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REVIEW ARTICLE

Traditional insights into ITK and its delineation for sustainable crop protection

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Abstract

The challenge of producing sufficient food to feed the growing population is aggravated by pests and diseases, with insect pests alone causing 15-20 percent losses in food production. Despite the availability of numerous synthetic and conventional pesticides, traditional practices, known as Indigenous Technical Knowledge (ITK), have been utilized by farmers for generations and have been adequate to date. These practices are deeply rooted in local culture and are environmentally safe. ITKs are a wealth of agricultural wisdom intertwined with religious and cultural beliefs that have significantly contributed to plant protection. It considers the interconnectedness of all living beings and the natural environment. In the context of the current scenario, it is essential to preserve and safeguard these traditional practices. Numerous government centres and policies are dedicated to this goal, recognizing the importance of documenting ITK for future use. Although ITKs were initially practiced without scientific validation, modern research has characterized and supported many of these methods. This review emphasizes the significance of Indigenous Technical Knowledge, the support systems in place and the necessity of detailed documentation and scientific characterization of ITK in use. By focusing on preserving and validating ITKs, we can reduce reliance on harmful chemical pesticides, promote sustainable agricultural practices and ensure food safety and security.

Keywords

characterization; culturable microbes; ITK concoctions; pest management; traditional knowledge

Introduction

Crop management and domesticating animals have been the most fundamental human activities since the beginning of agriculture (1). It is essential to optimize the use of per capita land and water resources to increase food production and create livelihood opportunities. The green revolution, which took place during the 1960s-70s in India, aimed at increasing the food grain production with its primary objective of producing High Yielding Seed Varieties (HYSVs) (2, 3). Using chemical fertilizers, herbicides, high-yielding cultivars, water and other green revolution technologies led to an incredible increase in agricultural production. Even though the results were highly encouraging, input-intensive agriculture has had some unfavourable implications for abiotic and biotic elements in the environment (4).

Though modern technologies in agriculture enabled the feeding of the increasing population, they resulted in increased loss in crop management due to pests, diseases and weeds. Arthropod pests are thought to be responsible for 18-20 per cent of annual crop productivity loss which amounts to more than US $470 billion (5, 6). The co-habitat relationship between insect pests and their natural enemies in any crop environment helps to maintain a balance. Excessive reliance on chemical pesticides has upset the equilibrium, resulting in pest outbreaks, causing insect pest and pathogens to gain resurgence and resistance to these chemicals thereby harming the ecosystem (7, 8). The use of chemical pesticides is around four million tonnes per year world-wide (FAO, 2018). Those used in agriculture damage plants, soil texture and beneficial soil bacteria. It also has a tremendous impact on the environment, affecting microbes, fishes, birds, animals and human health, indirectly affecting the tri-trophic interactions among them (9-11).

Organic farming could be defined as a system that neglects and excludes utilization of synthetic inputs like hormones, pesticides, fertilizers (United States Department of Agriculture-USDA, 1980). It integrates tradition, science and innovation, ensuring environmental health (1). The problem of pest control must be related to ecological organic agriculture, which is an environmentally friendly form of organic farming (12). Organically produced goods are environmentally safe and free from pesticidal residues (13). It is practised in 187 countries by 3.1 million farmers under 72.3 million hectares of organic farmland producing 75% of world's agricultural produce organically (14). Indigenous technical knowledge can play a crucial part in stabilizing the agro-ecosystem, reducing hazardous chemical load and cutting cultivation costs, which will result in profitable crop cultivation (15). The use of biopesticides, organic manures, organic mulching and environmentally friendly techniques are the mainstays of organic agriculture (16) as they contain bio-pesticidal qualities promoting plant growth, vitamins, enzymes and elements through excellent sources of microorganisms, hormones, micronutrients and macronutrients (17).

Indigenous Technical Knowledge

Through the ages, many plant protection techniques have been employed by people with diverse cultural backgrounds and religious convictions. Despite their knowledge, people used native customs, including several locally accessible plant species with insecticidal properties (18). Since organic agriculture is a traditional method, it is linked to several conventional organic formulations in the form of traditional knowledge held by indigenous people (16). Indigenous Technical Knowledge (ITK) is the common traditional practice and the specific knowledge of the native farmers of different regions worldwide who have their own customs, beliefs and traditions (19). This knowledge has been carried over generation after generation without being documented scientifically as it is dynamic and constantly shaped by interactions with external systems as well as internal innovation and experimentation (18).

