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

C. Swaminathan¹, P. Nivethadevi, K. Sangeetha and M.R. Nandhakumar²

¹Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai- 625104, Tamil Nadu, India
²Division of Crop Management, Kumaraaguru Institute of Agriculture, Erode, Tamilnadu – 638315

Email: swaminathanc@tnau.ac.in

Received-02.08.2022, Revised-13.08.2022, Accepted-28.08.2022

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 yield

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

*Corresponding Author
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 Vriksa meaning trees; Ayurveda meaning the traditional Hindu system of medicine (incorporated in Aharvarveda, 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, Bhumini pavana, Bijoptivithi, Padapavitaksa, Ropana vidhana, Nisecanavidhi, Posanavidhi, Drunaraksha, TaruCikitasa, Upavanakriya, Nivasasannataru, Subhasubha Laksana, Tara 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. She Sweda Iyengar, Government central Manuscripts library, Chennai, India 1950) and 3) Sarangadhar, 1363 A.D. Vrikshayurveda (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" (Jagn 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), Sarangadhar (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, Ammona 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)

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

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., *Gliricidia sepium* (2.76, 0.28, 4.60% NPK) and *Delonix regia* (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.
<table>
<thead>
<tr>
<th>S. No</th>
<th>Tree Species</th>
<th>Family</th>
<th>Parts used</th>
<th>Secondary metabolites Present</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td><em>Anthocephalus</em></td>
<td>Rubiaceae</td>
<td>Leaves</td>
<td>Indole and quinolone</td>
<td>Alka</td>
</tr>
</tbody>
</table>

**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.
<table>
<thead>
<tr>
<th>No.</th>
<th>Common Name</th>
<th>Family</th>
<th>Part of Plant</th>
<th>Alkaloids</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Pongamia pinnata</td>
<td>Leguminosae</td>
<td>Leaves, seeds</td>
<td>Fixed oil- Karanjin</td>
<td>Belma et al. (2012)</td>
</tr>
<tr>
<td>7.</td>
<td>Gliricidia sepium</td>
<td>Fabaceae</td>
<td>Fresh and dried leaves</td>
<td>Alkaloids and saponins</td>
<td>Sahgal et al. (2009)</td>
</tr>
<tr>
<td>8.</td>
<td>Melia azedarach</td>
<td>Meliaceae</td>
<td>Leaves, Fruits</td>
<td>Limonoid and Meliartenin</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Tephrosia vogelli</td>
<td>Fabaceae</td>
<td>Leaves</td>
<td>Rotenone &amp; Tephrosin</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Swietenia mahagoni</td>
<td>Meliaceae</td>
<td>Seeds and leaves</td>
<td>Scopoletin&amp;limonoids</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Eucalyptus camadulensis</td>
<td>Myrtaceae</td>
<td>Oil &amp; leaves</td>
<td>Terpenoids, alkaloids, limonene, eucalyptol</td>
<td></td>
</tr>
</tbody>
</table>

**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 increased many-fold (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. For revitalising the environment, different organic practises offer a significant contribution through the supply of plant nutrients.

**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\(^{-1}\)) 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 Delonix regia. 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 cluster beans (303.3 kg ha\(^{-1}\)). In black gram, the highest uptake of N was recorded (22.01 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 Delonix regia (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 Delonix regia (22.01 kg ha\(^{-1}\)). The highest available N and P were recorded in Leucaena leucocephala (303.3 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 cluster beans (303.3 kg ha\(^{-1}\)). In black gram, the highest uptake of N was recorded (22.01 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 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 (Swaminathan and Nandakumar, 2017). 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 Table 2, nitrogen uptake on vrikshayurveda of different crops was presented.
**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) Morinda ole ifera 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 *kunaphaja* 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) *Anthecephalus cadamba* 4) *Adina cordifolia* 5) *Morinda tinctoria* 6) *Pongamia pinnata* etc 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 repellent 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 salvifolium* 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 2020).

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

<table>
<thead>
<tr>
<th>S. No</th>
<th>crops</th>
<th>Green leaf manures</th>
<th>Nitrogen (kg/ha)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maize</td>
<td><em>Albizia lebbek</em></td>
<td>103.8</td>
<td>Nandakumar and Swaminathan (2011)</td>
</tr>
<tr>
<td>2.</td>
<td>Black gram</td>
<td><em>Pongamia pinnata</em></td>
<td>68.3</td>
<td>Swaminathan and Nandakumar (2017)</td>
</tr>
<tr>
<td>3.</td>
<td>Barnyard millet</td>
<td><em>Peltophorum ferrugineum</em></td>
<td>74.08</td>
<td>Swaminathan and Nandakumar (2017)</td>
</tr>
<tr>
<td>4.</td>
<td>Finger millet</td>
<td><em>Delonix regia</em></td>
<td>71.28</td>
<td>Swaminathan and Nandakumar (2017)</td>
</tr>
<tr>
<td>5.</td>
<td>Fox tail millet</td>
<td><em>Gliricidia sepium</em></td>
<td>43.9</td>
<td>Swaminathan and Nandakumar (2017)</td>
</tr>
</tbody>
</table>
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 punagam 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 *vriskshayurvedic farming* practices 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 Drurj (2001) worked out the bio-fungicidal properties of custard apple (*Annona squamosa*) and tulsí (*Ocimum sanctum*). These extracts were good inhibitors of growth as well as spore germination of *Cercospora canecens* in mungbean. Plant extracts were used to treat cowpea aphid-borne mosaic virus. Sprays of phyto-extracts of *Jatropha curcas* 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 *Vitex negundo* 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 neem. The overall efficacy was in the order of *Artemisia vulgaris > Azadirachta indica > Vitex trifolia > Ageratum conyzoides*. The plant extracts of neem, *Annona squamosa* and *Annona reticulata* were effective in reducing the onion diseases (Fusarium, *Alternaria porri* and *Stemphyllum 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 asafoetida* 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 *Prosopis* and *Punagam* leaf extract improved germination, root length, DMP, and shoot length in *Eleusine corokana*.

**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 of *Glicidia* 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 vriksayurvedic farming.**

The first systemic study on *vriksayurvedic 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 *vriksayurvedic 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, *Gliricidia sepium + Aeglemarmelos* also proved beneficial in bhendi. Application of *Gliricidia sepium* leaves at 10 t ha⁻¹ 45 days before onion sowing, followed by two foliar sprays 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 (25,30,53,67,82 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 *Moringa oleifera* 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 kg ha\(^{-1}\) 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.**

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species 1</th>
<th>Species 2</th>
<th>Yields</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>finger millet</td>
<td>Gliricidia sepium</td>
<td>Bougainvillea glabra</td>
<td>1429.7</td>
<td>Nandakumar (2017)</td>
</tr>
<tr>
<td>barnyard millet</td>
<td>Gliricidia sepium</td>
<td>Aegle marmellos</td>
<td>2140</td>
<td>Swaminathan and Nandakumar 2017</td>
</tr>
<tr>
<td>foxtail millet</td>
<td>Delonix regia</td>
<td>Morinda tinctoria</td>
<td>2120</td>
<td></td>
</tr>
</tbody>
</table>

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 Vrikshayurveda 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) Amritthakaraisal-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-cereals under Vrikshayurveda. 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


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar


Google Scholar