanimishra (1577 A.D) mentioned the methods of preparation of herbal *kunapajala* and *kunapajala* formulation. It is a better substitute for the synthetic fertilizers (Saxena *et al*. 2009).

*Vrikshayurveda* has become widely known among agriculturists not only in India but also in other countries. It is a practise of the Indian agriculture system and consists of many suggestions for organic farming, which deal with adopting traditional methods to produce quality food products. During the 1990's, the leaf extract of tree species (*Alangium salvifolium, Aegle marmellos, Annona squamosa, and Azadirachta indica*) was shown to be effective on the growth and development of cowpea and green gram (Swaminathan and Nandakumar, 2017).

**Concepts and Thrusts**

Plant disorders were classified into two types by Vrikshayurveda, *Nija* and *Aganthu*. The *Nija* disorders contained in *Surapala's Vrikshayurveda* are caused by the disturbance of the three dosas: *Vata, Pitta, and Kapha. Aganthu* disorders are caused by pests, hail, and lightning. According to *Vrikshayurveda*, plants also have these characteristics. Various procedures, such as the rules for sowing seeds and the planting process, are also described in various *vrikshayurvedic* texts. It also praises a pesticide cum fertilizer called kunaphajala made from fish and animal waste, and this experimental outcome has been proven in various plants like *Cassia angustifolia* and Brinjal.

Fertilizer consumption has increased from less than 1 million tonnes in the mid-1960s to almost 28 million tonnes today. Before the green revolution era, in the 1960s, fertilisers comprised only a small percentage of the nutrients needed for grain production and nutrition was substituted through organic amendments. However, in the post-green revolution period, more than 70% of the grain yield depends on fertilizers. The use of pesticides in agriculture is obvious for the prevention of crop-damaging pests, fungus, weeds, etc. About 15–25% of potential crop production is lost due to pests, weeds, and diseases. At present, per hectare consumption of pesticides in India is amongst the lowest in the world and stands at 0.6 kg/ha, compared to 5-7 kg/ha in the UK and 13 kg/ha in China (Yadav and Dutta 2019). But the good news is that the data from the government of India showed that the consumption of chemical pesticides has declined from 72,130 tonnes in 1991-92 to 56,090 tonnes during 2012–13 and the pattern of consumption shows wide fluctuations over the years (Indira Devi *et al*. 2017).

Continuous overuse of agrochemicals will gradually deplete the environment and ecosystem. Organic farming, on the other hand, can create a healthier environment and ecosystem for the present as well as future generations. Among those, *vrikshayurvedic* farming is a nature-based, environmentally friendly approach that ensures the conservation as well as utilization of all the resources in a sustainable way.

It would be a win-win situation as the farming community will be triggered to go for cultivation of the potential tree species useful for crop production in their lands and, also in village common lands, which will ensure a cleaner environment; minimizing the ill effects of fertilizers and agrochemicals while ensuring quality produce.

**Approaches in using trees and its parts**

Trees have an essential part in human life and have been so far viewed as a material for providing shade, construction, and furniture making. The indirect roles of the tree species are being ignored by most people, and it played a vital role in food production in previous years. In this system of farming, trees perform two major and important functions, such as: (i) green leaf manure incorporation into soil for fertility and nutrient management; and (ii) leaf-tea nutrition for crops and their protection from pests and diseases.

**Three pillars of LBNF aka. *vrikshayurvedic* farming**

It is practised by using the tree, its parts, and products. For each cultivation practice, a set of tree species has been identified and screened and used. The leguminous trees for supplying nutrients because of their high nutrient content and faster decomposition; and the plant extracts with secondary metabolites for growth promotion; tree species with bio-pesticidal properties for pest and disease management have been documented by the senior

author for the past 15 years. It's high time to explore fully the information available in the ancient texts and find a new way out.

**i) Biomass Transfer (BMT)**

The leaves of leguminous trees are widely used as manures and incorporated into soil before sowing or planting to supply nutrients for crop growth. This is done through BMT, i.e., the collection of tree leaf biomass from the nearby areas or within the farm itself, if available, and applying it to the field. The leguminous tree species, preferably N-fixing trees with high nitrogen content and a faster decomposition rate, are preferred as green leaf manure. A few tree species that are used for such green leaf manure are: 1*) Albizia lebbek 2) Senna siamea 3) Gliricidia sepium 4) Leucaena leucocephala 5) Delonix regia, 6) Peltophorum pterocarpum 7) Pongamia pinnata*as listed by Nair (1993), but the list is not limited to this (**Table 1**). For soil fertility improvement, according to Prakash and Bhushan (2003), incorporation of *Leucaena* green biomass increased organic carbon (0.21 to 0.31) available nitrogen, phosphorus and potassium (152.4, 23.4, 172 kg/ha) content respectively.

**Table 1.** Nitrogen content in tree leaves (Green weight basis) (Swaminathan and Nandakumar 2017)

| No. | Tree Species | Family | Leaf Biomass | Nitrogen content |
|---|---|---|---|---|
| 1 | *Acacia auriculoformis* | Fabaceae | 19.33 | Nitrogen- 2.1% |
| 2 | *Acacia mangium* | Fabaceae | 38- 40 t/ha | Nitrogen- 1.28 – 1.42% |
| 3 | *Albizia lebbek* (L.) Benth. | Leguminaceae | 14.5-15 t/ha | Nitrogen– 4.5% |
| 4 | *Azadirachta indica* | Meliaceae | 400 kg/tree | Nitrogen- 2.83 |
| 5 | *Calotropis gigantean* | Apocynaceae | 4-5 kg/plant | Nitrogen- 2.1% |
| 6 | *Cassia siamea* | Fabaceae | 14.6 t/ha | Nitrogen- 1.60% |
| 7 | *Delonix regia* Raf. | Leguminaceae | 50-60 kg/tree | Nitrogen- 2.76% |
| 8 | *Erythirna indica* | Leguminaceae | 5-6 t/ha | Nitrogen- 3.0- 4.0% |
| 9 | *Gliricidia sepium* (Jacq.) | Leguminaceae | 5-6 t/ha | Nitrogen- 2.76% |
| 10 | *Leucaena leucocephala* (Lam. | Leguminaceae | 13-14 t/ha | Nitrogen – 3.2% |
| 11 | *Peltophorum ferrugineum* (DC.) Hayne. | Leguminaceae | 30-40 t/ha | Nitrogen- 2.63% |
| 12 | *Pongamia pinnata* | Leguminaceae | 24-30 t/ha | Nitrogen- 3.31% |
| 13 | *Sesbania grandiflora* | Leguminaceae | 20 t/ha | Nitrogen 2.7-3.0 % |

**ii) Leaf-tea spray (LTS) for foliar nutrition**

Using natural tree leaf extracts as crop health tonics is attractive. These tonics can be used for seed treatment to ensure early germination and growth of crops and can also be used as foliar nutrition during various growth stages of crops (**Table 3**). The leaf extracts of trees contain secondary metabolites which are capable of promoting growth through physiological and biochemical changes in the plant system (Swaminathan and Nandakumar 2017). The nutrient contents of tree leaves viz., *Gliricidiasepium* (2.76, 0.28, 4.60% NPK) and *Delonixregia* (2.76, 0.46, 0.5% NPK). Gliricida lopping (3.5 per cent N) decomposed faster than other crop residues even under low moisture conditions, and the availability of N and P was also improved.

