NATIONAL SEMINAR

on

Integrating Biochar Production, Carbon Sequestration and Carbon Trading for Carbon Neutral Farming

5th to 6th December, 2024

COMPENDIUM OF EXTENDED SUMMARIES

Biochar

Organised By

Dr. S.V. Patil Chair for Research and Training for Farmers Welfare
University of Agricultural Sciences, Dharwad
Karnataka, India

University of Agricultural Sciences Dharwad

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Integrating Biochar Production, Carbon Sequestration and Carbon Trading for Carbon Neutral Farming

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MESSAGE

I am pleased to note that the farmer-centric various activities organised by UAS Dharwad through Dr.S.V.Patil Foundation for the welfare of the farming community ever since it is formed. The warm temperatures over time are changing the weather patterns and rainfall distribution and thereby bring about imbalance in nature, making the farming uneconomical and thus farmers are under distress.

The initiative undertaken for organising this national seminar on conversion of crop residue and wood wastes into a highly stable form of carbon known as biochar is commendable. The biochar is helpful in bringing the reduction of carbon dioxide in the atmosphere, improving the soil quality and boosting up the crop yields and thereby enhancing the air quality.

The Biochar plays pivotal role in turning bio waste into wealth in the form of Biochar. This process further developing a carbon credit certified project generates extra revenue to the local communities through carbon credits and carbon trading.

Biochar about 3,50,000 metric tonnes was produced during the year 2023 globally which is said to be 91 per cent more over what was produced in 2021. This indicates the tremendous scope for Biochar market trends. This stable biochar carbon compound helps to improve soil health, soil carbon sequestration and generates carbon credits.

Under these circumstances, the organisation of National Seminar on **Integrating Biochar Production, Carbon Sequestration and Carbon Trading for Carbon Neutral Farming** is the need of the hour and is a welcome move. I congratulate UAS Dharwad and Dr.S.V.Patil foundation for organising this national seminar and wish the event a grand success and come out with suitable recommendations to the Government.

(N.Chaluvarayaswamy)

Message

I am delighted to extend my warmest greetings to all the esteemed participants, organizers, and contributors to the National Seminar on *"Integrating Biochar Production, Carbon Sequestration, and Carbon Trading for Carbon Neutral Farming"* scheduled to be held at the University of Agricultural Sciences, Dharwad, from December 5 to 6, 2024.

This seminar marks a significant step in addressing the urgent need for sustainable agricultural practices and climate resilience. The compendium of abstracts and summaries received for presentation showcases the remarkable diversity of ideas, research, and innovations aimed at leveraging biochar to enhance soil health, mitigate climate change and promote carbon-neutral farming.

The seminar promises to be a platform for thought-provoking deliberations among scientists, academicians, policymakers, entrepreneurs, and farmers. I am confident that the discussions will provide valuable insights into the integration of biochar technologies in agricultural practices, thereby benefitting all stakeholders. These innovations have the potential to transform agricultural landscapes, offering solutions for waste management, carbon sequestration and increased agricultural productivity.

It is my firm belief that the outcomes of this seminar will empower farmers with practical and innovative solutions while fostering collaborations among industry and research institutions to propel biochar technologies toward wider adoption.

I extend my heartfelt wishes to the organizing committee, resource persons, and participants for a successful seminar and look forward to the impactful contributions this event will make toward a sustainable and carbon-neutral future in agriculture.

(P. L. Patil)
Vice-Chancellor
University of Agricultural Sciences
Dharwad

Message

It gives me immense pleasure to extend my warm greetings to the participants, organizers, and contributors to the National Seminar on *"Integrating Biochar Production, Carbon Sequestration, and Carbon Trading for Carbon Neutral Farming"* being organized at the University of Agricultural Sciences, Dharwad, on December 5-6, 2024.

Karnataka, the second-largest state after Rajasthan in terms of wasteland area, has been a leader in implementing watershed development programs. These programs, aimed at sustainable land and water management, have prominently included afforestation as a core activity. The integration of biochar technologies into these efforts holds immense promise, particularly in leveraging biochar prepared from forest biomass, which has shown significant advantages in terms of longer carbon sequestration periods and greater efficacy compared to biochar derived from agricultural residues.

The deliberations during this seminar will provide a much-needed platform for sharing innovative ideas, research insights, and technological advancements in biochar production and application. These discussions will undoubtedly help chart a roadmap for integrating biochar into watershed management practices, thereby enhancing soil health, conserving resources, and improving agricultural productivity.

I am confident that this seminar will greatly benefit all stakeholders, including policymakers, scientists, farmers and entrepreneurs. By emphasizing the potential of biochar in addressing climate change and promoting sustainable livelihoods, this event will contribute significantly to Karnataka's efforts in transforming wastelands into productive and sustainable ecosystems.

I extend my heartfelt congratulations to the organizing committee and my best wishes to all participants for a successful and impactful seminar. May this event catalyze meaningful collaborations and provide innovative solutions for achieving carbon-neutral and resilient farming systems.

(Mahesh B. Shirur)
Commissioner for Watershed Development Department
Karnataka, Bengaluru

ಕೃಷಿ ವಿಜ್ಞಾನಗಳ ವಿಶ್ವವಿದ್ಯಾಲಯ, ರಾಯಚೂರು
(ಐ.ಸಿ.ಎ.ಆರ್. ಮತ್ತು ನ್ಯಾಕ್ ಮಾನ್ಯತೆ ಹಾಗೂ ಯುಜಿಸಿ 12(ಬಿ) & 2(ಎಫ್) ಅನುಮೋದಿತ)

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ಕುಲಪತಿಗಳು

MESSAGE

It is a privilege to convey my warm wishes to the esteemed participants, dedicated organizers, and valued contributors of the National Seminar on *"Integrating Biochar Production, Carbon Sequestration, and Carbon Trading for Carbon Neutral Farming,"* being hosted at the University of Agricultural Sciences, Dharwad, on December 5-6, 2024.

The integration of biochar technology with sustainable agricultural practices is an emerging area of research with immense potential. At UAS Raichur, we have also initiated significant work on biochar production, it's by-products, carbon sequestration, and the possibilities of carbon trading. These efforts aim to provide innovative solutions to pressing challenges such as soil health degradation, climate change, and sustainable waste management. This seminar serves as a vital platform for intellectual exchange and collaboration among researchers, policymakers, entrepreneurs, and farmers. The compendium of abstracts and summaries received highlights the diverse perspectives and advancements in biochar research, demonstrating its vast potential to transform agricultural practices while addressing environmental concerns.

I am confident that the deliberations at this seminar will yield actionable strategies for integrating biochar technologies into farming systems, ultimately benefitting stakeholders across the spectrum. From enhancing soil fertility and water retention to contributing to carbon-neutral farming, the discussions and outcomes of this seminar will have far-reaching implications.

On behalf of UAS Raichur, I extend my heartfelt congratulations to the organizing committee and all participants for their efforts in making this event a success. I wish the seminar fruitful deliberations and look forward to its impactful contributions toward achieving sustainable and resilient agricultural systems.

(M. Hanumanthappa)
Vice-Chancellor
VICE-CHANCELLOR
UAS, RAICHUR.

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Theme I :

Biochar for Environmental Sustainability and Climate Action

Invited Presentation

IP: 1 Biochar for Sustainable Development: Insights and Recommendations

R K MEHTA

Founder, Progressive Biochar Society, Hyderabad

Biochar is an emerging sector in India, with artisanal production units operating for over 15 years, although only a few industrial-scale units are currently active. It plays a critical role in processing agricultural, urban, and other waste streams into biochar, offering a significant contribution to sustainable development. The potential of biochar to mitigate global warming and earn carbon credits through Carbon Dioxide Removal (CDR) methods makes it a promising technology for environmental sustainability.

Mr. R.K. Mehta, a retired professional and self-proclaimed "Biochar Crusader," has been at the forefront of several initiatives to promote biochar. He established the Whatsapp Group of Biochar Crusaders in July 2020, which now has 269 members, and the Progressive Biochar Society in February 2024, with over 150 members. His efforts include participation in seminars and webinars, publishing articles in agricultural magazines, and visiting biochar plants in India and abroad to understand and promote the sector.

Based on his observations, artisanal biochar production is being encouraged through training programs by consultants like Dr. Sai Bhaskar Reddy. In the last three years, entrepreneurs have started manufacturing biochar and bio-enhanced fertilizers, showing optimism about the sector's business potential. However, R&D efforts by institutions like ICAR, CSIR, and agricultural universities, while ongoing for over a decade, have not yet reached significant commercialization due to various challenges. In contrast, the biochar sector is well-developed globally, with regions like Europe, the USA, China, and South Korea leading the way. The USA alone hosts over 300 industrial biochar units. Research in the field is thriving, with more than 4,000 papers published annually, reflecting diverse and growing business opportunities.

To advance the sector in India, Mr. Mehta recommends popularizing the benefits of biochar in educational institutions and social organizations while enrolling individuals as biochar crusaders. He emphasizes the need for the Government of India to establish biochar quality standards for various applications and to create job opportunities by training biochar consultants and technicians in both urban and rural areas. Promoting entrepreneurship through supportive policies and capacity building is essential, as is processing urban waste into biochar for applications in urban areas. He also advocates for capital subsidies and other incentives to establish artisanal and industrial biochar manufacturing units and calls for the collation and publication of data from R&D centers. Additionally, combining biochar with biological inputs to create bio-fertilizers and establishing Biochar Clubs in agricultural universities, educational institutions, and major cities are proposed as crucial steps forward.

This presentation aims to inspire action and collaboration among policymakers, entrepreneurs, researchers, and academicians to unlock the full potential of biochar for sustainable development in India.

Keywords: Biochar, Sustainable Development, Carbon Credit, Entrepreneurship, R&D, Waste Processing, Policy Recommendations.

IP: 2 National Biochar Policy and Standards for India

N SAI BHASKAR REDDY

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India faces critical challenges at the intersection of sustainable agriculture, environmental degradation, and climate change. As a predominantly agrarian economy, the nation must urgently address soil health restoration, agricultural and organic waste management, and its obligations under the Paris Agreement to reduce greenhouse gas emissions. Biochar, a carbon-rich material produced from biomass pyrolysis, has emerged as a transformative solution, offering multifaceted benefits. It not only improves soil fertility and enhances crop productivity but also sequesters carbon for centuries, playing a pivotal role in climate change mitigation. This paper advocates for the formulation of a National Biochar Policy and Standards for India. The policy envisions integrating biochar into existing frameworks such as the National Biofuels Policy, Sustainable Agriculture Policy, and Natural Farming Initiatives, aiming to reduce dependency on chemical inputs, enhance soil health, and promote eco-friendly farming practices. The proposed policy outlines actionable steps to encourage farmer participation by offering financial incentives, conducting widespread awareness campaigns, and developing capacity-building programs. It emphasizes the importance of comprehensive standards for biochar production and classification, taking into account its quality and diverse application potential. Recognizing biochar as both an agricultural and industrial product, the policy calls for establishing accredited testing laboratories, implementing certification processes, and regulating manufacturing practices. It also suggests guidelines for permissible feed stocks, alongside export and import regulations to maintain quality standards and prevent market exploitation. A key focus of the policy is the integration of biochar into carbon credit mechanisms, providing financial incentives to producers while contributing significantly to India's Nationally Determined Contributions (NDCs). The policy stresses the development of robust Data Monitoring, Verification, and Reporting (DMVR) systems to quantify the impact of biochar on carbon sequestration, ensuring its recognition in voluntary and UN-accredited carbon markets. By implementing a robust National Biochar Policy and Standards, India can harness biochar's potential to revolutionize sustainable agriculture, enable efficient waste management, and bolster climate resilience. Aligning biochar applications with national priorities and international frameworks will position India as a global leader in biochar innovation and deployment, fostering ecological balance, soil health, economic growth, and long-term environmental sustainability.

IP: 3 On-Farm Production & Characterization of Various Bio-Wastes in the Kutch Desert of Gujarat, India.

MADHUKAR POTDAR

Founder President, Maha Dragon Fruit Association (MDFA), Pune, Maharashtra & Ex-Principal Agronomist,
C C Shroff Research Institute (CCSRI), Kutch, Gujarat.