These techniques use less or no chemicals, are eco-friendly, are less expensive, reduce diseases and pest incidence and enhance plant growth, soil fertility and microbial diversity (20). Organic formulations and their chemical compounds aiding in different aspects of agriculture are presented in Fig. 1. The practice of non-chemical techniques for controlling pests is of major importance in many countries. The crop production scenario in the agro-ecological region may change if these ITKs are successfully included in the Integrated Pest Management (IPM) strategy, resulting in lower production costs and higher net returns. The key element of the indigenous knowledge system is the wise use of plant and animal resources in their raw or processed forms, that are affordable, location- and culture-specific and sustainable.

Research organizations on ITK

DST (Department of Science and Technology), Government of India and NIF (National Innovation Foundation) have emphasized innovations based on traditional knowledge. Currently of advanced technology, several of these ITKs have already been studied, proven and even suggested for future agricultural profitability and sustainability (21). Several institutes are working to provide support and action to revive ITK in sustainable agriculture, as shown in Table 1.

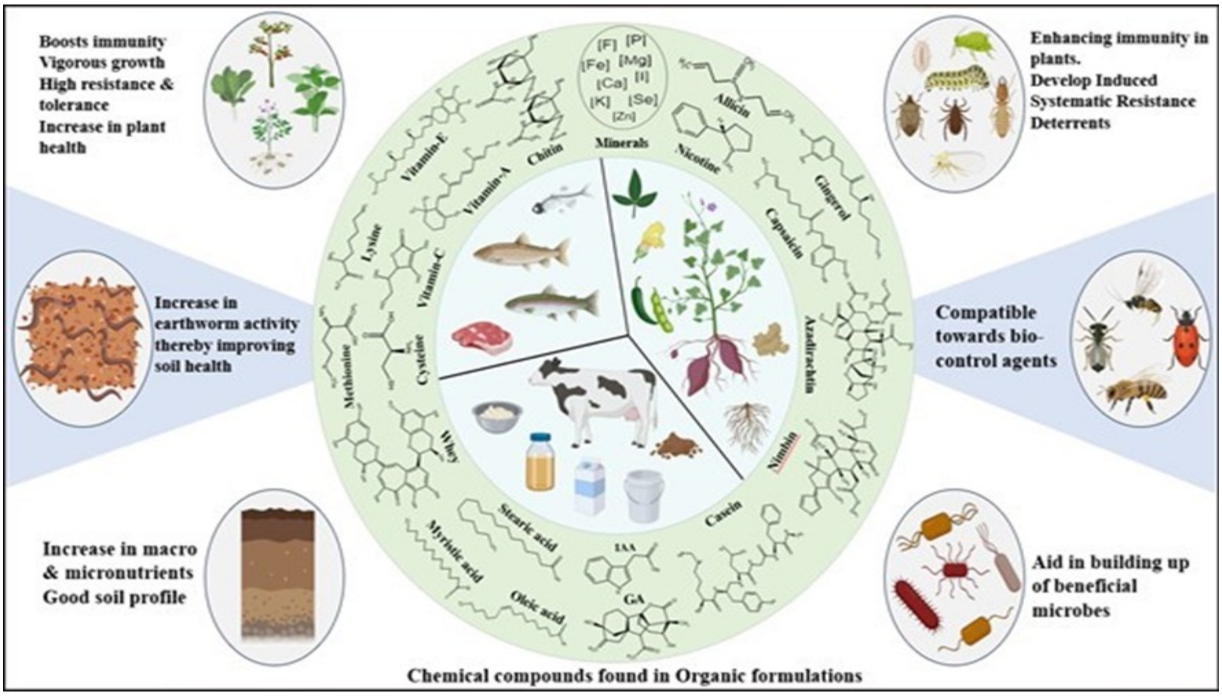

Fig. 1. Organic formulations and their chemical compounds aiding in different aspects of agriculture.