**Table 3.** Tree species used for foliar nutrition and the principle compounds

The leaf extracts of trees having secondary metabolites which are capable of promoting growth through physiological and biochemical changes in the plant system.

| No. | Tree Species | Family | Parts used | Secondary metabolites Present | Reference |
|---|---|---|---|---|---|
| 1. | *Alstonia scholaris* | Apocyanaceae | Leaves | Indole Alkaloids | Arulmozhi *et al.* (2007) |
| 2. | *Tabernaemontana coranaria* | Apocyanaceae | Young Leaves and bark | Alkaloids– appericine, taberhanine | Hoft *et al.* (1996) |
| 3. | *Erythrina indica.* | Papilionaceae | Leaves | Alkaloid- erythrinine | |
| 4. | *Dalbergia latifolia* | Papilionaceae | Leaves | Alkaloids | |
| 5. | *Dalbergia sissoo* | Papilionaceae | Leaves and stem bark | Alkaloids – rhamnose, dalbergine and dalberginone | Ali-Esmail and Al-Snafi. 2017 |
| 6. | *Sesbania grandiflora* | Papilionaceae | Leaves | Alkaloids | Arun *et al.* (2014) |
| 7. | *Morinda tinctoria* | Rubiaceae | Leaves | Alkaloids, morindone and saponins | |
| 8. | *Mangifera indica* | Anacardiaceae | Leaves, dried leaf powder and bark | Alkaloids- mangiferin, galluc acid and catechin | Shah *et al.* (2010) |
| 9. | *Aegle marmellos* | Rutaceae | Leaves, fruits and pulp | Alkaloids and coumarins | Ariharan and Nagendraprasad, 2014) |
| 10. | *Moringa oleifera* | Moringaceae | Leaves | Alkaloids- Moringinine, moringine | (Foidl*et al.*, 2001) |
| 11. | *Phyllanthus acidus* | Phyllanthaceae | Leaves, seeds | Alkaloids- squalene | |
| 12. | *Psidium gujava* | Myrtaceae | Leaves | Gallic acid, catechin | (Kawawa*et al.*, 2010) |
| 13. | *Phyllanthus emblica* | Phyllanthaceae | Leaves and bark | Alkaloids, glycosides and saponins | Jayagupta and Amit gupta (2013) |
| 14. | *Swietenia mahagoni* | Meliaceae | Seeds and leaves | Limonoids, scopoletin | Sahgal *et al* .(2009) |

**iii) Crop Tree Botanicals and Extracts (TBE) for crop protection.**

Due to the increasing need for eco-friendly, safe and selective bio formulations for total health care in crop production, utilisation of botanicals and other derivatives like oil, extracts, powder prepared from tree leaves and other parts like seeds, kernels, and bark will be largely employed for controlling pests and diseases, to a certain extent, weeds also. For this, leaf extracts of tree species having bio-pesticide properties, secondary metabolites having antimicrobial, anti-fungicidal and alkaloid properties will be used to control the pest and disease incidence of the grown crop.

Tree species having rich secondary metabolites will be used (Table 4). Rishi (2009) reported that since ancient times, virus-like diseases and management practises have been known in India. This knowledge has now been revived and adopted in organic farming, especially for medicinal and aromatic plants.

**Table 4.** Tree species used for Plant protection and the secondary metabolite present.
The leaf extracts of tree species having the bio-pesticide properties will be used to control the pests and diseases incidence of the grown crop. The trees listed in the table will be utilised.

| S. No | Tree Species | Family | Parts used | Secondary metabolite Present | Reference |
|---|---|---|---|---|---|
| 1. | *Azadirachta indica* | Meliaceae | Leaves, oil, seed kernels, neem cake | Azadirachtin | Lava Hassam *et al.* (2015) |
| 2.. | *Vitex negundo*. | Verbenaceae | Leaves | Alkaloids – nishidine negundocide, cucupin | Ahuja *et al.* (2015) |
| 3. | *Anthocephalus* | Rubiaceae | Leaves | Indole and quinolone | Alka |

| | | | | | |
|---|---|---|---|---|---|
| | *cadamba* | | | Alkaloids | Dwevedi*et al.* (2015) |
| 4. | *Adina cordifolia* | Rubiaceae | Wood and leaf extract | Alkaloid | Ved Prakash *et al.* (2015) |
| 5. | *Morinda tinctoria* | Rubiaceae | Leaves | Alkaloid- morindone, saponin | |
| 6. | *Pongamia pinnata* | Leguminosae | Leaves, seeds | Fixed oil- Karanjin | |
| 7. | *Gliricidia sepium* | Fabaceae | Fresh and dried leaves | Alkaloids and saponins | |
| 8. | *Melia azedarach* | Meliaceae | Leaves, Fruits | Limonoid and Meliartenin | Lava Hassam *et al.* (2015) |
| 9. | *Tephrosia vogelli* | Fabaceae | Leaves | Rotenone &Tephrosin | Belmain *et al.* (2012) |
| 10. | *Switenia mahagoni* | Meliaceae | Seeds and leaves | Scopoletin&limonoids | Sahgal *et al.* (2009) |
| 11. | *Eucalyptus camadulensis* | Myrtaceae | Oil & leaves | Terpenoids, alkaloids, limonene, eucalyptol. | |

**Functions of trees in crop and soil management**

**Nutrient management**

According to FAO, fertiliser consumption in India has increased significantly during the past three decades. From the 1970's to 2018, total NPK consumption per hectare has been increased many-folds (from 11–95 kg/ha to 165.85 kg/ha). There has been an increasing focus on the adverse environmental impact of both the underuse and the overuse of plant nutrients. For revitalising the environment, different organic practises offer a significant contribution through the supply of plant nutrients. Among other things, *vrikshayurveda* revitalises and rebuilds the soil properties and also ensures the soil fertility through substitution of nutrients through different green biomasses.