Abstract: A low-cost pyrolys is unit was developed at the C C Shroff Research Institute, Mandvi, Kutch, Gujarat, using two barrels (200 L and 25 L capacities) (Potdar, 2016). Various crop residues, including Vetiver grass, cotton, wheat, Tulsi, Agathi, Dates, Pomegranate, and Prosop is, were air-dried and converted into biochar through slow pyrolys is. The biochar samples of Prosop is wood, Tulsi wood, and Vetiver biomass were analysed for physicochemical properties at the Gujarat Institute of Desert Ecology (GUIDE), Bhuj, Kutch, Gujarat.

The results revealed significant variation in the physicochemical properties of the biochar samples. All biochars were nutrient-rich, containing nitrogen, phosphorus, potassium, calcium, magnesium, and organic carbon, along with low bulk density, high cation exchange capacity (CEC), and extremely high water-holding capacity. These properties suggest potential benefits for improving soil health and crop production.

Further research into the commercial production and agronomic applications of biochar from farm waste is essential to enhance soil fertility, ensure food security, and promote climate resilience.

Introduction

Biochar, a carbon-rich material produced through pyrolys is of biomass, has great potential for improving soil health, carbon sequestration, and pollution remediation. Prosop is juliflora (mesquite), though invasive in some regions Kutch is a promising source for biochar due to its ability to combat soil erosion and improve fertility. Similarly, Vetiver (Chrysopogonzizanioides) and Tulsi (Ocimum sanctum) are valuable medicinal and aromatic plants with strong potential for biochar production, benefiting both soil and aromatic oil industries.

Material and Methods

A low-cost pyrolysis unit was developed in 2016 at the C C Shroff Research Institute, Mandvi, Kutch, Gujarat, using two barrels (200 L and 25 L capacities). Various crop residues, including Vetiver grass, cotton, wheat, Tulsi, Agathi, Dates, Pomegranate, and Prosop is, were air-dried and converted into biochar through slow pyrolysis. The biochar samples of Prosop is wood, Tulsi wood, and Vetiver biomass were analyzed for physicochemical properties at the Gujarat Institute of Desert Ecology (GUIDE), Bhuj, Kutch.

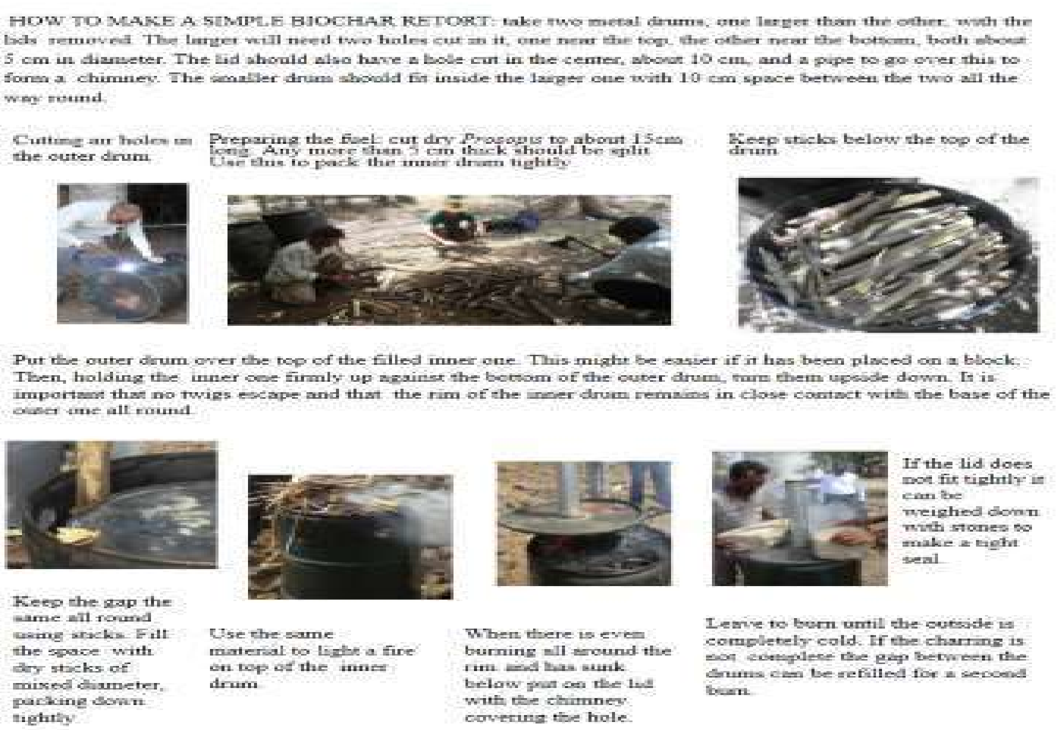
Results and Discussion

The mean physico-chemical characteristics of Biochar made from Prosop is wood, Tulsi wood & Vetiver biomass are presented in Table 1.

The physicochemical properties of biochar produced from Prosop is wood, Tulsi wood, and Vetiver biomass vary significantly, offering different benefits for soil improvement in regions like Kutch, Gujarat.

Bulk Density: Vetiver biochar has the lowest bulk density (0.14 g/cm^2), which suggests it may improve soil porosity and aeration more effectively than Prosop is (0.28 g/cm^2) and Tulsi (0.26 g/cm^2). This can enhance root growth and water infiltration, crucial for arid soils in Kutch.

Figure 1: A Portabale Tow-Barrel Nested Retort: BIOCHAR UNIT



HOW TO MAKE A SIMPLE BIOCHAR RETORT: take two metal drums, one larger than the other, with the lids removed. The larger will need two holes cut in it, one near the top, the other near the bottom, both about 5 cm in diameter. The lid should also have a hole cut in the center, about 10 cm, and a pipe to go over this to form a chimney. The smaller drum should fit inside the larger one with 10 cm space between the two all the way round.

Cutting air holes in the outer drum.

Preparing the fuel: cut dry *Prosopis* to about 15cm long. Any more than 5 cm thick should be split. Use this to pack the inner drum tightly.

Keep sticks below the top of the drum.

Put the outer drum over the top of the filled inner one. This might be easier if it has been placed on a block. Then, holding the inner one firmly up against the bottom of the outer drum, turn them upside down. It is important that no twigs escape and that the rim of the inner drum remains in close contact with the base of the outer one all round.

If the lid does not fit tightly is can be weighed down with stones to make a tight seal.

Keep the gap the same all round using sticks. Fill the space with dry sticks of mixed diameter, packing down tightly.

Use the same material to light a fire on top of the inner drum.

When there is even burning all around the rim and has sunk below put on the lid with the chimney covering the hole.

Leave to burn until the outside is completely cold. If the charring is not complete the gap between the drums can be refilled for a second burn.

Table 1: Mean physico-chemical characteristics of Biochar of Prosopis wood, Tulsi wood & Vetiver biomass

Sr No	**Paramater**	**Unit**	**Prosopis wood**	**Tulsi wood**	**Vetiver biomass**
1	Bulk Density	g/cm2	0.28	0.26	0.14
2	Water Holding Capacity	wt%	1800.80	1325.90	1666.00
3	Moisture	%	3.90	3.90	5.50
4	Specific Gravity		2.80	0.27	0.14
5	pH		6.80	7.00	6.80
6	Electrical Conductivity	microS/cm	605.50	739.20	1473.00
7	Exchangeable Acidity		1000.00	600.00	1000.00
8	Cation Exchange Capacity	meq/100 gm	5.20	8.80	6.90
9	Total Nitrogen	%	1.10	0.84	0.98
10	Phosphate	mg/kg	4190.00	2933.90	3344.40
11	Sodium	mg/kg	819.40	3114.00	571.40
12	Potassium	mg/kg	3698.00	4548.00	5654.00
13	Calcium	mg/kg	2410.00	2728.00	2862.00
14	Magnesium	mg/kg	244.00	146.40	292.80
15	Total Organic Carbon	%	26.50	24.00	29.10
16	Biochar Recovery	%	45.10	51.15	41.70
17	C:N ratio		24.09	28.57	29.69

Water Holding Capacity: Prosop is biochar shows the highest water holding capacity (1800.80 wt%), followed by Vetiver (1666.00 wt%) and Tulsi (1325.90 wt%). Given the water scarcity in Kutch, Prosop is and Vetiver biochars could significantly improve soil moisture retention, benefiting crops in dry conditions.

Cation Exchange Capacity (CEC): Tulsi biochar has the highest CEC (8.80 meq/100 g), suggesting it has greater potential for nutrient retention and exchange. This is essential for enhancing soil fertility in nutrient-poor soils like those in Kutch, compared to Prosop is (5.20 meq/100 g) and Vetiver (6.90 meq/100 g).

Nutrient Content:

Nitrogen: Prosop is biochar (1.10%) is the highest in nitrogen, which is critical for promoting plant growth. This makes Prosop is an excellent choice for enhancing soil fertility.Phosphate: Prosop is (4190 mg/kg) also shows the highest phosphate content, benefiting soil phosphorus levels that are often limiting in arid soils. Potassium: Vetiver (5654 mg/kg) contains the highest potassium content, which is essential for plant stress tolerance, especially in Kutch's harsh climate.Calcium and Magnesium: Vetiverbiochar is rich in both calcium (2862 mg/kg) and magnesium (292.80 mg/kg), contributing to soil structure and plant health.

Organic Carbon: Vetiver biochar (29.10%) has the highest organic carbon content, which contributes to long-term soil fertility and microbial activity. Prosop is (26.50%) and Tulsi (24.00%) also show strong carbon content, which will help in carbon sequestration and improve soil structure.

Biochar Recovery: Tulsi biochar has the highest biochar recovery rate (51.15%), suggesting it is more efficient in conversion processes, potentially making it a cost-effective choice for large-scale production.

C:N Ratio: The C:N ratio of biochar is crucial for its decomposition and nutrient release. Vetiver has the highest C:N ratio (29.69), followed by Tulsi (28.57) and Prosop is (24.09). A higher C:N ratio suggests slower decomposition, making Vetiver more suitable for long-term soil improvement.

Potential for Kutch

Given the region's arid conditions, biochar from Prosop is and Vetiver holds significant promise for improving soil fertility, water retention, and plant health. Prosop is biochar, with its high nitrogen and phosphate content, is ideal for enhancing soil fertility and supporting crop production in degraded soils. Vetiver biochar, with its superior water-holding capacity, organic carbon content, and potassium levels, could be particularly beneficial in drought-prone areas by improving moisture retention and plant resilience. Tulsi biochar, with its high CEC and efficient recovery, could also be explored for agronomic use, especially for nutrient-poor soils.

Further research on the commercial production and large-scale application of biochar from these species in Kutch could help improve soil health, boost agricultural productivity, and contribute to climate resilience in the region.

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IP: 4 Innovative Solutions for Biochar Production: Advancing Rural Employment and Sustainable Agriculture through Customized Pyrolysers

ANIL CHOUK

CEO, Sanjeevini Agro, Nagpur

Sanjeevini Agro Machinery, Nagpur, established in 2006, specializes in the design, supply, and servicing of state-of-the-art customized pyrolysers for biochar production, along with a wide range of agricultural machinery. The company manufactures and exports floating fish feed machines, biochar machines, biomass pellet machines, and other allied equipment that contribute significantly to sustainable agriculture and rural employment generation.

Our biochar machinery portfolio includes eight efficient models, ranging from ₹4.9 lakh to ₹3 crore, suitable for both batch and continuous production. Over 100 units have been successfully installed across India and neighboring countries like Bhutan, empowering more than 100 entrepreneurs to produce biochar and charcoal profitably.

Sanjeevini Agro's machines are robust, user-friendly, and tested by esteemed institutions like MPKV Rahuri, Maharashtra. The company's clientele includes government departments such as the Fishery Departments in Maharashtra, Punjab, and Andaman & Nicobar, as well as international markets in the UAE, Nepal, and Kenya.

With a focus on core agricultural needs, Sanjeevini Agro Machinery aligns its efforts with the "Make in India" initiative by fostering innovation and self-reliance. By providing high-quality, efficient machinery, we contribute to sustainable practices, income generation, and rural development.

This seminar provides an opportunity to share insights on the role of advanced pyrolysis technology in biochar production and its implications for agriculture, rural employment, and environmental sustainability.