Table 1. Institutes supporting and promoting ITK

S. No	Institutes	Objectives	References
1.	Globally Important Agriculture Heritage Systems / (GIAHS-Food and Agriculture Organization, Italy)	Verifying, promoting and protecting globally critical agricultural heritage systems and their dependent livelihoods	22,23
2.	International Institute of Rural Reconstruction (IIRR, Philippines)	To rebuild the distinctive resources found in rural areas by providing health and educational services	
3.	Traditional Knowledge Digital Library (TKDL-CSIR, India)	Documenting data from traditional knowledge related to farming techniques, food and traditional cultural expressions	
4.	Indigenous Technical Knowledge Portal for Agriculture (ITKPA-ICAR, India)	Facilitate the integration of Indigenous Technical Knowledge (ITK) into agricultural research and extension	
5.	Indigenous Technical Knowledge Resource Centres (ITKRC, India)	Support national data management of Indigenous technical knowledge systems and sharing of their indigenous technical knowledge systems among agricultural communities	
6.	Agricultural Technology Application Research Institute (ICAR-ATARI) Farm Science Centre as Krishi Vigyan Kendra (ICAR-KVK)	Resource hubs for the rebirth of ITK to achieve the objective of sustainable agriculture	

ITK practices in pest control

Since 1200 BC, plant-based insecticides have been used in agriculture. *Aragwadhadigana* of Surrata included *Cassia fistula* L. in Aragvedha, *Alstonia scholaris* L. in Saptapurana, *Pongamia pinnata* L. in Karanja and Neem; *Azadirachta indica* in Nimb for use against worms (maggots). The pesticide properties of neem were also mentioned in several texts in the Vedic period (22). The ancient Sanskrit medical scripts recorded neem's benefits and are well recognized in India (23). Some of the ITK's that are widely in practice for plant growth and pest control includes Panchagavya (20), kunapajala (24), Darekasthra (25), fish amino acid (26, 27), five -leaf extract, pathilai karaisal (28), neemhasthra, agneyasthra (29), brahmahasthra, coconut- buttermilk ghol, amrit dhara (30). The method of preparation and uses of organic formulation is given in Table 2. Botanicals obtained from various plant parts, viz., roots, stems, barks, leaves, flowers, fruit seeds and rhizomes of plants, are used to prevent, repel and kill insects because of certain bioactive chemicals (31, 32). El-Sayed (33) documented that extracts and solutions derived from 20 different plant parts possess insecticidal effects on lepidopteran pests. Biological features of 1,005 plant species countering insects were previously identified (34) that contained antifeedants (384), attractants (97), repellents (297) and growth inhibitors (31). Some of the botanical extracts that were effective in controlling insect pests are given in Table 3.

Cow dung is being used for many purposes in households. It holds a good role in controlling many pests. The use of cow urine and cow dung has been reported against insect pests (35). It was previously reported that the extracts obtained from cow dung, brick kiln and Cycas cone effectively against yellow stem borer (YSB) in rice and cow dung extract coated on rice leaf was found to deter the moths from oviposition (36). When the extract was sprayed at 2% concentration, it acted as a seed protector for various pests. Cow urine can be used as a molluscicide in rice fields (37). Mandibulate insects on vegetable crops are controlled by spraying cow urine and rice starch (38). Fish-washed water applied to lemon tree was effective for the control of *Anoplophora versteegi* (39).

Mustard oil has been used for storing of pulses as it has allyl isothiocyanate and antimicrobial properties. Ash mixed with food grains in 1:1 ratio can cause insect damage, leading to desiccation and death (40). Coconut dust and wood ash can be used to control pests attacking the seeds of tomatoes in storage