**Nutrient acquisition and availability**

Vani and Bheemaiah (2003) revealed that alley cropping + green leaf manuring (*Dalbergia* and *Leucaena*) + 80 kg of N $ha^{-1}$ increased uptake of N in castor (116.4 kg N ha-1). Furthermore, P and K were also significantly more abundant under alley cropping with *Dalbergia* green leaf manure and N application. Patel *et al.* (2003) investigated the effect of fertiliser N and Gliricidia leaves on cluster bean yield. They recorded nutrient uptake of cluster beans (96, 30.6, and 152) NPK kg $ha^{-1}$ with *Gliricidia* leaves @ 10 t $ha^{-1}$ compared to 100 per cent of the recommended dose of nutrients + *gliricidia* leaves (134, 44, and 211 kg $ha^{-1}$ NPK uptake). Application of green manure significantly increased the P content in soil. In laboratory conditions, application of *Sesbania aculeata* as green leaf manure significantly increased the available K content in soil (Debnath and Hajra 1972)**.**

Vani and Bheemaiah (2003) reported that the application of green leaf manure (*Leucaena, Albizia, and Dalbergia)* at 5 t $ha^{-1}$ improved the soil available NPK and also significantly increased soil organic carbon. Nandakumar and Swaminathan (2011) concluded that the highest available N and K in maize were identified in *Albizia lebbek* as green leaf manure (212.60 kg $ha^{-1}$ and 149.8 kg $ha^{-1}$) and the highest available phosphorus was recorded in *Delonix regia* (15.50 kg $ha^{-1}$). In black gram, the highest uptake of N was recorded (299.8 kg $ha^{-1}$) was recorded in *Pongamia pinnata* and it was followed by *Albizia lebbek*, and the highest P and K (24.41 and 353.7 kg $ha^{-1}$) uptake was recorded in *Delonixregia* (Swaminathan and Nandakumar 2017). According to Swaminathan and Nandakumar (2017), the highest available nitrogen and potassium (310. 4 kg ha-1 and 348.46 kg ha-1) were recorded in Peltophorum ferrugineum (285.3 kg ha-1 and 347.97 kg ha-1) and the highest available phosphorus (23.15 kg ha-1) was recorded in Delonix regia (22.01 kg ha-1). The highest available N and P were registered in finger millet when *Delonix regia* (303.3 kg $ha^{-1}$ and 26.40 kg $ha^{-1}$) as green leaf manure was followed by *Leucaena leucocephala* and *Gliricidia sepium*, and more available potassium was recorded in *Leucaena leucocephala* (368.6 kg ha-1), which was on par with *Delonixregia*(Swaminathan and Nandakumar 2017).

Swaminathan and Nandakumar (2017) reported that the highest N, P and K (12.72, 7.97 & 12.71 kg $ha^{-1}$) in onion was recorded in *Gliricidia sepium*, which was on par with *Senna siamea.* The N uptake in bhendi was highest in *Albizia lebbek* (13.89 kg $ha^{-1}$) and the highest P and K (2.71 kg $ha^{-1}$ and 21.57 kg $ha^{-1}$) were recorded in *Gliricidia sepium* (Anbukkarasi 2011)**.** Swaminathan and Nandakumar (2017) concluded that the highest available N, P, and K were recorded when *Gliricidia sepium was used* as green leaf manure and it was followed by *Albizia* lebbek. In Table2, nitrogen uptake on *vrikshayurveda* of different crops was presented**.**

**Table 2.** Nitrogen acquisition by crops in *vrikshayurvedic farming*

| S. No | crops | Green leaf manures | Nitrogen (kg/ha) | Reference |
|---|---|---|---|---|
| 1. | Maize | *Albizia lebbek* | 103.8 | Nandakumar and Swaminathan (2011) |
| 2. | Black gram | *Pongamia pinnata* | 68.3 | Swaminathan and Nandakumar (2017) |
| 3. | Barnyard millet | *Peltophorum ferrugineum* | 74.08 | Swaminathan and Nandakumar (2017) |
| 4. | Finger millet | *Delonix regia* | 71.28 | Swaminathan and Nandakumar (2017) |
| 5. | Fox tail millet | *Gliricidia sepium* | 43.9 | Swaminathan and Nandakumar (2017) |
| 6. | Onion | *Gliricidia sepium* | 12.72 | Swaminathan and Nandakumar (2017) |
| 7. | Bhendi | *Albizia lebbek* | 13.89 | Anbukkarasi and Sadasakthi (2011) |

**Foliar nutrition for crops**

Many experiments have been conducted by the senior author to identify tree species that could be used for foliar nutrition of crops. Tree species that have secondary metabolites of plant origin that are capable of promoting growth through physiological and biochemical changes in the plant system used for foliar spray. Tree species viz.,1) *Moringa oleifera 2) Aegle marmelos 3) Morinda tinctoria 4) Alangium salvifolium 5) Annona squamosa and 6) Ocimum sanctum* and other plants (Swaminathan and Nandakumar 2017). However, a complete analysis of the secondary metabolites present in each tree species would further enhance the research.

**Functions of trees in crop Protection**

The most frequent method of managing pests and diseases in most agricultural sectors is through the application of pesticides (Jallow *et al*. 2014**).** About 2.5 million tonnes of pesticides are used each year. Selectivity and efficacy of synthetic chemicals and isolated bioactive compounds have improved recently, and they will provide a greater opportunity for adopting integrated management practices (Satpathy *et al*. 2020**).** Organic farming and biological control are two of the most important areas that must be adopted to rectify the ills. India has a rich source of plants that could be harnessed as botanical pesticides. The use of botanical pesticides utilises the secondary metabolites and has become really important in today's agriculture. They have become an effective weapon against crop pests by suppressing the harmful effects on behavior, physiology, growth, reproduction, and other functions of phytophagous insects. In India, use of plant products is in use for over a century to minimize losses due to pests.

Protection and treatment practises recommended in *Vrikshayurveda* involve methods of application that are followed even today, but with more efficiency. The leaf extracts from neem, Pungam (Naik and Dumbre 1985), *Aegle marmelos*, *Vitex negundo* and *Albizia amara* and the dry fruits of 'kadukkai' are a few tree species having insecticidal and antifungal properties. The presence of antifungal, antibacterial, and bio-pesticidal properties present in leaf extracts in the form of secondary metabolites may also help to reduce pest infestation and inhibit spore germination and fungal growth. The leaf extracts that have higher peroxidase, polyphenol oxidase and phenyl alanine activity also reduce the pest and disease menace. Using *kunaphajala* for seed dressing, root dipping, wound dressing, soil drenching, fumigation, smoking, crude spraying and dusting also helps to reduce pest and disease infestation. Other species like 1) *Azadirachta indica 2) Vitex negundo 3) Anthocephalus cadamba 4) Adina cordifolia 5) Morinda tinctoria 6) Pongamia pinnataetc are also used as botanicals* (Swaminathan and Nandakumar 2017).