Keywords: Biochar Production, Pyrolysers, Sustainable Agriculture, Rural Employment, Make in India, Customized Machinery.

IP: 5 Biochar, Bio-oil and Biogas: A Commercial Perspective of Biomass Pyrolysis

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Abstract: Biomass pyrolysis has emerged as a transformative technology in waste management and resource utilization, offering significant commercial opportunities through its primary outputs: biochar, bio-oil, and biogas. This presentation delves into the commercial viability of these by-products, highlighting their diverse applications and market potential.

Biochar, a high-carbon material, finds extensive use in agriculture as a soil conditioner and organic fertilizer. With its ability to enhance soil fertility, improve water retention, and sequester carbon, biochar holds great promise in addressing soil degradation. In India, the average selling price for biochar ranges between ₹06-12 per kilogram, driven by its demand in sustainable farming and carbon credit markets.

Bio-oil, a complex mixture of chemicals, presents versatile applications. It can be processed to extract valuable chemicals such as furfural, phenols, and acetic acid, which are in high demand across various industries. Additionally, bio-oil serves as a base ingredient in

Agricultural inputs, including bio-based fertilizers, pesticides, herbicides, and fungicides. This dual role significantly enhances its commercial appeal, positioning bio-oil as a critical

Component in both chemical and agricultural markets.

Biogas, is utilized internally for heating the pyrolysis process, optimizing energy efficiency and reducing operational costs. Beyond this, surplus biogas can be redirected to meet other thermal energy requirements, offering cost-effective and sustainable energy solutions for industries.

This presentation will explore the production economics, current market trends, and future growth prospects of these biomass pyrolysis by-products. It aims to provide insights into establishing a sustainable and profitable business model, leveraging biomass waste as a resource for generating value-added products while contributing to environmental sustainability.

Theme II:
Innovative Applications for Biochar Utilisation
Invited/Oral Presentation

IP: 6 Nanobiochar for efficient waste valorization, sequestering carbon and soil fertility management

VIKAS ABROL AND PEEYUSH SHARMA

Division of Soil Science and Agriculture Chemistry
Faculty of Agriculture
Sher-e-Kashmir University of Agriculture and Technology of Jammu

Introduction

Global warming is one of the most significant threats of present times due to high concentrations of greenhouse gases in the atmosphere, rising temperatures, and an increase in the frequency and intensity of extreme weather events. According to the Intergovernmental Panel on Climate Change (IPCC), anthropogenic activities particularly the burning of fossil fuels and deforestation have resulted in unprecedented levels of carbon dioxide (CO_2), reaching 420 ppm. This has contributed to a global temperature rise of approximately 1.1°C and a 151% increase in CO_2 emissions since the pre-industrial era (IPCC, 2023).

Biochar is a carbonaceous by-product of lignocellulosic biomass developed by various thermochemical processes. Biochar can be transformed into "nano-biochar" by size reduction to nano-meters level. Nano-BC offers considerable opportunities especially for the remediation of hazardous contaminants as well as the improvement of crop productivity. Nano-biochar presents remarkable physico-chemical behavior including; higher stability, unique nanostructure, higher catalytic ability, larger specific surface area, higher porosity, improved surface functionality, and surface active sites(Brewer *et al*., 2014, Abrol *et al*., 2016, Ouyang *et al*., 2013). Nano-biochar efficiently regulates the transport and absorption of vital micro-and macro-nutrients, in addition to toxic contaminants (heavy metals, pesticides, antibiotics). Furthermore, due to high porosity, surface functionality and larger surface-to-volume ratio, nano-BC functions as an excellent immobilization material for enzymes and can thus function as a nanocatalyst in bioremediation.

Recently, nanobiochar has emerged as an innovative material in the fields of environmental sustainability, waste valorization, carbon sequestration, and soil fertility management.

Nanobiochar for Efficient Waste Valorization:

Organic waste, such as agricultural residues, municipal solid waste, and industrial by-products, poses significant environmental challenges, including landfilling, air pollution, and the depletion of natural resources. Nanobiochar offers an innovative approach to valorizing waste by transforming these materials into valuable resources with multiple applications. Nanobiochar can be produced from abundant and renewable biomass. This fertile condition makes Nanobiochar more practical, sustainable, and inexpensive technology. The production of nanobiochar typically begins with pyrolysis, a thermal decomposition process in the absence of oxygen that breaks down biomass into three primary products: biochar, bio-oil, and syngas. By controlling the pyrolysis conditions (e.g., temperature, pressure), biochar can be tailored into nanobiochar with enhanced properties. Nanobiochar, due to its increased surface area, porosity, and reactivity, can capture heavy metals, organic pollutants, and excess nutrients, allowing for the clean-up of contaminated environments, including wastewater and polluted soils.

Carbon Sequestration through Nanobiochar:

Climate change is one of the most significant challenges facing the planet, and reducing atmospheric carbon dioxide (CO_2) concentrations is central to mitigating global warming. Nanobiochar offers a highly effective means of sequestering carbon, helping to combat climate change.Biochar is primarily composed of C, accounting for a significant proportion of its composition, typically ranging from around 50% to nearly 90% by weight. The high C content of biochar is essential for its C sequestration potential for several reasons. When applied to the soil, biochar acts as a sink, effectively capturing and retaining Cover extended periods, preventing its release back into the atmosphere as CO_2. (Li *et al*., 2022)Moreover, the abundant C content of biochar allows for a higher C saturation level in the soil. As biochar is added to the soil, it provides additional C that can exceed the soil's natural C-holding capacity (Singh *et al*., 2022). This surplus C can be effectively sequestered, contributing to an overall increase in soil C stocks and mitigating the net increase in CO_2 in the atmosphere.

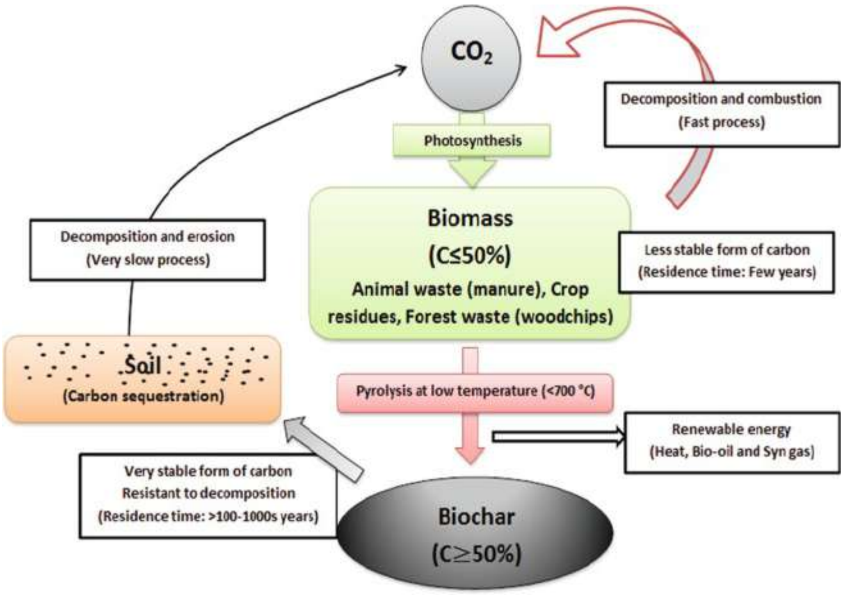

Fig. 1 Process of carbon sequestration by biochar (Gupta *et al.*, 2020)

Carbon Stabilization:

When organic materials such as plant biomass are pyrolyzed to create biochar, a substantial portion of the carbon in the original biomass is locked into a stable, solid form that resists microbial decomposition. Unlike other forms of organic matter that decay and release CO_2 back into the atmosphere, the carbon in biochar remains sequestered for hundreds or even thousands of years. Nanobiochar, with its larger surface area and enhanced stability, has the potential to sequester even more carbon than conventional biochar, making it an even more efficient tool for carbon capture.

Enhanced Surface Area for Carbon Adsorption:

The nano-sized particles in nanobiochar increase the material's surface area compared to regular biochar. This enhanced surface area not only improves the material's ability to adsorb contaminants but also provides more sites for the adsorption of atmospheric CO_2. The increased surface reactivity of nanobiochar may also facilitate the binding of CO_2 in a more stable form, improving its carbon storage potential. As such, nanobiochar can serve as a long-term carbon sink, potentially offsetting some of the carbon emissions generated by industries, agriculture, and deforestation.

Soil as a Carbon Sink:

When nanobiochar is applied to soils, it not only enhances soil properties but also contributes to long-term carbon sequestration. The carbon stored in nanobiochar may remain in the soil for decades, reducing the concentration of greenhouse gases in the atmosphere. Additionally, by reducing soil degradation and improving soil health, nanobiochar can promote plant growth, which further increases the ability of soils to store carbon through the process of photosynthesis. This makes nanobiochar an essential tool in global efforts to reduce atmospheric carbon levels and combat climate change.

Nanobiochar for Soil Fertility Management:

Soil health is critical to ensuring sustainable agricultural productivity. The addition of nanobiochar to soil can significantly improve soil fertility and overall plant health, contributing to food security and sustainable farming practices.

Improving Soil Structure:

Nanobiochar improves soil structure by increasing porosity, aeration, and water retention. These changes help to prevent soil compaction, promote root growth, and improve nutrient and water availability to plants. The increased surface area of nanobiochar also improves soil aggregation, which is crucial for maintaining soil structure and preventing erosion, particularly in sandy or clay-heavy soils. The porous nature of nano biochar enhances soil structure, improving aeration and water-holding capacity. This is beneficial for plant growth, as it facilitates root development and nutrient uptake. Moreover, it acts as a reservoir formoisture, reducing water loss through evaporation and enhancing water retention in the soil.

Nutrient Retention and Release:

Nanobiochar exhibits a high cation exchange capacity (CEC), meaning it can retain positively charged nutrients such as nitrogen, potassium, and phosphorus. These nutrients are essential for plant growth but are often lost through leaching in conventional farming practices, especially in highly irrigated or acidic soils. The high CEC of nanobiochar helps reduce nutrient loss by adsorbing excess nutrients and releasing them slowly as needed by plants. This not only improves plant nutrient uptake but also reduces the need for synthetic fertilizers, leading to cost savings for farmers and reducing the environmental impact of over-fertilization, such as nutrient runoff and water pollution.

Soil remediation:

Nanobiochar has the ability to alter soil pH, which is particularly beneficial for acidic soils. By raising the pH, nanobiochar creates a more favourable environment for plants and improves nutrient availability. Furthermore, the adsorption capacity of nanobiochar helps mitigate the toxicity of heavy metals like arsenic, lead, and cadmium, which can accumulate in soils due to industrial pollution or the use of contaminated irrigation water. By adsorbing these toxic elements, nanobiochar reduces their bioavailability in the soil, thus preventing plant uptake and minimizing health risks to humans and animals.

Soil Microbial Activity:

Its porous structure provides a habitat for microbes such as nitrogen-fixing bacteria and other soil organisms that play a key role in nutrient cycling and soil health. Enhanced microbial activity improves soil fertility, increases nitrogen fixation, and supports the breakdown of organic matter, further enhancing soil quality and plant growthultimately enhancing soil fertility and productivity. Additionally, the presence of microbes can aid in the degradation of organic pollutants, further contributing to environmental remediation efforts.

Challenges and Future Directions:

Despite the promising potential of nanobiochar, several challenges must be addressed before it can be widely implemented in environmental and agricultural applications.

Cost and Scalability:

The production of nanobiochar involves pyrolysis at high temperatures and may require additional steps to engineer its nanoscale properties. This can make the production process energy-intensive and costly, which limits its economic feasibility for large-scale applications. Overcoming these cost barriers, through process optimization and cost-effective production methods, will be key to making nanobiochar accessible for commercial use.

Research Gaps:

Although substantial research has been conducted on biochar, studies on nanobiochar are still in their early stages. Further research is necessary to explore its full potential, particularly with regard to its long-term environmental impacts, efficiency in carbon sequestration, and role in soil health and plant productivity. Additionally, research into optimizing production methods and exploring new sources of biomass for nanobiochar production is critical for its future success.