Table 2. Widely used ITK concoctions for pest control

ITK Concoction	Method of Preparation	Dose (Foliar spray)	Pest Control	References
Kunapajala	Fish bones and meal combined with animal waste (1kg), cow dung (1kg), cow urine (1kg) and water (2L) stirred and kept for aerobic fermentation for 25 to 30 days.	1%	Tea mosquito bug (*Helopeltis antonii*), Looper (*Biston suppressaria*)	16,26,46
Panchagavya	Cow dung (7kg), urine (10L), milk (3L), ghee (1L) and curd (2L) were mixed with coconut water (3L) and jaggery (3kg) along with water and kept for 15 days.	3%	Detrimental effect on insects	47-49
Neemasthra	Grounded neem leaves (5 kg) are mixed with cow urine (5 L), cow dung (2 kg) and water (50 L) and allowed for fermentation	3-6%	Sucking pests of vegetable crops	50,51
Brahmasthra	2 kg leaves of neem, custard apple, papaya, pomegranate and guava in 10 litres of cow urine and the contents are boiled.	5%	Borer and sucking pests	52
Agneyasthra	Leaves of bindweed (1 kg) and neem (5 kg) are added with chilli and garlic (500 g each) in cow urine (10 L) and boiled.	3%	Borers, leaf folders and sucking pests	30,31
Darekasthra	Branches of dark trees with leaves (2 kg) are added to water (40 L), cow urine (2 L) and cow dung (400 g), stored for 2 days and the solution is strained.	5%	Sucking pests, young caterpillars	53
Fish amino acid	The fermentation of fish with jaggery and banana is mixed in a 1:1 ratio and allowed for fermentation.	3%	Deter lepidopteran pests	28,31
Pathilai karaisal	Neem leaves (5 kg) and 2 kg of Notchi, Aristolochia, Papaya, Moonseed, Custard apple, Erukam, Kolinji, Kaatamanakku, Pungam leaves are added to water (200 L), cow urine (5 L), cow dung (3 kg) mixed well and allowed for fermentation up to 3 months	10%	Lepidopteran pest	30,31
Coconut- buttermilk ghol	Buttermilk (5L) mixed with coconut water (1L), fruit juice (1 L), turmeric (100 g)	1%	Plant protection against insects	53
Amrit Dhara	Add peppermint (15 g), ajwain (15 g), kapur (15 g) and mix well	4-6%	Sucking pests	30,31

Table 3. Botanical concoctions used in ITK

Composition	Method of preparation	Ratio (extract: water)	Pest control	References
Aloe (2 kg), Vitex (5 kg) + Water (10 L)	The extract is prepared by boiling vitex leaves in water and adding strained and grinded aloe leaves.	1:60	Leaf folder, hairy caterpillar, stem borer, armyworm and semi-looper in rice	54
Tobacco leaf	The extract is prepared by boiling tobacco leaves.	1:2	Lepidopteran pests on vegetables	41
Coriander (200 g) +Water (1 L)	Seeds were soaked in water for 10 minutes and extracted.	1:2	Repellent against spider mite	54
Onion, Garlic	Garlic and onion extracts are obtained by grinding.	1:1	Leaf-dwelling insects and grasshoppers in maize	55
Marigold (500 g), Chilli (10 pods) +water (15 l)	Overnight soaking of chopped marigolds and chilli pods in water.	1:2	Control many agricultural pests	54
Vitex (2 kg) +Water (5 l)	Boiling vitex leaves in water for 30 minutes.	1:10	Diamondback moth, rice leaf folder, semilooper, hairy caterpillar and rice stem borer	54
Neem (1 kg) +Water (2 l)	Neem leaves are ground with water and the extract is kept in a mud pot, covered with a cloth and kept without any disturbance for three days.	1:6	Leaf hoppers, scales, aphids, plant hoppers, grasshoppers, weevils, beetles and thrips	54,55
Neem leaves (2 kg), Tobacco (500 g), Green chillies (500 g), Garlic cloves (250 g), Cow urine (20 l)	Cow urine with other components is mixed well, boiled (15 minutes) and cooled for 2 days. The mixture is filtered and stored in the shade for 3 months.	10:20	Cutworms (*Helicoverpa armigera*)	56

(The phylogenetic relationship among bacteria found from various formulations obtained from cow by products was performed. The phylogenetic tree clearly revealed that aerobic bacteria formed a separate clade from that of anaerobic bacteria. Among the aerobic bacteria, Gram positive *Microbacterium*, *Janibacter*, *Bacillus* and *Lactobacillus* formed separate cluster from the Gram-negative bacteria. Gram negative *Bacteroides* appeared as biphylectic, forming a separate clade from the *Larkinella* and also formed a separate deep phylogenetic lineage form the cluster containing *Pseudoxanthomonas*, *Stenotrophomonas*, *Pseudomonas*, *Xenophilus*, *Comomonas* and *Xylophilus*. Interestingly *Blautia coccoides* is an anaerobic bacterium, Gram-positive with potential probiotic characters is formed as a distinct lineage from the aerobic Firmicutes. However, this deep phylogenetic lineage is not supported by high boot-strap value.)