**Pest management**

Attempts have been made to control pests in crops by using various tree leaf extracts, i.e., botanicals and products like kernel extracts, oil extractions. The role of neem (*Azadirachta indica*) in plant protection has been well documented (Swaminathan and Raguraman 2007), and neem leaf extract and neem seed kernel extract (NSKE) at 5% could effectively control onion thrips (Hazara *et al*. 1999), whitefly in brinjal, while *Gliricidia sepium* Sridhar *et al*. (2000) reported that Aegle *marmellos* leaf and root extracts effectively controlled caterpillars in red gram. Aqueous leaf and seed extracts of *Annona squamosa* and their powders showed insecticidal, antifeedant, and repellant activity against a number of insects and pests. Lower thrips incidence was observed with *Gliricidia sepium* as green leaf manure and leaf extract of *Alangium salvifoliumin* aggregatum onion (Swaminathan and Nandakumar 2017).

The occurrence of pest incidence (Aphids) as well as weeds was also very low when a combination of *Albizia lebbek + Annona squamosa was* also contributed to a higher yield in maize (Nandakumar

and Swaminathan 2011). Anbukkarasi and Sadasakthi (2011) reported that in Bhendi, *Albizia* lebbek and *Annona squamosa* showed a decrease in shoot and fruit borer incidence. Application of fishmeal to a standing paddy crop might give better results than top dressing with urea (Nene 2012**).** Application of pungam leaf extract at 3 per cent during 30 and 45 DAS (2.23 t $ha^{-1}$) or following seed treatment before sowing and spraying of 3 per cent leaf extract during 30 and 45 DAS (2.19 t $ha^{-1}$) is the best to reduce the aphid incidence to get higher yields in sorghum (Swaminathan *et al*. 2012**).**

The weed management through various *vrikshaurvedic farming* practises in maize has been reported by Swaminathan and Nandakumar (2017).

**Disease management**

Several reports indicate that extracts of tree leaves could also play a role in the prevention and control of diseases of various crops. Kadadiya and Dhruj (2001) worked out the bio-fungicidal properties of custard apple (*Annona squamosa*) and tulsi (*Ocimum sanctum*). These extracts were good inhibitors of growth as well as spore germination of *Cercospora canescens* in mungbean. Plant extracts were used to treat cowpea aphid-borne mosaic virus. Sprays of phyto-extracts of *Jatrophacurcas* had 100 per cent inhibition of the virus for up to 30 days. In carrot, the studies by Kannan (2001) suggested that a combination of different extracts of *Azadirachta indica* and *Vitexnegundo* could be suitably effective for postharvest rot diseases.

The efficacy of five plant extracts, viz., *Azadirachta indica, Ocimum sanctum, Datura stramonium, Lantana camara,* and *Diosphros cordifolia*, was tested on the fruit rot pathogen of sponge gourd using water extraction and acetone extraction 20 per cent acetone extracts of *Azadirachta indica* (90.02 per cent) showed better inhibition.Various plant extracts, viz., *Prosopis juliflora, Catharanthus roseus,* and *Lawsonia inermis,* were evaluated to test their efficacy against the causes of *Colletotrichum capsici* under in-vitro conditions. Field trials conducted in chillies revealed that *Prosopis juliflora* showed a 59.9 per cent reduction in chilli fruit rot disease incidence over control.

Devi *et al*. (2003) reported the efficacy of five plant extracts, viz., *Artemisia vulgaris, Ageratum conyzoides, Vitex trifolia, Crocus calamus,* and neemal. The overall efficacy was in the order of *Artemisia vulgaris > Azadirachtaindica>Vitex trifolia > Ageratum conyzoides*. The plant extracts of neem, *Annona squamosa* and *Annonareticulate were* effective in reducing the onion diseases (Fusarium, *Alternariaporri* and *Stemphylium vesicarium),* but to control bottle gourd mosaic virus, spraying of bark extract from *Terminalia arjuna* showed a maximum (85.6 per cent) inhibitory activity. The Albizia lebbek + Annona squamosa combination had the lowest percentage of yellow vein mosaic virus (19.21%) (Anbukkarasi and Sadasakthi 2011).

**Influence of trees in growth and development of crops**

The application of *Ferula asfoetida* leaves to ash gourd improved the vegetative growth, flowering, and yield of crops. The legume tree extracts increased the vegetative growth and flowering in balsam, while in sorghum it enhanced the seed germination, plant height, and root length (Devarani and Rangasamy 1998). Seed treatment with Prosopsis and Pungam leaf extract improved germination, root length, DMP, and shoot length in *Eleucine corocana*.

**Crop yields**

The recent public awareness of the harmful effects of agrochemicals due to their indiscriminate use in crop production has paved the way for a return to environmentally friendly traditional agriculture. The increased grain yield (1440 kg/ha) with the application of *Leucaena* leaves @ 10 t $ha^{-1}$ compared to the non-application control, which was recorded with a yield of 940 kg $ha^{-1}$ in sorghum and in paddy, 100 per cent substitution of N through the green leaves of *Leucaena* improved yield up to 2055 kg $ha^{-1}$ as reported by Prakash and Bhusan (2003). Incorporation leaves of Gliricidia and Sesbania bispinosa as green leaf manure significantly increased yield (Karim and Savill 1991) and in cluster bean (Patel *et al*.2003).

**Systematic studies on *vrikshayurvedic* farming.**

The first systemic study on *vrikshayurvedic* farming in green gram was conducted at the Agricultural College and Research Institute, Madurai, Tamil Nadu by the senior author. In subsequent years, the studies were expanded to include Black gram, maize, Finger millet, Barnyard millet, Fox tail millet, Onion, and Bhendi and compared to zero inputs and scientific crop production.The yields of the different crops influenced by *vrikshayurvedic* farming are presented in Table 5. In green gram, a maximum mean grain yield of 2140 kg $ha^{-1}$ was recorded when *Gliricidia sepium* as green leaf manure at 10 t $ha^{-1}$ and *Aeglemarmelos* at 5 per cent concentration as foliar spray during 30 and 45 DAS**.** The foliar application of tree leaf extracts increased the yield and nutrition of green gram (Zodape *et al*. 2010).