Conclusion:

Nanobiochar represents a transformative innovation in the fields of waste valorization, carbon sequestration, and soil fertility management. Its unique properties make it an effective material for addressing environmental challenges such as pollution, climate change, and soil degradation. With continued research and sustainable production practices, nanobiochar could become a crucial tool for advancing global sustainability, fostering circular economies, and ensuring the long-term health of our planet's ecosystems and agricultural systems.

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IP: 7 Fortification of Biochar by Nanoparticles for Water Filtration, Energy and Agricultural Applications

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Abstract: Fortification of biochar with nano particles offers a sustainable and versatile approach to create advanced materials with enhanced properties. This research enlightens synthesis methods, characterizing materials comprehensively to optimize and explore novel applications in various fields. The innovative method of fortifying biochar with nanoparticles greatly improves its characteristic and expands its uses in agriculture, energy storage, and water purification.The novel synthesis processes, characterisation methodologies, and functionalization strategies that produce highperformance nanocomposite materials are highlighted in this study.Nanoparticles are successfully incorporated into biochar using a variety of methods, including as ball milling, in situ synthesis, and impregnation.To ensure even dispersion, biochar is impregnated by soaking it in a solution of nanoparticles, then drying and calcining it. Strong linkages can be formed on the surface of the biochar via direct precipitation or development of nanoparticles made possible by in situ synthesis. By grinding two elements together, ball milling creates a strong composite material. In order to clarify the characteristics of nanocomposite materials, characterization procedures are essential. The capabilities of biochar can be significantly increased by functionalizing it using nanoparticles. Silver, iron oxide, and zinc oxide are examples of metal nanoparticles that greatly increase catalytic efficacy and antibacterial activity. In the meanwhile, graphene oxide and carbon nanotubes improve mechanical strength and electrical conductivity. Superior adsorption and catalytic capabilities result from the addition of heteroatoms such as nitrogen, sulfur and many more, which enrich the material with functional groups for applications in the waste water remediations, energy storage and agricultural applications.

Keywords: Biochar, fortification, nanoparticles, water filtration, energy, agriculture

IP: 8 Biochar Production, Characterization and its' influence on Soil Fertility and Yield in Dry DSR-Mustard Cropping System

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Introduction

Biochar is charcoal produced through pyrolysis under controlled temperature and low oxygen environment, and generally characterized by a fine texture and high surface area (Lal, 2015). The emission of greenhouse gases and soil carbon depletion are alarming global concerns. Now at days, Biochar gaining attention in agriculture for its potential to enhance soil carbon sequestration. When added to soil, biochar improves fertility by increasing nutrient retention, creating more exchange sites for nutrients, and stimulating microbial and enzymatic activities. These benefits not only enhance soil health but also contribute to reducing carbon emissions, making biochar a promising tool for sustainable agriculture and climate change mitigation.

Biocharswere produced by using kiln method from crop biomasses (maize cob rind, pigeonpea and cotton stalks) and characterized by adopting standard analytical techniques. The field experiments conducted during 2021-22 with *Kharif*-dry DSR and *Rabi*-mustard to study both direct and residual effect of biochars on crop yields and cost economics were calculated.

Standardization of Biochar production and Characterization

The properties of biochars are influenced by factors such as feedstock type, biomass size and length and moisture content. Among the various biochars tested, pigeon pea stalk biochar (PPSB) demonstrated superior morphological, spectral, physico-chemical properties and elemental composition compared to cotton stalk and maize cob rind biochar. However, the biochar production methods are distinct, necessitating standardization of loading rates and reaction times to achieve maximum yields for specific biomass types while considering available resources and prevailing conditions.

Biochar on growth and yield of rice crop

The field experiments conducted during the *Kharif* dry Direct Seeded Rice (dry-DSR) indicated that the application of biochars in conjunction with recommended package of practices (RPP) resulted in better yields compared to RPP alone, regardless of the biochar type. This confirms the positive effects of biochar on soil moisture retention and nutrient availability over an extended period, particularly with higher biochar doses. Among the biochars tested, PPSB exhibited more significant positive effects than cotton stalk biochar (CSB) and maize cob rind biochar (MCRB). The treatment of RDF + PPSB at 15 t ha^{-1} resulted in significantly improved growth parameters, yield attributes, nutrient uptake, root development, and nutrient accumulation.

Residual effect of utilization of different biochars on mustard

In the *Rabi* mustard field experiment, biochars showed a notable residual effect on mustard crop performance. Overall, RPP combined with biochars produced higher yields compared to RPP alone. Similar to the dry DSR results, the treatment of RDF + PPSB at 15 t ha^{-1} recorded significantly enhanced growth parameters, yield attributes and nutrient uptake.

Cost economics of biochar utilization in rice-mustard cropping system

The cost-effectiveness of biochar production and its application was analyzed based on the use of farm waste and family labor. The cost analysis demonstrated that producing and applying biochar is economically beneficial, resulting in higher yield increases for both primary and residual crops.

Conclusion

Crop biomass can be efficiently converted into biochar using the kiln method through pyrolysis, with biochar quality depending on feedstock type, loading rate, reaction time and other conditions. Standardizing production methods is essential to maximize yields for each biomass type. Morphological and spectral analyses (SEM-EDS, FT-IR) revealed that biochar from pigeon pea stalks was superior to that from cotton stalks and maize cob rind. Applying biochar with recommended fertilizers resulted in higher paddy and mustard yields due to improved water and nutrient retention, extended availability and enhanced root morphology. Pigeon pea biochar, with its irregular honeycomb structure and higher Al and Si content, showed the best performance. Considering the cost benefits and agricultural advantages of biochar, promoting its production at the farm level using affordable indigenous kiln methods should be encouraged as a climate-resilient, sustainable, and eco-friendly practice through necessary policy support.

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OP: 9 Impact of application of enriched coconut shell biochar on productivity of Soybean (*Glycine max* L.) in acidic soil over two growing seasons

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Abstract: Afield study was conducted to investigate the effect of application of enriched coconut shell biochar on soybean productivity in acidic soil. This research was carried in ICAR-KVK, Hadonahalli, Doddaballapura Taluk, Bangalore Rural, District. The experimental soil has the soil pH is 5.83, making it slightly acidic. The organic carbon content is 0.46%, which is relatively low. The results revealed that application of enriched biocharrecorded significantly higher productivity and seed yield of soybean. This research helps to developing a sustainable approach for improving availability of phosphorus by reducing fixation and soybean crop production in acidic soils.

Key words: Enriched Biochar, PSB, Organic Carbon, Phosphorus, Seed yield

Introduction

Soybean (*Glycine max* L.) is a vital oilseed crop globally, known for its high protein and oil content, with diverse applications in food, feed, and industry. As demand increases, optimizing soybean cultivation in varied agroecological conditions is crucial. A major challenge in regions with acidic soils is maintaining nutrient availability and soil health, which are essential for high yield and quality. Acidic soils, common in tropical and subtropical areas, have low pH and often lack essential nutrients like phosphorus (P) and zinc (Zn) while containing toxic levels of aluminium (Al) and manganese (Mn) (Chintala*et al.,* 2014). These conditions can hinder soybean growth, resulting in reduced germination, delayed flowering, poor seed quality, and lower economic returns. To counter these effects, soil management strategies, such as using organic amendments like farmyard manure (FYM) and biochar, are essential. (Hanumanta*et al*., 2024).

Biochar, a carbon-rich material from the pyrolysis of organic biomass, improves soil properties by buffering pH, retaining nutrients, reducing heavy metals in soil and enhancing microbial activity(Nandini and Prakasha, 2022; Bramarambika*et al.,* 2021). When enriched with nutrients like P and Zn, biochar can serve as a slow-release fertilizer. Additionally, incorporating phosphate-solubilizing bacteria (PSB) into FYM and biochar can further enhance nutrient availability, particularly phosphorus (Manikanta*et al*., 2024). While the benefits of biochar and PSB on soil health and crop yield are documented, limited research exists on their combined effects on soybean cultivation in acidic soils, especially regarding economic viability. This study aims to explore the influence of enriched biochar, alone and combined with other amendments, on soybean growth and yield attributes over two growing seasons (2022 and 2023).This research aims to provide insights into the potential of enriched biochar as a sustainable solution for improving soybean productivity in acidic soils, contributing to sustainable agriculture and food security.

Material and Methods

The experiment was carried out at ICAR-KVK, located in Hadonahalli, Doddaballapura Taluk, Bangalore Rural District, Karnataka, India, which falls under Eastern Dry Zone of Karnataka and is situated at 13° 37' North latitude 77° 54' East longitude and at an altitude of 880 meters above the mean sea level. The initial properties of the experimental site as follows: the pH was 5.83, which was acidic in nature, electrical conductivity was 0.31 dS m^{-1}, available soil nitrogen, phosphorus and potassium content was 278.12, 25.81 and 193.68 kg ha^{-1}, respectively. The test crop selected was Soybean, variety JS-335. The experiment was carried out following randomized complete block design (RCBD) with thirteen treatments and three replications. The treatments are mentioned below.

Treatment details

T_1	Absolute Control
T_2	Package of Practice (RDF+ FYM at 6.25 t ha^{-1})
T_3	100 % NPK + $ZnSO_4$ + Biochar at 10 t ha^{-1}
T_4	100 % NPK + $ZnSO_4$ + PSB enriched FYM at 6.25 t ha^{-1}
T_5	100 % NPK + $ZnSO_4$ + PSB enriched Biochar at 10 t ha^{-1}
T_6	100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 100 % Zn enriched Biochar at 5 t ha^{-1}
T_7	100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 75 % Zn enriched Biochar at 5 t ha^{-1}
T_8	100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 50 % Zn enriched Biochar at 5 t ha^{-1}
T_9	100 % NK + 75 % P + PSB enriched FYM at 6.25 t ha^{-1}+ $ZnSO_4$
T_{10}	100 % NK + 75 % P + PSB enriched Biochar at 10 t ha^{-1} + $ZnSO_4$
T_{11}	100 % NK + 75 % P + PSB enriched FYM at 3.125 t ha^{-1} + 100% Zn enriched Biochar at 5 t ha^{-1}
T_{12}	100 % NK + 75 % P + PSB enriched FYM at 3.125 t ha^{-1} + 75 % Zn enriched Biochar at 5 t ha^{-1}
T_{13}	100 % NK + 75 % P + PSB enriched FYM at 3.125 t ha^{-1} + 50 % Zn enriched Biochar at 5 t ha^{-1}

(**Note:** RDF=30:80:37.5:12.5 of N: P_2O_5: K_2O: Zn kg ha^{-1}, FYM-6.25 t ha^{-1}, Biochar at 10 t ha^{-1})

Results and Discussion

The results pooled data 0f 2022 and 2023 indicated significant improvements in soybean growth parameters 30, 60 and at harvest of the crop growth stage, such as germination percentage, plant height, number of leaves and dry matter accumulation, particularly in treatments involving application PSB-enriched FYM along with zinc enriched biochar. Treatment T_6 (100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 100 % Zn enriched Biochar at 5 t ha^{-1}) consistently showed the highest values for growth attributes 30, 60 and at harvest of the crop growth stages, followed closely by T_7 and T_5.

The pooled data of two seasons 2022 and 2023 showed that application of recommended 100% NPK+PSB enriched FYM at 3.125 t ha^{-1} + 100% Zn enriched Biochar at 5 tha^{-1} (T_6) recorded significantly more seed yield (23.61 q ha^{-1}), root biomass (0.35 t ha^{-1}), stem biomass (0.79 t ha^{-1}), leaf biomass (1.69 t ha^{-1}), total biomass yield 2.83 (t ha^{-1}) and 100 seeds weight (20.88 g) compared to control and T_2 which had the package of practice. Which was on par with the treatments (T_7)100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 75% Zn enriched Biochar at 5 t ha^{-1} and (T_8) 100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 50% Zn enriched Biochar at 5 t ha^{-1}

Due to application of 100 % NPK + PSB enriched FYM at 3.125 t ha^{-1} + 100 % Zn enriched Biochar at 5 t ha^{-1} (T_6), significant increase in growth parameters such as plant height, number of leaves and yield of soybean plant was reported. With biochar use in combination with PSB enriched FYM, there were several variables relating to the crop growth attributes. Those factors will operate either individually or at the same time. Indeed, a reduction in soluble Al and Fe led to rise in pH, (Manikanta and Mamatha, 2024) a controlled and gradual release of nutrients, and because of biochar specific physical-chemical properties with low bulk density, which would improve the porosity and aeration status of the soil, which would indirectly increase the available plant water and boost microbial function, should have led to the improvement of growth parameters of biochar and agricultural lime treatment over control and other rate of application. Most of these changes in soil's physical and chemical properties in biochar transformed soils are familiar with other research (Rohitha *et al.*, 2021; Nimbalkar*et al.*, 2023).