(38). It was already documented the use of chilli and turmeric powder in storage provides protection (41). The strong smell of chilli controls pests like floor beetles, lesser grain borer and pulse beetles. Cloves with salt, chilli powder, edible oils and condiments are used to store grains, keeping them fresh and protecting them from insects. Ginger pieces were added to rice storage yarns (42). Storage yarns were coated with thin paste made of cow dung, urine and clay to keep them airtight (43).

Characterization of the ITK concoctions

Traditional organic liquid formulations prepared on farm are rich in microbial flora and add mineral and organic matter to the soil because of the ingredients like cow waste, jaggery and plant materials (44-46).

Physicochemical properties

The physicochemical properties of different organic formulations like Kunapajala, Fish amino acid, Panchagavya, Neemasthra, Agniasthra, Egg amino acid, Jeevamirtham, Beejamrutha, Sasyamrutha and five leaf extract were analyzed for pH, availability of N, P, K and other micronutrients (16,28,46,47). The studies showed that the pH of the organic formulations ranged between 4 and 9. The nitrogen percent ranged between 0.02 and 0.80% (46), the phosphorus content was between 0.50- 9.0 mg/kg and the potassium content was 25- 120 mg/kg (28).

The chemical parameters analyzed at 20 days after the preparation of panchagavya, revealed available nitrogen, phosphorus, potassium and zinc at 3983 ppm, 2450 ppm, 1966 ppm and 41.66 ppm, respectively and organic carbon content of 0.56%. Fermented fish waste extract had organic carbon content of 3.56±0.09% and other nutrients like nitrogen (0.02-1.87%), phosphorus (0.13-0.49), potassium (0.07-0.93%), calcium (0.54%), magnesium (0.26%) and sulphur (0.04%). Trace elements like copper (3.1 ppm), zinc (38.2 ppm), manganese (4.8 ppm) and iron (118 ppm) were also found (48, 49).

The nutrient analysis of Beejamrutha and Jeevamrutha, highlights notable differences in their pH levels and nutrient profiles. Beejamrutha exhibits an alkaline (pH-8.02) nature, while Jeevamrutha is acidic (pH-4.92). Both serve as excellent sources of essential macro and micronutrients. The nutrient composition analysis of Beejamurtha reveals 2.38% nitrogen, 0.127% phosphorus, 0.485% potassium, 16 ppm magnesium, 36 ppm copper and that of Jeevamrutha reveals 1.96% nitrogen, 0.173% phosphorus, 0.280% potassium, 46 ppm magnesium and 51 ppm copper (50).

A biopesticide formulation (BPF) prepared by a farmer in Uttar Pradesh, India has been standardized and scientifically validated under laboratory and field conditions. The decoction consists of plant extracts: *Allium* sp., *Calotropis*, *Phyllanthus emblica*, *Azadirachta indica*, *Ferula*, *Solanum lycopersicum* extract, *Curcuma zedooria,* in cow urine. Macro and micronutrient contents were analyzed and was found to have nitrogen (3.79%), potassium (0.8%), zinc (4.36 ppm), copper (0.27 ppm), iron (45.3 ppm), manganese (5.75 ppm), magnesium (76.4 ppm). The crude extract of *Polyathia longifolia* leaf was found to have insecticidal activity. Ethyl acetate- 35 per cent in hexane was mixed to the extract and was found to have antifeedant and insecticidal activity against *S. litura* and *Lipaphis erysumi* (38).

Bioprospecting

Bioprospecting can be defined as the exploration of valuable biological matter containing biochemical properties and genetic diversities for commercial purposes. It involves economic and scientific activities enduring development and economic growth (51, 52). Plant Growth-Promoting Bacteria (PGPB) can be found in abundance (45, 53) and micro-organisms that act as pesticides (4) within the organic traditional formulations.

Microbiome diversity in organic concoctions

Entomopathogenic bacteria are spore and non-spore-forming types, including *Clostridium*, *Bacillus* and *Paenibacillus*, *Xenorhabdus*, *Photorhabdus* and *Pseudomonas*. Infection occurs to vulnerable people when the insect ingests these bacteria (54). Culture-based methods are time consuming (55), so metagenomics is used as it is culture-independent analysis. Metagenomics is done either based on sequencing (sequence-based analysis) or on expression (functional analysis) (56).