Anbukkarasi and Sadasakthi (2011) observed that the higher fruit yield was obtained when Albizia *lebbek* as green leaf manure and seed soaking along with two foliar sprays of *Annonasquamosa* leaf extract at 25 and 45 DAS were used in bhendi. Similarly, *Gliricidiasepium + Aegle marmelos also* proved beneficial in bhendi. Application of *Gliricidia sepium* leaves at 10 t ha-1 45 days before onion sowing, followed by two foliar sprayings of Aegle marmelos leaf extracts at 5% 30 and 45 days after sowing, resulted in a higher yield.

In the maize crop, higher grain yield (1820 kg $ha^{-1}$) was recorded with green leaf manure as *Albizia lebbek + Annona squamosa* at 5 per cent concentration with five (25,39,53,67,82 DAS) foliar

sprays. It was followed by *Morinda tinctoria* (1795 kg $ha^{-1}$), which was five times higher than the zero input management (305 kg $ha^{-1}$) and almost 50 per cent of the yield was realised from high input management (Nandakumar and Swaminathan 2011).

Swaminathan *et al*. (2012) revealed that the highest germination per cent, root length, shoot length, and vigour index of seed in black gram was recorded in seed fortification with *Moringaoleifera* leaf extract (94%) followed by *Annona squamosa* (92%). Swaminathan and Nandakumar (2017) concluded that green leaf manure incorporation and leaf extract spray significantly influenced the seed yield of black gram. *Pongamia pinnata* as green leaf manure and four sprays (30, 37, 44, and 51 DAS) of *Moringa oleifera* as foliar nutrition obtained a higher grain yield of 585 $kgha^{-1}$ and it was on par with *Pongamia pinnata* + *Annona squamosa* (514 kg ha-1). This showed a decreased rate of 12.5 kg $ha^{-1}$ compared to higher inputs and an increased rate of 388.3 kg ha-1 compared to zero inputs. The highest yield of 1960 kg $ha^{-1}$ of barnyard millet was received with green leaf manure as *Peltophorum ferrugineum* and four foliar sprays of Annona *squamosa* at (20, 40, 60, and 80 DAS), which is more than two times higher than zero input (861 kg ha-1) and almost 91.1 per cent of the yield realised from high input management, and it was followed by *Delonix regia* + *Annona squamosa* (Swaminathan and Nandakumar 2017).

In finger millet, the highest grain yield of 808 kg/ha was obtained when received *Delonix regia* as green leaf manure and foliar sprays of *Moringa oleifera* at 36,52,68, and 85 DAS, which was four times higher than the zero input management (83 kg $ha^{-1}$) and almost 80 per cent of the yield realised from high input management (CPG management), it is given by the State Governments in India for each crop and published by the government every year). It was on par with results from *Delonix regia* + *Annona squamosa* (Swaminathan and Nandakumar 2017). The highest grain yield of foxtail millet (1689.4 kg $ha^{-1}$) was obtained with *Gliricidia sepium* as green leaf manure and *Mangifera indica* with five foliar sprays. This showed a decreased rate of 207.9 kg $ha^{-1}$ compared to higher input management and four times higher than zero input management (346.2 kg $ha^{-1}$). It was followed by *Gliricidia sepium* + *Bougainvillea glabra* (Swaminathan and Nandakumar 2017). Higher inputs recorded the highest grain yield per hectare. This might be due to increased nutrient availability and better uptake and utilisation of nutrients. Table 5 shows a comparison of *vrikshayurvedic* treatments with higher and zero inputs of different crops.

**Table 5.** Influence of *vrikshayurvedic* farming treatments comparison with higher inputs and zero inputs in different crop yields- A comparison.

| **Crop** | **Treatments** | **Vrikshayurvedic farming** | **Conventional farming** | **Zero input method** | **Reference** |
|---|---|---|---|---|---|
| | | **Yield (kg $ha^{-1}$)** | **CPG yield (kg $ha^{-1}$)** | **Zero input (kg $ha^{-1}$)** | |
| Onion | *Gliricidia sepium* + *Aegle marmellos* | 16180 | 18650 | 475 | Swaminathan and Nandakumar (2017) |
| | *Senna siamea* + *Annona squamosa* | 15680 | | | |
| Bhendi | *Albizia lebbek* + *Annona squamosa* | 1396 | 1475 | 550 | Anbukkarasi and Sadasakthi (2011) |
| | *Gliricidia sepium* + *Aegle marmellos* | 1260 | | | |
| Maize | *Albizia lebbek* + *Annona squamosa* | 1820 | 3900 | 305 | Nandakumar and Swaminathan (2011) |
| | *Albizia lebbek* + *Morinda tinctoria* | 1795 | | | |
| Black gram | *Pongamia pinnata* + *Moringa oleifera* | 585 | 597.92 | 197.08 | Swaminathan and Nandakumar (2017) |
| | *Pongamia pinnata* + *Annona squamosa* | 514 | | | |
| Finger millet | *Delonix regia* + *moringa oleifera* | 808 | 1337 | 83 | Swaminathan and Nandakumar (2017) |
| | *Delonix regia* + *Aegle marmellos* | 558 | | | |
| Barnyard millet | *Peltophorum ferrungineum* +*Annona squamosa* | 1960 | 2151 | 861 | Swaminathan and Nandakumar (2017) |
| | *Delonix regia* + *Annona squamosa* | 1760 | | | |
| Foxtail | *Gliricidia sepium*+ | 1689.4 | 1897.3 | 346.2 | Swaminathan |

| | | | | | |
|---|---|---|---|---|---|
| millet | *Mangifera indica* | | | | and Nandakumar (2017) |
| | *Gliricidia sepium* + *Bougainvillea glabra* | 1429.7 | | | |
| Green gram | *Gliricidia sepium* + *Aegle marmellos* | 2140 | - | - | Swaminathan and Nandakumar 2017 |
| | *Delonix regia* + *Morinda tinctoria* | 2120 | | | |

To infer, from the series of experiments (Fig.2) conducted at Tamil Nadu Agricultural University, Madurai on food crops like onion, bhendi, maize, black gram , finger millet, barnyard millet and foxtail millet with, three different ways of crop production, viz., zero input, conventional farming as per Crop Production Guide recommendations and the traditional method of *vrikshayurvedic* farming, revealed that there may be yield reduction to an extent of 13.4%, 5.35%, 46.7 %, 2.16 %, 39.56 %, 8.87 %, and 10.95 % for the crops listed above, in that order, respectively. The reduction may be compensated through a premium price as the product is chemical free (Swaminathan and Nandakumar 2017).