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OP: 10 Assessing of different decomposers with biochar in sugarcane trash management for enhancing ratoon sugar cane (*SaccharumOfficinarum*L) yield

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Abstract: Burning of sugarcane trash is a hazardous practice which has affected soil health, air, human health *etc.* leading to massive impact as well as monetary losses. The present study aimed at Assessing of different decomposers with biochar in sugarcane trash management for enhancing ratoon sugar cane yield at farmers field. Average of two years in data in table revealed that yield, economics of soil properties and nutrients. It is observed that. Average of two years root length 4.83cm and Sugarcane yield 97.92 t/ha recorded higher yield with application of Compost Culture 15 kg/ha and biochar 1 t/ha with retention of Sugarcane trash residue followed by application of liquid discomposure 15lit/ ha with biochar 1 ton/ha (93.79t/ha) compared to farmer practice if burning of trash in field itself Same trend followed economics which is 18.23% increase over the farmer practice (trash burning) and same trend followed in economics and available of nutrients

Introduction

Sugarcane straw decomposition is a key process to investigate in order to guide management decisions, because it controls nutrient mineralization, contributes to GHG emissions to the atmosphere, and provides substrate for soil organic matter (SOM). Several factors directly or indirectly affect the decomposition rate, with the most important being the amount and quality of straw, edaphoclimatic conditions, and management practice. It is the oldest crop known to mankind which is a major cash crop of tropical and subtropical regions. It plays a decisive role in the economy of sugarcane growing countries. As a C4 plant type, sugarcane have high potential of accumulating crop biomass up to 381 t/ha sugar content up to 14.5 per cent and it also produces 10 to 12 t of dry matter ha-1, which could be obtained from the detrashed dried sugarcane leaves on 5th and 7th months. The detrashing operation would also facilitate easier adoption varied intercultural operations in grown up sugarcane crop. In addition, the studies by Sangeetha *et al.,* (2023) revealed that the cane trash contains 68 per cent of organic matter, 0.42 per cent of nitrogen, 0.15 per cent of phosphorous and micronutrients. However, conventionally the cane trashes are burnt after harvest which results in inadequate plant population, environmental pollution through carbon generation and exhaustion.

Methods of Materials

KrishiVigyan Kendra for Haveri district of Karnataka state is situated in Hanumanamatti. It organized various activities mandated by Indian Council of Agricultural Research (ICAR), New Delhi *viz.* On-farm testing (OFT) during 2019-20 and 2020-21 was conducted on specific identified problem to come up with the result that which of the technologies tested is more suitable to the resources available in the district and cost effective. This is a form of participatory study where farmers' perspective is given most importance. To conduct this trial, the Ranebennuru block of Chodyanapura village was chosen based on the maximum area under sugarcane cultivation totally the trial was conduct in three farmers' field. Accordingly University of Agriculture science, Dharwad developed compost culture was taken as for assessment with farmer practice technology option TO1- Burning of trash/residue (Farmer practices),TO2 -Retention of residue & apple. of compost culture @15 kg/ha. Along with 1 tonn of bio char ha, TO3-Retention of residue + appln. of Waste decomposer 10 lit/ ha along with 1 tonn of bio char per ha is the consortium of microorganisms recommended for composting all the agro-wastes. For one ton of trash, 15 kg inoculums are recommended per ha. Waste decomposer was released from National Centre for Organic and Natural Farming.

Results and Discussion

The result of assessment of different Compost Culture along with biochar for management of Sugarcane trash for ratoon sugarcane yield. Average of two years (2019-20 and 2020-21) in maintained in table perusal of the data in table revealed that yield economics of soil properties and nutrients. It is observed that. Average of two years root length 4.83cm and Sugarcane yield 97.92 t/ha recorded higher yield with application of Compost Culture 15 kg/ha and biochar 1 t/ha with retention of Sugarcane trash residue followed by application of liquid discomposure 15lit/ ha with biochar 1 ton/ha (93.79t/ha) compared to farmer practice if burning of trash in field itself Same trend followed economics which is 18.23% increase over the farmer practice (trash burning). Gross income (₹ 2, 35,008 / ha) and net income (₹1,73,078/ ha and B:C ratio 3.80 same trend as followed are confirming with those of Yadav *et. al*. (2014) and Sangeetha *et. al*. (2023). This is due to application of biochar-inoculant along with biochar ensured Substantial accumulation of essential of nutrients, Key major responsible for all Physiological activities favoring early crop vigor growth and better Crop establishment in terms of augmented yield improvement.. The reasoning could be due to additional incorporation of organic rich bio-char in combination of compost culture positive influence on varied soil-physic-chemical characteristics and also results in considerable addition of macro and micro nutrients for effective growth and establishment of sugarcane crop. available Nitrogen (386.5 kg / ha), available P_2O_5 (39.8 kg / ha), available K_2O (205 kg/ha), available Zn (0.65 ppm / ha), available Fe (2.82 ppm / ha). Soil organic carbon and available macro and micro nutrients was average of two years increasing trends might have been attributed to better decomposition of trash by soil microbes under improved nutrition results Zhang *et al*. (2024) also reported benefits in soil-fertility status with crop-residue incorpon ration.

Table 1: Study of different compost with biochar in sugarcane trash management on yield and economics for ratoon sugar cane yield

Observations	Initial Soil properties (After harvest of plant cane)	TO1:Burning of trash/residue (Farmer practices)	TO2 ;Retention of residue & apple. of compost culture @ 15 kg/ha and bio char	TO3:Retention of residue + appln. of 10 lit liquid decomposer with 1tonn bio char
Texture	Clay loam	Clay loam	Clay loam	Clay loam
pH (1.2.5)	8.20	8.23	8.05	8.10
EC (Ds/m)	1.50	1.67	1.42	1.46
OC (%)	0.54	0.42	0.72	0.70
Available N (kg/ha)	344.6	312.4	386.5	355.6
Available P_2O_5 (kg/ha)	35.8	31.8	39.8	37.6
Available K_2O (kg/ha)	201.0	191.7	205.6	202.5
Available Zn (ppm)	0.42	0.46	0.65	0.62
Available Fe (ppm)	1.95	1.85	2.82	2.79

Table: 2 Available nutrients (kg/ha) for assessing of different decomposers with Bio char in sugarcane trash management ratoon sugar cane yield

Observations	TO1 Burning of trash/residue (Farmer practices)	TO2 Retention of residue & apple. of compost culture @15 kg/ha along with 10 tonnes bio char	TO3 Retention of residue + appln. of liquid decomposer 10 Lit along with 10 tonnes bio char
Root length(cm)	3.41	4.83	4.54
Cane yield (t/ha)	86.71	97.92	93.79
Gross Cost (Rs./ha)	2,08,104/-	2,35,008/-	2,25,096/-
Cost of Cultivation (Rs./ha)	57,930/-	61,930/-	60,255/-
Net Return (Rs./ha)	1,50,170/-	1,73,078/-	1,64,841/-
B : C ratio	3.59	3.80	3.73
Increased yield (%)	-	12.92	8.16

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OP: 11 Mg(Ion)-Modified Biochar for Nutrient Supply in Soil

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Abstract: Magnesium (Mg) is an essential macronutrient for plant growth and development, and it is important for photosynthesis, chlorophyll production, as well as enzyme activation. Biochar, a carbon-rich retardation of the pyrolysis of biomass, has been reported to improve soil parameters and nutrient availability after pyrolization. The introduction of Mg (ion)-modified biochar (Mg-MBC) can effectively augment the beneficial effects of biochar on increasing mineral supply to crops. Biochar provides a porous framework allowing for the adsorption and retention of Mg ions, thereby preventing leaching and providing slow-release Mg to the soil. This study includes comparative characterizations of biochar derived from sugarcane bagasse and magnesium-modified biochar, utilizing techniques such as X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) to explore their potential applications in soil nutrition. The application of magnesium-modified biochar (Mg-MBC) will enhance the solubilization of magnesium, thereby increasing its availability for crops, such as soybean, which experiences competitive sorption with potassium (K). Biochar will also improve soil structure by enhancing porosity and water retention capacity, indirectly fostering soybean growth through improved root development and nutrient uptake. Additionally, Mg-MBC can stimulate microbial activity within the soil, facilitating nutrient cycling and promoting overall plant health.

Keywords: Biochar, Mg-ions, soil nutrition, XRD, FTIR, SEM

OP: 12 Assessing *Prosopis juliflora* Biochar quality and its synergistic effect with gypsum on yield attributes of Rice and Wheat under coastal soils

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Abstract: This study explores the chemical composition of biochar prepared from *Prosopis juliflora* using brick kilns and its effectiveness as an amendment in rice and wheat under coastal soils. Quality analysis showed that treated biochar had a higher carbon content (74.21%) and essential nutrients, contributing to soil health. Field results confirmed that the application of biochar @ 4 t/ha + gypsum @ 50% of GR (T_9) recorded significantly higher growth and yield attributes of *kharif* rice and *rabi* wheat, demonstrating its potential under coastal salt affected soils.

Key words: Biochar, Gypsum, Rice-wheat sequence, Coastal soil

Introduction

Prosopis juliflora, an invasive species in many arid and semi-arid regions, has potential for use in sustainable agriculture through biochar production. This study evaluates the quality of biochar produced and examines its synergistic effects with gypsum on rice and wheat yield. With its high carbon content and porous structure, biochar can improve soil properties by enhancing water retention, nutrient availability, and microbial activity. When combined with gypsum, known for its ability to reduce soil sodicity and improve soil structure, we hypothesize a compounded, synergistic effect on crop yield and soil health. In salt-affected soils, achieving successful crop growth is challenging due to issues like poor soil structure, low nutrient availability and high salinity levels, which hinder plant growth and yield. This study explores the use of *Prosopis juliflora* biochar combined with gypsum as a potential solution to overcome these barriers and improve the yield of *kharif* rice and *rabi* wheat in coastal saline soils, ultimately supporting higher crop productivity and resilience in coastal agricultural systems.

Materials and Methods

Prosopis juliflora wood was collected for biochar production and traditional brick kilns were adapted for slow pyrolysis to maximize carbon content and biochar yield.

Figure: Biochar production initiated under visionary leadership of Hon'ble VC, NAU

Treated (with 25% spent wash and 0.5% phosphoric acid) and untreated biochar samples were analyzed for quality, and a field experiment was conducted in a large plot technique at the Coastal Soil Salinity Research Station, NAU, Danti-Ubharat, during 2023–2024. Treatments included various combinations of biochar and gypsum applied to rice, with residual effects observed in wheat.

Results and Discussion

Quality tests showed that treated biochar had higher carbon content (74.21%) and lower pH (6.5) due to acidifying agents and organic matter from the spent wash, enhancing stability and making it suitable for coastal soils. In contrast, untreated biochar had lower carbon (66.19%) and higher pH (8.7). Treated biochar also contained essential nutrients like potassium (1,730 mg/kg) and calcium (1.25%), supporting soil fertility.

Table 1: Composition of treated and untreated biochar from *Prosopis juliflora*

Parameter	Unit	Treated Biochar	Untreated Biochar	Test Method
Carbon	%	74.21	66.19	IS 1350 (Part 4) 2022
Hydrogen	%	3.66	3.27	IS 1350 (Part 4) 2022
Oxygen	%	13.57	22.39	ISO 1928
Nitrogen	%	0.17	0.13	IS 1350 (Part 4) 2022
Phosphorus	%	Not Detected	Not Detected	IS 5305
Potassium	mg/kg	1730	4313	SOP/INS/CL/02
Calcium	%	1.25	1.18	IS 1727 2018
Magnesium	%	0.12	0.1	IS 1727 2018
pH	-	6.5	8.7	pH meter

Biochar and gypsum applications improved rice and wheat yields, with the highest yield (5,878 kg/ha for rice and 3,060 kg/ha for wheat) observed with 4 t/ha biochar + 50% GR which is likely due to biochar's ability to enhance soil water retention and nutrient availability. Gypsum complemented this by displacing sodium ions and reducing sodicity, which aided root growth and nutrient uptake. Biochar's residual effect supported sustained wheat growth, enhanced soil health over time and promoted resilience.