A comparative analysis was made on microbial population dynamics in bioenhancers (17). They made a comparative study between Panchagavya, Amritpani and Jeevamirtha and found that total bacterial colonies were higher in Panchagavya (62.5 × 10^8 cfu/ml), fungal colonies were higher in Jeevamirtha and actinomycetes colonies were comparatively higher in Amritpani (2.00 × 10^7 cfu/ml). The bacterial diversity of cow dung by 16S rRNA gene libraries, 47 16S rRNA gene clones, which belong to the phyla Bacteriodetes, Firmicutes, Proteobacteria and Verrucomicrobia, were sequenced. The microbiome found in cow dung is given in Fig 2. Bacteria present in the phylum Bacteroidetes, Firmicutes, Proteobacteria and Verrucomicrobia were reported at 38.3%, 29.8%, 21.3% and 2%, respectively, in the culture-independent analysis of cow dung microbiota (57).

It has been previously studied cultivable bacteria using panchagavya (cow dung, urine and milk) ingredients and different organic formulations (50). 169 isolates were obtained for short-length sequencing and 96 isolates were documented. The isolates included 43 genera, which were grouped into seven different classes viz., Flavobacteria, Cytophagia, Bacilli, Alphaproteobacteria, Betaproteobacteria, Actinobacteria and Gammaproteobacteria. Researchers reported the presence of *Clostridium leptum* and *Bacteroidetes* group as the predominant groups present in the faecal matter of cows (58). M1T8B9 type strain cultured from cow faeces was identified as *Microbacterium suwonense* and was considered a member of *Microbacterium* based on evolutionary analysis and morphological characteristics (59). A phylogenetic tree representing the relationship between the species found in Panchagavya is given in Fig 3.

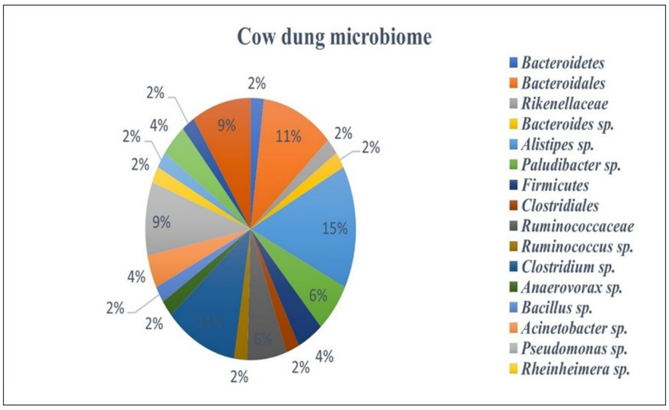

Fig. 2. Microbiome found in cow dung.

Isolation of certain LAB (lactic acid bacteria), such as *Streptococcus*, *Pediococcus*, *Lactobacillus* and *Leuconostoc* have been isolated. Molecular phylogeny has made it feasible to categorize organisms according to evolutionary relationships and characterize microbes' diversity. 16S rDNA sequence analysis is used to study microbial communities quickly and has emerged as a critical criterion for the phylogenetic determination of bacteria (54). The microbial genera *Bacillus* is widely used for biological control of pests and diseases. Bacillus is one of the most often used microbial genera for biologically managing pests and diseases. It is well recognized that *Bacillus* species produce a wide range of metabolites that can stop cellular organisms like bacteria, fungi, insects and nematodes from growing and functioning, as well as acellular microorganisms like viruses. By producing antimicrobial chemicals, toxins or enzymes, *Bacillus* can cease the development of diseases and pests (60).

Species of this genus, like *B. cereus*, *B. licheniformis*, *B. subtilis*, *B. velezensis*, *B. thuringiensis* etc., are known for producing antimicrobial compounds (61). The two main ways that biocontrol agents combat diseases and pests are synthesizing antimicrobial chemicals (including lytic enzymes and crystal