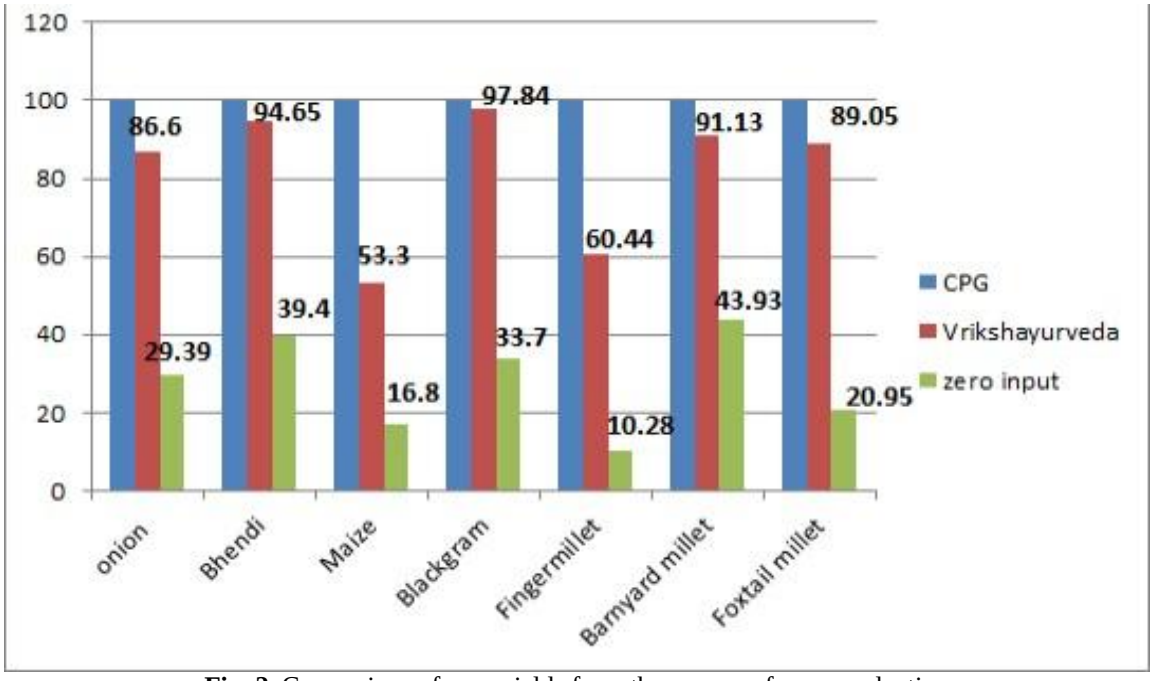


**Fig. 2**. Comparison of crop yields from three ways of crop production

**Supportive evidences in *vrikshayurvedic* farming**

Apart from trees and plants, animal by-products have also been used in *vrikshayurveda*. Ancient Indian farmers had achieved a level of agricultural technology comparable to what is used in modern times. The seed selection, selection of soil, classification of diseases, pest control, storage, plant nutrients, plant protection, crop rotation, and intercropping clearly indicate that the level of knowledge was equivalent to modern agriculture**.** Kunapajala, the manure explained in *Vrikshayuveda* is of great relevance in agriculture and horticulture, which contains aminoacids, sugars, fatty acids, keratins, and macro and micronutrients. The use of organic manures is safe and increases water holding capacity and microbial biomass.

*Kunapajala* application gives phenomenal effects on yield and quality, but *kunapajala* preparation and application techniques need to be researched further (Bhat *et al.* 2012). *Sarkar et al. (2014) showed that Panchagavya* and *Kunapajala* individually as well as in combination, proved their efficacy in promoting the growth and yield attributes of vegetable crops. *Panchagavya* and *kunapajala* together and individually were found to be the best for enhanced utilization of leaf nitrogen, efficient photosynthetic activity, and improved yields. The usage of white mustard has also been explained in *Vrikshayurveda* and it contains the enzyme signaling. This enzyme helps pest colonization and it acts as an antifungal. Moreover, white mustard is less volatile and pungent and has a longer effect.

Various uses of honey, milk, and cow dung are explained in many places. Cow dung contains bile pigments, nitrogen, phosphorous, and potassium, which are the nutrients essential for plant growth. Panchagavya is a combination of five products obtained from the cow and is also mentioned in

Vrikshayurveda texts. It had a significant role in providing resistance to disease, pests and increasing overall yields (Subhashini Sridhar *et al*. 2001; Swaminathan *et al*. 2007)**.** Panchagavya was an important one that enhanced the biological efficiency of crops and the quality of fruits and vegetables (Swaminathan *et al*. 2007)**.** *Amirthakaraisal-organic* pesticide reduced the incidence of root-borne diseases, increased the soil enzymatic activities and acted as a nutrient and growth promoter when applied through irrigation. *Thaemorkaraisal* is the combination of coconut, fermented milk, and palm jaggery used to induce flowering, maintain uniform flowering in rice (Tony Cisse 2004), and also increase the chlorophyll content.

## CONCLUSION

The use of synthetic chemicals and fertilizers in agriculture for the past three decades has resulted in very serious problems in the current era of the modern agricultural system, both economically and environmentally, such as human and health hazards, deterioration of soil health, poor quality foods, and environmental pollution. Hence, there is a need to develop alternate options to produce chemical-free food production. Therefore, a balanced fertilization strategy combining the use of chemical, organic, and bio fertilizers was evaluated. Furthermore, to keep out synthetic chemicals and fertilizers, the traditional agriculture of *vrikshayurvedic* farming deals with an ancient science of plant life. It is a highly scientific method and solution for present situations. *vrikshayurvedic* farming also discusses various topics related to plant life science, such as procuring, preserving, and treating seeds before planting; soil pH selection; nutrition and fertilizer; plant diseases; and plant protection from internal and external diseases, among others. It is an eye opener for future years of chemical-free farming.

### Lacunae and Future line of work

The growing demand for less expensive, environmentally friendly, safer, and more selective bio formulations for total health care in crop production should spur interest in and research into natural tree products as crop health tonics. In many cases, natural products offer improved selectivity, better toxicological and environmental safety, and increased efficiency. The new tools of molecular biology and biotechnology will allow the industry to amplify the production of such developed crop health tonics or bio-formulations in agriculture so that commercial biosynthesis will become economically feasible.