Table 2: Growth and Yield Attributes of *Kharif* Rice and *Rabi* Wheat

Treatment	*Kharif* Rice				*Rabi* Wheat			
	Plant Height (cm)	Tillers/ m^2	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Plant Height (cm)	Spikes per Plant	Grain Yield (kg/ha)	Straw Yield (kg/ha)
T_1	111.4	6.64	3730	5053	57.6	6.64	2180	3320
T_2	119.8	8.8	4592	5990	65	7.8	2380	3720
T_3	121.3	8.96	4780	6248	64.8	7.92	2540	3820
T_4	117.4	7.84	4446	5821	63.9	6.96	2360	3560
T_5	112.2	8.76	4866	6244	64.5	7.56	2560	3820
T_6	125.2	8.96	5000	6512	64.9	7.52	2580	3860
T_7	121.7	10.16	5548	7342	70.3	9.04	2860	4360
T_8	121.2	9.08	5154	6624	66.4	8.24	2720	4180
T_9	124.4	10.2	5878	7484	72.9	8.52	3060	4720

T_{10}	121.1	8.84	5356	7099	64.7	8.36	2740	4200
SEm±	2.17	0.25	177	239	1.89	0.45	108	185
CD@ 5%	6.22	0.73	508	687	5.43	1.29	311	531
CV (%)	4.05	6.43	8.02	8.31	6.47	12.8	9.33	10.46

T_1: Control (no biochar or gypsum), T_2: Biochar @ 2 t/ha, T_3: Biochar @ 4 t/ha,

T_4: Gypsum @ 25% of GR, T_5: Gypsum @ 50% of GR, T_6: Biochar @ 2 t/ha + Gypsum @ 25% of GR, T_7: Biochar @ 2 t/ha + Gypsum @ 50% of GR, T_8: Biochar @ 4 t/ha + Gypsum @ 25% of GR, T_9: Biochar @ 4 t/ha + Gypsum @ 50% of GR, T_{10}: Gypsum @ 50% of GR + Biocompost @ 5 t/ha

Conclusion

The application of biochar @ 4 t/ha + gypsum @ 50% of GR (T_9) significantly improved growth and yield attributes of *kharif* rice and *rabi* wheat in coastal soils by enhancing soil health and nutrient retention.

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Theme II:
Innovative Applications for Biochar Utilisation
Poster Presentation

PP : 13 Chemical characterization of biochars derived from agricultural residues

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Abstract: Biochar is widely recognized as an efficient tool for carbon sequestration and soil fertility. The understanding of its chemical properties, which are strongly related to the type of the initial material used and pyrolysis conditions, is crucial to identify the most suitable application of biochar in soil. A selection of organic wastes with different characteristics (e.g., Cotton stalk, Redgram stalk and Maize Straw) werepyrolyzed at two temperatures (300 & 400^{O} C) in order to optimize the chemical properties of biochar as a soil amendment. Low-temperature pyrolysis produced high biochar yields. In contrast, high-temperature pyrolysis led to biochars with a high C content. The biochar obtained from cotton stalk showed a high yield. The biochar obtained from woody materials (Cotton and Redgram) showed high carbon content.

Introduction

The interest in the application of biochar as a method for mitigating the global-warming effects is steadily increasing. In addition to the studies on the use of biochar for carbon sequestration, a number of reports have focused on alternative applications of biochar for the improvement of soil fertility, plant growth and decontamination of pollutants such as pesticides, heavy metals and hydrocarbons (Beesley*et al*., 2011). The diverse range of biochar applications depends on its chemical properties, which are governed by the pyrolysis conditions (heating temperature) and the original feedstock. Thus, detailed information about the complete production process is a key factor in defining the most suitable application of biochars. The biochar chemical properties can cause changes in the soil nutrient and C availability and provide physical protection to microorganisms against predators and desiccation, this may alter the microbial diversity and taxonomy of the soil. The type of feedstock material is another important factor that determines the final application of the biochar and its effect in soil, because its properties are affected by the nature of the original material.

Objective : The objective of this study is to know the chemical characteristics of biochar for its use in agriculture by investigating at two pyrolysis conditions and agricultural wastes used as feed stocks. To achieve this objective, the chemical properties of the biochars obtained at two different temperatures (300 & 400^{O}C) were evaluated. Cotton and redgram stalk and maize straw were used as the starting materials, because the global amount of residues from these crops is substantial.

Material and Methods

A. **Biochar preparation from agricultural residues:** The biochars used in this work were obtained from cotton and redgram stalks and maize straw residues. Out these three, two are of woody in nature. All materials were first dried in air and then cut into small pieces (less than 4–5 cm), these were then kept in oven (370 cm3) that was used in a commercially. This was charred for 10 h at temperature of 300^{O}C and 400^{O}C) at a heating rate of 10 ^{O}C min^{-1}. The temperature regulation was performed with the following temperature ramp: (1) temperature equilibration at 30^{O}C, followed by linear heating (at a rate of 5^{O} C min^{-1}) from 30 to 105 ^{O}C, isotherm for 10 min and ramping of 105 ^{O}C min^{-1} 105 to 300 and 400 ^{O}C.
B. **Biochar chemical analysis:** After the pyrolysis process, all samples were ground and sieved to less than 0.5mm in diameter. The biochar yield was calculated as the proportion of the weight of pyrolysis product to the original material. The pH of each mixture (1 V 10, w=v ratio) was measured with pH meter. The composition of C and N was determined using the Walkley& Black method and the Kjeldhal method.

Results and Discussion

The characteristics of the biochars derived from different agricultural wastes are shown in Table 1. Low-temperature pyrolysis produced a higher biochar yield. The biochar yields reduced as the pyrolysis temperature increased. Moreover,the type of feedstock also affected the biochar yields. The cotton stalk yielded highest followed by redgram stalk and lowest yielded by maize residue. The pH value of biochars increased with temperature, probably as a consequence of the relative concentration of non-pyrolyzed inorganic elements, already present in the original feedstocks (Novak et al., 2009). Analytical element C/N ratios is useful indicator of the character of biochar. Data suggest that an increase in the temperature results in a larger loss of N compared to that hat of C and resulted in wider C/N ratio indicates a change in the biochar recalcitrance (Harvey *et al.,* 2012). C/N ratio widened as the temperature increased, reflecting the loss of easily available nitrogen. A C/N ratio of more than 35 results in microbial immobilization. A ratio of 20 to 30 results in equilibrium between mineralization and immobilization. This ratio is more towards release of nitrates readily. Having C/N ratio that is too high or too low may cause the loss of nitrate from the soil and cause a decrease in agricultural productivity. Looking to this, among three agricultural wastes that is cotton stalk, redgram stalk and maize straw, biochar prepared from redgram stalk and maize straw is having C/N ratio between 20 to 30 and is ideal(24:1) for soil microbes, although most soils have a C/N ratio less than that. So it is clear that soil fertility could be buffered through application of biochar prepared from different agricultural wastes (Jindo*et al.,* 2014)

Table 1. Yield and chemical characteristics of the biochars derived from different agricultural wastes

Agricultural wastes	Temperature	Biochar yield (%)	pH(H_2O)	C (%)	N (%)	C/N ratio
Cotton stalk	300^{O}C	35.8	7.02	60.2	1.7	35.6
	400^{O}C	28.6	8.13	69.1	1.3	51.6
Redgram stalk	300^{O}C	32.3	6.43	60.5	2.8	21.8
	400^{O}C	25.2	7.39	67.6	2.5	26.9
Maize straw	300^{O}C	23.4	8.62	39.9	1.6	24.8
	400^{O}C	18.2	9.81	32.5	1.1	29.5

Conclusion

The data presented in this work showed that both the pyrolysis temperature and the type of feedstock strongly influence the chemical properties of the biochars. In particular, an increase in the temperature decreased the biochar yield, increased the pH, and increased the carbon and decreased the nitrogen content. Because of recalcitrant chemical character in woody type biochars, they yielded more biochar yield having lower pH value than maize straw. Higher N content was observed in redgram it may be because as it is legume.

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PP: 14 Biochar as a potential technology in carbon sequestration

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Abstract: At present climate change increases desertification and drought globally, novel and effective solutions are required in order to provide food for growing population and sustainability of soil. Biochar, a nutrient-rich material from biomass offers promising solutions for agriculture amid climate change. It enhances soil nutrient density, water retention and micro-biota, reducing the need for chemical fertilizers and boosting crop yields. Biochar also aids in carbon sequestration, providing environmental and economic benefits and has potential in carbon credit systems. Its application in soil amendment addresses key agricultural challenges, making it a valuable tool for sustainable food production.

Introduction

Anthropogenic climate change and unsustainable agriculture have led to drought, excessive fertilizer use and food insecurity. Biochar, a potential solution, can improve soil quality and sustainability in agriculture. Key soil quality aspects include texture, microbial activity and nutrient/moisture retention. While traditionally used untreated, modified biochar enhances soil functionality. It boosts soil health and plant yields without synthetic fertilizers, addressing water and nutrient storage issues as well as sequester carbon, mitigating climate change. While many studies on biochar focus on specific topics like its effects on microbiota, crop yield, or economic assessments, this summary uniquely summarizes multiple aspectslike, biochar's role in soil improvement, climate change mitigation and future agricultural applications such as crop yield and carbon sequestration potentiality. Biochar, produced through pyrolysis of biomass, enhances soil health, controls pollution and supports sustainable agriculture. Its benefits extend to soil health, agriculture, wastewater treatment and climate change mitigation.

Biochar can improve soil quality, boost crop productivity and help capture carbon, reducing greenhouse gases like CO_2, N_2O and CH_4. Plants can help soil absorb about 12% of anthropogenic CO_2 emissions each year. The effectiveness of biochar varies depending on how it's sources and production,location and environmental conditions. Most studies are small-scale, making it hard to compare results. Biochar is important for agriculture and climate protection plans, but more large-scale field research is needed to understand its full impact.

Materials and Methods

There are many ways to produce biochar and the method of production has a huge impact on the resultant characteristics of biochar. Biochar is produced through pyrolysis process, *i. e.* thermo-chemical conversion of biomass in an oxygen-deprived environment. The study characterizes biochar produced from fivedifferent agricultural residues,those are coconut shell, coconut husk, sugarcane bagasse, rice husk and cotton stalk, assesses the global potential of these residues to sequester carbon in soils.The proximate and ultimate analysis characterizations of the agricultural residues and its biochar are determined. In reality much of these residues may be burnt in the field or used locally as fuel. It has been assumed here that all residues burnt in the field on average 20% of residues are available for biochar production (Mašek and Zimmerman, 2014).

Results and Discussion

The experimental data published here regarding biochar yields, biochar carbon content and recalcitrance (Table 1A) were used to determine the potential biochar yield, biochar carbon content and the long-term carbon sequestration potential of each residue type (Table 1B).Biochar yield from five agricultural residues varies from 28% to 39%, Average carbon content found to be 46%, The R_{50}

recalcitrance index showed biochar of different sources to be either class 2, Biochar carbon sequestration potential was 23.8 - 28.7 per cent.The assessed residues are at current availability in global level, by using these could produce 285.2 Mt of biochar. This quantity of biochar has the potential to sequester 0.42Pg CO_2 yr^{-1} in soils over long time periods.

Table1. Characteristics of raw feedstocks and biochar (A). Theoretical potential for global biochar production, carbon content of biochar, equivalent CO_2 of the carbon in biochar, and long term carbon storage potential of biochar from the different residues (B).