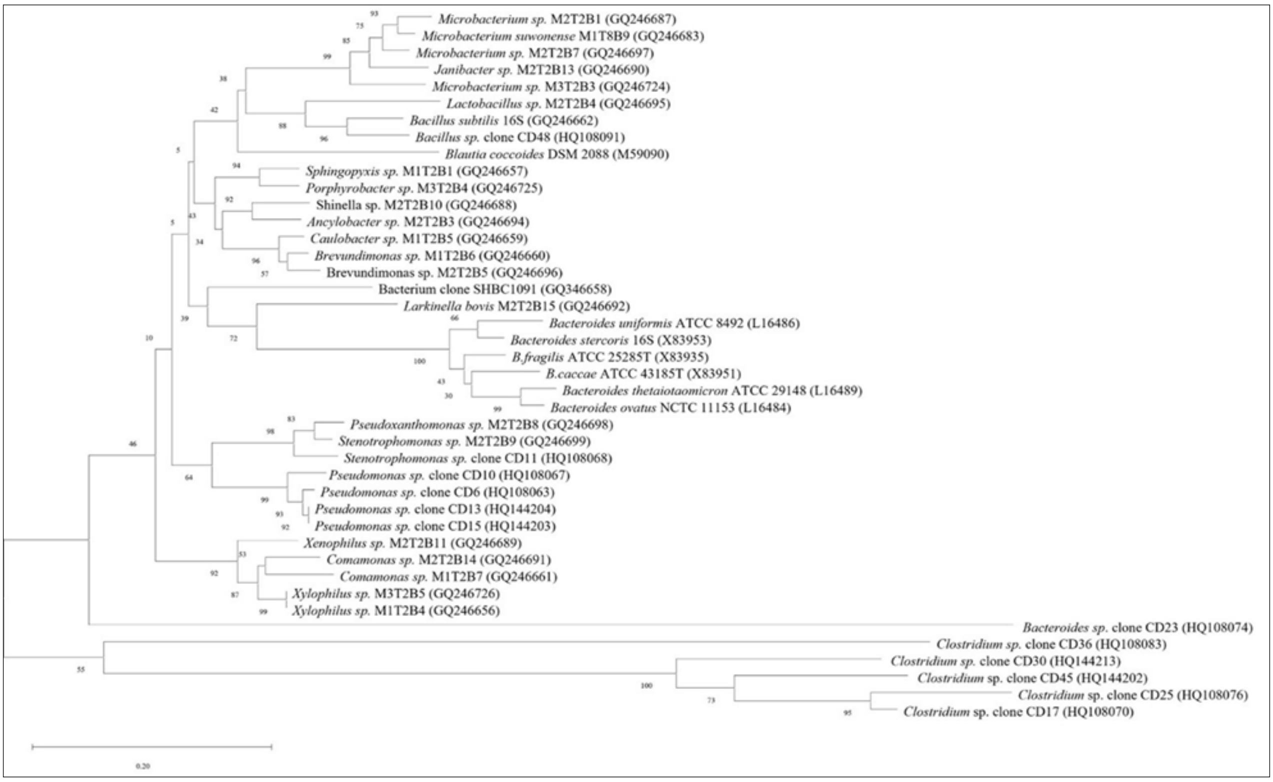

Fig. 3. Phylogenetic tree representing the relationship between the species found in Panchagavya.

proteins to volatile organic compounds and antimicrobial metabolites) and induced systemic resistance (ISR). Root colonization and biofilm production are potential mechanisms of biocontrol activity. *B. atrophaeus*, *B. velezensis*, *B. subtilis* species of *Bacillus* are found to have root colonization and biofilm formation properties as a mechanism of biocontrol (50).

Conclusion

The organic liquid formulations have a variety of applications and are crucial for plant growth and development, disease and insect control, improved yield and related yield attributes that enhance the quality of the product and reduce the need for synthetic, inorganic and chemical inputs like fertilizers, herbicides, insecticides, fungicides, etc. In addition to avoiding the use of pesticides, they also rejuvenate the soil and its constituent parts, allowing for the effective use of the resources at hand and ensuring security. The farmer may quickly obtain the locally available raw ingredients needed to prepare these organic inputs, saving money and requiring only rudimentary preparation skills. Consequently, using organic liquid formulations in agriculture is economical but also environmentally and user-friendly. The scientific rationale is crucial when appropriate application of these solutions in crops, which provides the necessary nutrients, growth stimulants and biocontrol agents to boost crop output.

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Authors' contributions

ASP wrote the first draft of the paper. GR and GP shared ideas, concepts and reviewed the paper completely. RA edited and shared inputs for upgrading the paper. CM reviewed the paper. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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