- ✓ Identifying the principal compound present in the leaf extracts of tree species responsible for plant production and protection needs to be done. Assessing the performance of ruling and local varieties of nutri-cerelas under *Vrikshyurveda*. This work has been started by our team and we have completed identification of compounds in 10 tree species.
- ✓ Low cost and cheap natural resources are required to develop the management protocol with low cost and cheap natural resources. Exploring the possibility of reducing the duration of *in situ* decomposition of 45 days through external application of microbial agents. Studies post-harvest technology and value addition on thus produced grains needs to be done.

## REFERENCES

**Abbott, L., Murphy. K. and Daniel, V.** (2007). Soil biological fertility. A key to sustainable land use in Agriculture. *Springer*.

Google Scholar

**Ahuja, S.C., SiddharthAhuja and Uma** (2015). Nirgundi (*Vitexnegundo*) – Nature's Gift to Mankind. *Asian Agri-History*,**19** (1): 5–32.

Google Scholar

**Ali-Esmail and Al-Snafi** (2017). Chemical constituents and pharmacological effects of *Dalbergiasissoo*-A review. *IOSR Journal of Pharmacy*, **7**(2): 59-71.

Google Scholar

**Anbukkarasi, V. and Sadasakthi, A.** (2011). Effect of *Vrikshayurveda* treatments on improved yield, quality and economics of bhendi. (*Abelmoschusesculentus* L. Moench) cv. Arka anamika. *Agriculture Science Digest*, **31**(4): 270-274.

Google Scholar

**Ariharan, V.N. and Nagendra Prasad, P.** (2014). Quantitative phytochemical analysis on leaf extract of *Aeglemarmelos*. *Journal of Chemical and Pharmaceutical Research*, **6**(3): 1100-1104.

Google Scholar

**Arulmozhi, S., Mazumder, P.M., Ashok, P. and Narayanan, S.L.** (2007). Pharmacological activities of *Alstonia scholaris* Linn. (Apocynaceae)-A Review. *Pharmcongnosy Reviews*,**1**: 163-170.

Google Scholar

**Arun, A., Karthikeyan, P., Sagadevan, P., Umamaheswari, R. and Rex Peo, R.** (2014). Phytochemical screening of *Sesbaniagrandiflora* (Linn). *InternationalJournal of Biosciences and Nanosciences*,**1**(2): 33- 36.

Google Scholar

**Belmain, R.S., Amoah, A.B., Nyirenda, P.S., Kamanula, J.F. and Stevenson, P.C.** (2012). Highly variable insect control efficacy of *Tephrosia vogelli* chemotypes.*Journal of Agricutural and Food Chemistry*, **60**(40): 10055-10063.

Google Scholar

**Bhat, S., Ashok, B.K., Acharya, R. and Ravishankar, B.** (2012). Importance of kunapajala (traditional liquid organic manure) of vrikshayurveda in medicinal plants cultivation. *Global Journal of*

*Research on Medicinal Plants and Indigenous Medicine Review*, **1**(7): 272 – 279.
Google Scholar

**Debnath, N.C. and Hajra, V.** (1972). Transformation of organic matter in soil in relation to mineralization of carbon and nutrient availability. *Indian Society of Soil Science*, **20**(2): 95-102.
Google Scholar

**Devarani, N. and Rangasamy, A.** (1998). Nutrient and drought management practices for rainfed sorghum under vertisol. *Madras Agriculture Journal*, **85** (7-9): 391-393.
Google Scholar

**Devi, M.N., Singh, T.K. and Devi, L.C.** (2003). Efficacy of certain botanicals insecticides against cotton aphid, *Aphisgossypii* Glorer on brinjal. *Medicinal and Aromatic plants abstract*,**25**(4): 819.
Google Scholar

**Dwevedi, Alka, Sharma, Kuldeep and Sharma, Yogesh K.** (2015). *Cadamba*: A miraculous tree having enormous pharmacological implications. *Pharmacognosy reviews*, **9** (18): 107-113.
Google Scholar

**Foid, l.N., Makkar, HPS and Becker, K.** (2001). The potential use of *Moringaoleifera* for agriculture and industrial uses. *Managua Nicaragua*, pp. 1–20.
Google Scholar

**Hazara, A.H., Shakkela, M., Khan, J., Igbal, M. and Khan, S.** (1999). Effect of non-chemical methods and botanical insecticides on onion thrips, (Thrips *tabaci* sp, Thysanoptera: Thripdae) in onion crop in Balochistan. *Sarhad. Journal of Agriculture*,**15**(3): 619-624.
Google Scholar

**Hoft, M., Verpoorte, R. and Beck, E.** (1996). Growth and alkaloid contents in leaves of *Tabernaemontana Pachysiphon stapf* (Apocynaceae) as influenced by light intensity, water and nutrient supply. *Ecophysiology*,**107**: 160-169.
Google Scholar

**Indira Devi, P., Judy, Thomas and Rajesh, K. Raju** (2017). Pesticide Consumption in India: A Spatiotemporal Analysis. *Agricultural Economics Research Review*,**30** (1): 163-172.
Google Scholar

**Jallow, M., Awadh, D., Albaho, M., Devi, V. and Thomas, B.** (2017). Pesticide risk behaviours and factors influencing pesticide use among farmers in Kuwait. *Science of The Total Environment*.**574**: 490-498.
Google Scholar

**Gupta, Jaya, and Gupta, A.** (2013). Phytochemical screening of *Phyllanthus emblica* (L.) using different solvents. *Journal of Chemical Tracks*,**15**(1): 117-120.
Google Scholar

**John** (2010). Sustainability Rural. In. Leslio A. Duram (ed.) Encyclopedia of organic, sustainable and local food.
Google Scholar

**Kadadiya, H.J. and Dhruj, I.U.** (2001). Antifungal property of some plant extracts against *Cercosporacanescens* Mungbean leaf spot instant. *Journal of Mycology and Plant. Pathology*, **31**(1): 101-103.
Google Scholar

**Kannan, C.** (2001). Management of post-harvest fungal diseases of carrot using botanicals. *South Indian Horticulture*, **49** (Special): 271-274.
Google Scholar

**Karim, A.B. and Savill, P.S.** (1991). Effect of spacing on growth and biomass production of *Gliricidia sepium (Jacq) walp* in an Alley cropping system. *Agroforestry Systems*, **16**: 213-222.
Google Scholar

**Kawawa, R.C.A., Muyekho, F.N., Obiri, J.F., Agevi, H. and Obiet, L.** (2016). The allelopathic Impact of *Psidiumguajava* L., Leaf Extracts on the Germination and Growth of *Cassia occidentalis* L.seeds. *IOSR Journal of Agriculture and Veterinary Science*, **9** (7):101-105.
Google Scholar