Parameters	Coconut shell	Sugarcane bagasse	Rice husk	Cotton Stalk	Coconut Husk
A					
Carboncontentinfeedstock(%)	52.6	45.9	42.5	46.0	44.7
Biochar yield (%)	28.2	27.7	39.0	28.0	30.8
Fixed C content in Biochar (%)	91.9	69.9	86.1	71.2	74.9
R_{50} recalcitrance index	0.59	0.53	0.54	0.50	Continued
C sequestration potential (%)	28.7	27.3	26.0	23.8	26.8
B					
Estimated biomass available for biocharproduction (Mt/year)	8.86	657.4	204.35	57.14	8.11
Biochar yield (Mt/year)	4.9	182.1	79.7	16.0	2.5
Biochar carbon (Mt)	4.4	127.3	68.6	11.3	1.9
CO_2 eq. of biochar carbon (Mt)	16.1	467.2	251.8	41.5	7.0
C remaining long-term (Mt)	2.7	67.57	37	5.65	0.93
CO_2 eq. of C stored long-term (Mt)	9.9	247.75	135.66	20.68	3.41

Note:

$R_{50}>0.7$ Most recalcitrant (more stable), $0.5<Q_{50}<0.7$ Minimal degradation,
R50<0.5 More degradable (less stable), CS= Carbon sequestration

CONCLUSIONS

Potential of biocharto sequester carbon in long term depends on the biomass availability, total carbon content, biochar yield, carbon content in the biochar,recalcitrant potential, carbon sequestration potential of the feed stock used for biochar production. Biochar, a recalcitrant form of carbon made by thermo-chemical conversion of biomass play a great role in mitigating climate change by sequestering atmosphere carbon, improving soil quality and ultimately food security.

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PP: 15 Prospect of biochar production from sugarcane bagasse- a review

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As the world grapples with climate change and the need for sustainable agricultural practices, innovative solutions are emerging to address multiple challenges simultaneously. One such solution that has gained significant attention in recent years is biochar – a carbon-rich material produced from biomass through a process called pyrolysis. While biochar can be made from various organic materials, using agricultural waste like sugarcane bagasse offers a particularly promising opportunity to create value from what would otherwise be a disposal problem.

What is Biochar?

A porous, carbonaceous material that is produced by pyrolysis of biomass and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing. It is not made to be burnt for energy generation. Biochar is produced through pyrolysis – heating biomass at temperatures ranging from 350°C to 1000°C in a low-oxygen environment. Biochar is distinguished from other carbonized materials like torrefied biomass or hydrothermal char by its specific production methods, quality characteristics, and intended uses.

Sugarcane crop and its scenario

Sugarcane is an important crop globally not only for sugar production, but also as a bioenergy crop due to its remarkable dry matter production capacity.Sugarcane is India's largest cultivated cash crop, having more than 90 % and 51 % share of the national cash crop and total agro production. The sugar industry is essential to the livelihood of around 50 million sugarcane farmers and 0.5 million sugar mill workers in India. Over the past few decades, there has been a notable rise in sugarcane production, driven by the increasing demand for sugar, ethanol, and jaggery derived from this versatile crop. Consequently, the sugar industry generates a significant amount of agricultural waste. This waste primarily takes the form of bagasse, which remains after sugarcane undergoes processing in factories to extract sucrose or alcohol. Without proper utilization, bagasse is commonly disposed of as solid waste or utilized as a fuel source for the milling process. For every ton of sugarcane, approximately 280 kg of wet bagasse is produced, highlighting the substantial quantity of this residue.Although some sugar mills utilize wet sugarcane bagasse for fueling the milling process, a significant portion remains stockpiled and is often incinerated on-site, resulting in a highly flammable biomass that poses significant risks to the industry and its surroundings. Recognizing the importance of addressing this issue, conversion of agricultural waste into biochar as an efficient means of harnessing energy following biomass devolatilization.

Why Bagasse?

Bagasse is the fibrous residue left over after sugarcane stalks are crushed to extract their juice. It is one of the most abundant agricultural byproducts globally, with over 500 million tons produced annually. It was estimated that about 38.8 MT sugarcane top & leaf (STL) and 96.3 MT sugarcane bagasse (SB) are produced in India annually. Out of which, about 47 % STL and 37 % SB remain unused. Surplus STL & SB has an estimated 17.6±0.4 MT biochar potential, sequestrating 18.8±0.4 MT CO_2e carbon in the soil. STL & SB-derived biochar application at 10 t ha^{-1} could sequestrate 51.9±1 and 47±2.2 MT CO_2e carbon due to enhanced crop yield and reduced soil organic carbon mineralization. Also, biochar application at 10 t ha^{-1}

could reduce about 0.08 MT NPK fertilizer consumption and 0.22±0.13 MT N_2O emissions from sugarcane cultivation, having 0.28±0.17 and 65±38 MT CO_2e reduced carbon footprint, respectively.

Overall, sugarcane residues - biochar system for carbon sequestration could reduce 220.3±45.1 MT CO_2e carbon footprint, about 9.5±2 % of total GHG emission from India at the 2019 level. Mapping sugarcane-producing states revealed that Karnataka, Maharashtra, and Uttar Pradesh shared about 75.5 % of surplus STL & SB potential. Andhra Pradesh, Bihar, Gujarat, Haryana, and Tamil Nadu have a 16.5 % combined share in surplus STL & SB potential. Chen *et al.* (2010) reported that sugarcane bagasse-derived biochar application at 3 % by weight in 30 cm ploughing soil could increase sugarcane yield by 42.5±3.9 %, Nitrogen availability by 29.9±1.3 % and moisture content in soil by 39±12.7 %. Quirk *et al.* (2012) reported that biochar application at 10 t ha^{-1}could reduce by 28±16 % N_2O emissions from sugarcane cultivation.Traditionally, bagasse has been used as a low-grade fuel in sugar mills or as a raw material for paper production. However, converting bagasse into biochar offers several advantages:

1. Waste Valorization: Converting bagasse to biochar creates a value-added product from what is often considered a waste material.
2. Renewable Resource: Sugarcane is a fast-growing crop, making bagasse a renewable and sustainable feedstock for biochar production.
3. Carbon Sequestration: Biochar production can lock away carbon that would otherwise be released back into the atmosphere through natural decomposition or burning. One tonne of bagasse derived biochar would sequester in the order of 2.3 tonnes of CO_2 equivalents.
4. Improved Soil Health: When used as a soil amendment, bagasse biochar can enhance soil fertility, water retention, and microbial activity.
5. Reduced Environmental Impact: Proper management of bagasse through biochar production can minimize the environmental issues associated with its disposal or burning.

Production Process of biochar

1. Feedstock Preparation: The bagasse must be dried to an appropriate moisture content, typically below 20%. This can often be achieved through natural air-drying or using waste heat from the sugar production process.
2. Pyrolysis: The dried bagasse is heated in a low-oxygen environment. The specific temperature and residence time can be adjusted to optimize for desired biochar characteristics. Generally, higher temperatures (>500°C) produce biochar with higher carbon content and surface area, while lower temperatures may retain more nutrients from the original biomass.
3. Cooling and Separation: The hot biochar must be cooled in a controlled manner to prevent combustion when exposed to air. This step may also involve separating the solid biochar from any condensable gases or bio-oils produced during pyrolysis.
4. Post-Processing: Depending on the intended application, the biochar may undergo additional treatments such as grinding, sieving, or activation to enhance specific properties.
5. Quality Control: To ensure consistent quality and safety, the produced biochar should undergo testing for key parameters like carbon content, pH, nutrient levels, and potential contaminants.

Key Properties of Bagasse Biochar

The specific characteristics of bagasse biochar can vary significantly depending on production conditions and the initial state of the bagasse. Fresh and aged bagasse biochar exhibit different properties at various pyrolysis temperatures:

Fresh bagasse biochar:

- Carbon content increases with temperature: 43.07% (350°C), 67.73% (500°C), 68.61% (650°C)
- Fixed carbon content rises: 15.33% (350°C), 62.40% (500°C), 69.86% (650°C)
- Ash content increases: 6.08% (350°C), 17.22% (500°C), 20.24% (650°C)

Aged bagasse biochar:

- Lower carbon content than fresh biochar at all temperatures
- Carbon content increases: 25.75% (350°C), 35.66% (500°C), 43.67% (650°C)
- Fixed carbon content rises: 13.72% (350°C), 31.69% (500°C), 36.59% (650°C)
- Higher ash content than fresh biochar, increasing from 20.30% (350°C) to 50.86% (500°C) and 53.73% (650°C).

Composition of biochar

1. Carbon Content: For fresh bagasse, carbon content increases significantly with pyrolysis temperature, from 43.07% in raw bagasse to 68.61% at 650°C.
2. Fixed Carbon: At 650°C, fresh bagasse biochar contains 69.86% fixed carbon, indicating high stability and potential for long-term carbon sequestration.
3. Surface Area: High surface area (often 200-400 m^2g^{-1}) due to its porous structure, which enhances its ability to retain water and nutrients.
4. pH: Generally alkaline, with pH values often between 8-10. This can be beneficial for acidic soils but may require careful management in other contexts.
5. Nutrient Content: While most nutrients are volatilized during pyrolysis, bagasse biochar often retains significant potassium and some phosphorus, magnesium, and calcium.
6. Cation Exchange Capacity (CEC): Moderate to high CEC, which improves its ability to hold and exchange nutrients in soil.
7. Water Holding Capacity: Can retain 2-3 times its weight in water.

Using fresh bagasse yields biochar with higher carbon content and lower ash. Higher temperatures produce biochar with more stable carbon, which is beneficial for long-term soil carbon sequestration. However, lower temperature biochar may retain more of the original biomass structure and nutrients, which could be advantageous for some agricultural uses.

Applications of Bagasse Biochar

1. Soil Amendment
2. Composting Additive
3. Animal Feed Supplement
4. Water Filtration
5. Industrial Materials
6. Climate Change Mitigation

Challenges and Considerations

While bagasse biochar offers numerous benefits, there are also challenges and considerations to keep in mind:

1. Production Costs
2. Quality Control
3. Regulatory Framework
4. Application Guidance
5. Long-Term Effects

Future Outlook

The potential for bagasse biochar is significant, but realizing its full potential will require continued research, development, and scale-up efforts. Some key areas for future focus include:

1. Optimized Production: Developing more efficient and cost-effective pyrolysis technologies specifically tailored for bagasse feedstock.
2. Customized Products: Creating “designer” biochars with properties optimized for specific applications through control of production conditions and post-processing techniques.
3. Co-Products: Exploring the potential of bio-oil and syngas produced during pyrolysis for additional value streams.
4. Life Cycle Assessment: Conducting comprehensive analyses to quantify the full environmental and economic impacts of bagasse biochar production and use across different applications.
5. Policy Support: Developing supportive policies and incentives to encourage biochar adoption, particularly for its carbon sequestration potential.
6. Market Development: Expanding markets for biochar products beyond agriculture, including in environmental remediation, industrial materials, and carbon offset programs.

Conclusion

Biochar production from bagasse represents a promising pathway to transform an abundant agricultural waste into a valuable resource with multiple environmental and economic benefits. By sequestering carbon, improving soil health, reducing waste, and offering diverse applications across sectors, bagasse biochar has the potential to contribute significantly to sustainable development goals.However, realizing this potential requires a systems approach that considers the entire value chain – from sustainable sugarcane production and efficient bagasse collection to optimized pyrolysis processes and appropriate end-use applications.

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PP: 16 Integrating biochar production, carbon sequestration and carbon trading for carbon neutral farming – a review

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Abstract: The biochar production, carbon sequestration, and carbon trading as an integrated strategy for achieving carbon-neutral farming. Biochar, derived from biomass pyrolysis, provides a long-term carbon sink, enhancing soil health and mitigating greenhouse gas emissions. Studies highlight biochar’s potential for substantial carbon sequestration and agricultural productivity benefits, particularly when derived from crop residues. However, challenges, including sink saturation, socio-economic barriers, and adoption limitations, remain—especially in developing regions. The paper advocates for standardized carbon credit mechanisms, resource mapping, and participatory research to optimize biochar's impact on sustainable farming, rural resilience, and climate goals."