**Koul, O., Isman, M. and Kethar, C.** (1990). Properties and uses of neem. *Canadian Journal of Botany*, **68**: 1-11.
Google Scholar

**Lava, Hassam, Al-naser, Z. and Nader, S.** (2015). Phytotoxic activity of foliar applications of *Melia azedarach* extracts on growth and yield of *Cicer arietinum L.* in open field condition. *International Journal of Chem Tech Research*, **8**(4): 1982-1990.
Google Scholar

**Naik, R.L. and Dumbre, R.B.** (1985). Effect of some vegetable oils used as surface protectants against *Callosobruchus maculates* on storability and qualities of cowpea. *Bull.Grain Technology*,**23**: 33-39.
Google Scholar

**Nair, P. K. R.** (1993). An Introduction to Agroforestry, Kluwer Academic publishers, USA.
Google Scholar

**Nandakumar, M.R. and Swaminathan, C.** (2011). Influence of *vrikshayurvedic* practices on growth and yield of maize. (*Zea mays L.).Madras Agricuture Journal*, **98**(4-6): 169-172.
Google Scholar

**Nene, Y.L.** (2012). Potential of some methods described in vrikshayurveda in crop yield increase and disease management. *Asian Agriculture History*, **16**(1): 45-54.
Google Scholar

**Patel, J.J., Patel, B.M., Patel, B.T. and Patil, R.G.** (2003). Study on use of *Gliricidia sepium* leaves for leaf manuring in cluster bean-pearl millet rotation under dryland condition. *Agriculture Science Digest*,**23**(1): 10-13.
Google Scholar

**Prakash, O.M. and Bhushan, L.S.** (2003). Effect of fertilizer substitution through white lead tree

(*Leucaena leucocephala*) green biomass on growth, yield and economics at wheat *(Triticum asetivum)* crop in degraded lands. *Indian Journal of Agricuture Science*,**73**(6): 311-314.

Google Scholar

**Raychaudhuri, S.P., Raw, R.K., Raghavan, D., Kumar, Krishan J. and Bali, B.** (1964). Agriculture in ancient India. *Geography*.

Google Scholar

**Rishi, N.** (2009). Significant plant virus diseases in India and a glimpse of modern disease management technology. *Journal of General Plant Pathology*,**75**: 1.

Google Scholar

**Sadhale, N.** (1996). Surapala's vrikshayurveda (The science of plant life by surapala), Secundrabad, India. *Asian Agriculture History Foundation*.

Google Scholar

**Sahgal, G., Ramanathan, S., Sasidharan, S., Mordi, M.N., Ismail, S. and Mansor, S.M.** (2009). Phytochemical and antimicrobial activity of *Swietenia mahagoni* crude methanolic seed extract. *Tropical Biomedicine*, **26** (3): 274–279.

Google Scholar

**Sarkar, S., Kundu, S.S. and Dipankar, Ghoral** (2014). Validation of ancient liquid organics-Panchagavya and Kunapajala as plant growth promoters. *Indian Journal of Traditional Knowledge*, **3**(2): 398-403.

Google Scholar

**Satpathy, S., Gotyal, B.S. and Ramesh Babu, V.** (2020). Role of novel insecticides and their selectivity to natural enemies: A Review. *Journal of Environmental Biology*,**41**: 149-160.

Google Scholar

**Saxena, R.C., Choudhary, S.L. and Nene, Y.L.** (2009). A text book of Ancient History of Agriculture. Asian Agri-History Foundation (AAHF), Secunderabad and Rajasthan chapter of AAHF, pp- 139, Udaipur, India.

Google Scholar

**Shah, K.A., Patel, M.B., Patel, R.J. and Parmar, P.K.** (2010). *Mangiferaindica* (Mango). *Pharmacognosy Reviews*, **4**(7): 42–48.

Google Scholar

**Sridhar, S., Arumugasamy, S., Saraswathy, H. and Vijayalakshmi, K.** (2000). Organic vegetable gardening. *Centre of Indian Knowledge system*, Chennai.

Google Scholar

**Subhashini, Sridhar, Arumugasamy, A., Vijayalakshmi, K. and Balasubramanian, A.V.** (2001). Vrikshayurveda for plants. Centre for Indian Knowledge systems, Chennai, Tamil Nadu. 47.

Google Scholar

**Swaminathan, C. and Nandakumar, M.R.** (2017). *Vrikshayurvedic farming*-The Traditional Indian Agriculture, Daya publishing House, A divison of Astral International Private Ltd. New Delhi.

Google Scholar

**Swaminathan, C. and Raguraman, S.** (2007). Silviculture of neem and its role in Agro forestry and Social Forestry. Neem Research -A Treatise. (Eds.) Singh K K, Suman Phogat and Alka Tomar.Kalyani Publishers, Ludhiana.

Google Scholar

**Swaminathan, C. and Nandakumar, M.R.** (2012). Vrikshayurvedic farming - New vistas in Indian Agriculture. In proceedings of the 3rd International Agronomy Congress organized by the Indian Society of Agronomy, IARI, New Delhi.

Google Scholar

**Swaminathan, C., Swaminathan, V. and Vijayalakshmi, K.** (2007). Panchagavya Boon to organic farming. *International Book Distributors, New Delhi.*

Google Scholar

**Tony cisse** (2004). Techniques for organic paddy cultivation. *Indigenous Agricultural News*,**4**: 1-4.

Google Scholar

**Vani, K.P. and Bheemaiah, G.** (2003). Efficient use of fertilizer through Alley cropping and green leaf manures for increased productivity of rainfed castor. *Annual Agriculture Research Science*, **124**(3): 598-604.

Google Scholar

**Ved Prakash, Saxena, Sarika, Gupta, Savitha, Saxena, Ashish Kumar, Yadav, Rajkumar, Singh**, **Sunil Kumar** (2015). Preliminary phytochemical screening and biological activities of *Adina cardifolia*. *Journal of Microbial and Biochemical Technology*, **7** (1): 33-38.

Google Scholar

**Yadav, S. and Dutta, S.** (2019). A Study of Pesticide Consumption Pattern and Farmer's Perceptions towards Pesticides: A Case of Tijara Tehsil, Alwar (Rajasthan). *InternationalJournal of Current Microbiological Applied Science*, **8**(4): 96-104.

Google Scholar

**Zodape, S.T., Soumita, Mukhopadhyay, Eswaran, M., Reddy, P. and Chikara, J.** (2010). Enhanced yield and nutritional quality in green gram (*Phaseolusradiate* L.) treated with seaweed (*Kappahychusalvarerzii*) extract. *Journal of Science and Industrial Research*,**69**(2): 468-471.

Google Scholar