Introduction

The urgency of climate change mitigation has heightened the exploration of innovative solutions, especially in agriculture, where sustainable practices can make a measurable impact. Among these solutions, biochar production has emerged as a promising strategy to reduce greenhouse gas (GHG) emissions, enhance soil health, and sequester carbon. To meet global climate targets, such as limiting warming to 2 °C, carbon sequestration through methods like biochar and soil carbon sequestration (SCS) is gaining recognition. However, integrated assessment models (IAMs) still underrepresent these negative emissions technologies (NETs), which can offset agricultural emissions (Smith (2016)). As the global agricultural sector confronts climate change risks, implementing sustainable practices like biochar is essential (Singh *et al*., 2023). However, a lack of high-resolution maps of crop residue availability and the need for a comprehensive dataset limit precise estimates of biochar production potential and global carbon sequestration capacity (Karan *et al*., 2023). On a global scale, biochar’s contributions to mitigating climate change extend beyond soil fertility and carbon storage. With rising CO_2 levels and significant emissions from agricultural activities, biochar application offers a scalable solution for reducing methane and nitrous oxide emissions (Salma *et al*., 2024).

Materials and Methods

1. Biochar Production

Biochar was produced through the pyrolysis of agricultural residues, specifically from pigeon pea stalks (PPS), in a [specify type, e.g., batch or continuous] pyrolysis reactor (Venkatesh*et al*., 2022). The pyrolysis was conducted under oxygen-limited conditions at varying temperatures ranging from [specify temperature range, e.g., 400-600°C], with a residence time of [specify duration, e.g., 1-3 hours] to optimize carbonization.

2. Carbon Sequestration Assessment

The potential for carbon sequestration was evaluated through soil organic carbon (SOC) measurements taken at multiple time points following biochar application (Kumara *et al*., 2023). SOC was quantified using [specify method, e.g., combustion method] to ascertain the stability and persistence of biochar-derived carbon in the soil.

3. Life Cycle Assessment and Carbon Trading Analysis

LCA results were integrated with economic analyses to explore the potential for carbon trading. The potential carbon credits generated through biochar application were calculated based on [specify method, e.g., carbon accounting frameworks or market standards], emphasizing the economic feasibility of integrating biochar into carbon trading markets (Xia *et al*., 2021).

Results and discussion

1. Soil carbon pools & sequestration and Carbon footprint (Singh *et al*., 2023)

Potentially, soil C pool can be divided into two major parts; active or labile carbon (LC) pool and passive or non-labile carbon (NLC) pool. The data depicted in Fig. 2 indicating highest active C pool under BC after two years of RWCS followed by RI and NR. Similarly, passive C pool was also reported maximum with BC (1.25%) being significantly higher over both RI and NR. The effect of nitrogen management practices on both active and passive C pool was non-significant.

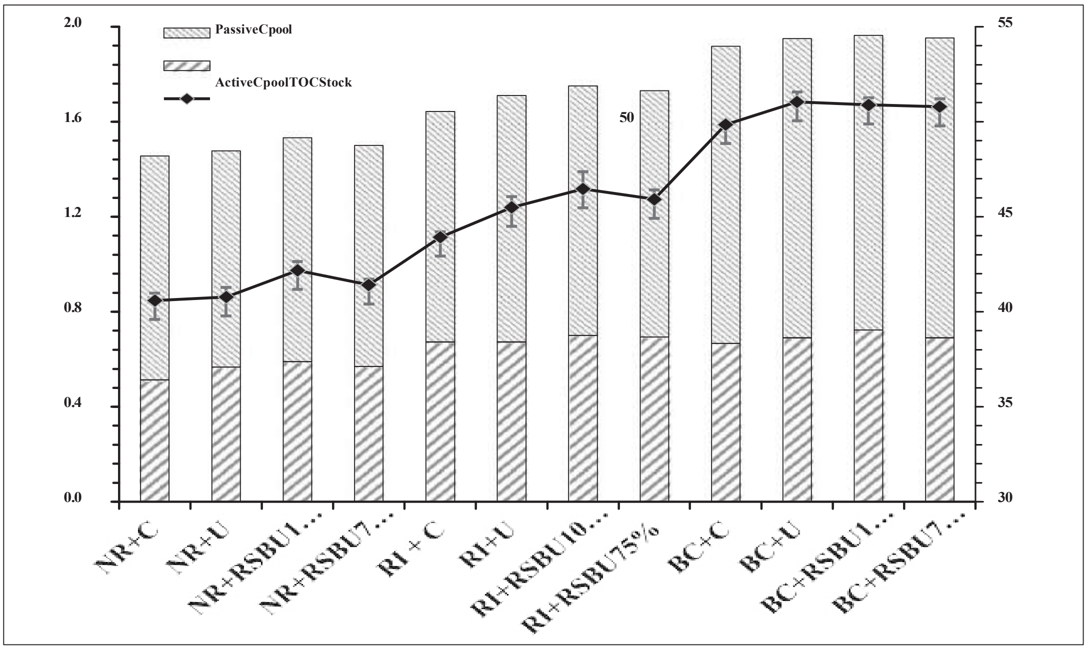

Fig.1. Effect of different residue and nitrogen management practices on active &passive C pool and sequestration under rice-wheat system

Note: NET – Negative Emission Technology, BECCS – Bioenergy with Carbon Capture and Storage, DAC – Direct Air Capture, EW – Enhanced Weathering, AR – Afforestation and Reforestation, SCS – Soil Carbon Sequestration

were higher than RI and NR treatments. The levels of soil present stock in soil are the key determinant of soil quality and its overall potential for sustainable land use under different production systems. The residue management in combination with nitrogen management practices significantly influenced the TOC stock (Fig. 2). The residue recycling through BC and RI increased soil C stock by 22.82% and 10.21%, respectively over NR. The effect of nitrogen management practices on SOC sequestration (SOC stock) was significant while non-significant on TOC stock after two years of RWCS. The soil C stock under all the nitrogen treatments in combination with biochar was increased over both RI and NR treatments.

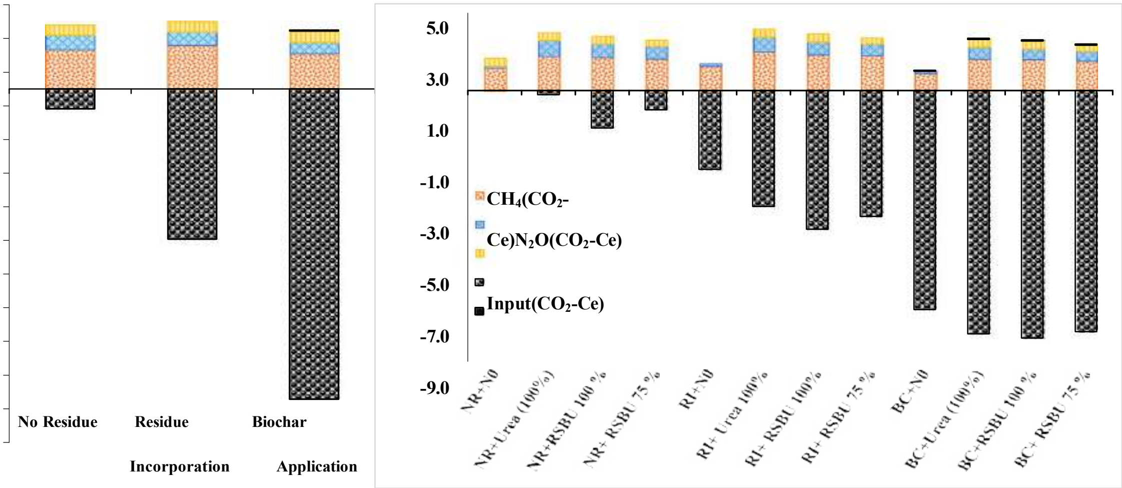

Fig.2. Annual carbon footprint of (A) nitrogen management practices through SRNFs in combination with residue management practices and (B) residue management practices alone under rice-wheat system

Note: NET – Negative Emission Technology, BECCS – Bioenergy with Carbon Capture and Storage, DAC – Direct Air Capture, EW – Enhanced Weathering, AR – Afforestation and Reforestation, SCS – Soil Carbon Sequestration

After two years of RWCS, the carbon footprint (CF) was calculated for residue and nitrogen management practices (Fig.3) considering production inputs (fertilizer, irrigation, soil preparation, pesticides, tillage, and manpower), biochar production, GWP as carbon source while soil C sequestration as sink. The data depicted in Fig. 3a showed positive CF under NR due to higher emissions and poor carbon buildup. Net negative CF recorded with BC (−14.91 t CO_2-Ce ha^{-1}) was nearly thrice than the CF under RI (−4.91 t CO_2-Ce ha^{-1}). The source: sink ratio under NR, RI and RSB were 1:0.31, 1:2.23 and 1:5.25, respectively reflecting higher soil C sequestration potential under biochar. Among the different nitrogen management practices carbon footprint was maximum with Urea 100% followed by RSBU 100% under and RSBU 75% in combination with all the residue treatments (Fig.3b). The CF with of all the nitrogen management practices under NR was reported to be higher than RI and biochar application. Whereas the soil C sequestration or net negative CF was considerably increased under all the nitrogen treatments in combination with biochar application.

Conclusion

Integration of biochar production, carbon sequestration, and carbon trading offers a robust framework for advancing carbon-neutral farming and enhancing agricultural sustainability. Biochar has demonstrated significant potential to reduce greenhouse gas (GHG) emissions and enhance carbon sequestration, positioning it as a critical tool in combating climate change. Its ability to remain stable in the soil for long periods is pivotal for achieving effective climate mitigation. Long-term studies are essential to understand the full extent of biochar's carbon accrual and its long-lasting impacts on soil health and fertility. Both biochar and soil carbon sequestration (SCS) exhibit considerable negative emission potential, with lower impacts on land and water use compared to conventional agricultural practices. However, current integrated assessment models (IAMs) often overlook these strategies, necessitating advocacy for their inclusion.

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PP: 17 Influence of various crop residue biochars on soil carbon pools and yield of watermelon in lateritic soils of Konkan

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Abstract: The study on “Effect of various crop residue biochar on soil carbon pools and yield of watermelon inlateritic soils of Konkan” conducted at the College of Horticulture, Dapoli, during the Rabi season 2022focused on the impact of three biochars rice husk biochar (RHB), coconut husk biochar (CHB), and arecanut husk biochar (AHB) on soil carbon pools under watermelon crop in Alfisols of Konkan. Fourteen treatments combining two biochar levels (2, 4 ton ha^{-1}) and two levels of recommended dose of fertilizers (100% and 75%) were xamined usingarandomized block design with three replications. The experimental soil was sandy loam, moderately acidic with high organic carbon, medium nitrogen availability, low phosphorus availability, and elevated potassium content. Biochar enhanced soil carbon pools, including organic carbon, water-soluble carbon, labile carbon, microbial biomass carbon, inorganic carbon, and total carbon, at different watermelon growth stages and yield of watermelon.

Keywords : Biochar, carbon pools,watermelon, Konkan etc.

Introduction

Intensification of production systems has led to deterioration of soil quality in several cases. Soil quality plays a key role in determining production capacity any cropping system. The decreased level of organic matter causes a strong reduction in soil fertility. Crop residue generally creates management problems to the farmers at farm. Abundantly available crop residues are existing in huge quantities. These residues are either partially utilized or unutilized due to various constrain. Burning of crop residues causes environmental pollution, is hazardous to human health, produces greenhouse gases causing global warming and results in loss of plant nutrients like N, P, K and S.

Konkan region of Maharashtra is abundant with the biomass of the fruit crops and cereals. Soils of Ratnagiri and sindhudurga districts are lateritic types. This large amount of biomass can be efficiently used for maintaining the soil health and soil quality, by converting it into soil amendments through the process of pyrolysis.

Use of biochar in Agril system is a viable option that can reduce farm waste and improve the soil quality and soil productivity.

Crop residue management is a pressing issue in agriculture, with woody plant debris posingcomposting challenges. Instead, farmers often resortto burning, releasing greenhouse gasesand losing valuable biomass. In India, converting millions of tons of unused crop leftovers intobiochar could address this issue, providing a sustainable soil amendment to enhance carbon contentand fertility. Modern agriculture's reliance oninorganic fertilizershasnegativelyimpacted soil fertility and carbon pools. The integration of organic sources, especially biochar,is recognized as a key strategy for maintaining soil quality and fertility. Biochar, with its large surface area and microspores, aidsnutrientretention, servesasahabitat for beneficial microbes, and promotes organic carbon storagein soil, contributing to improved soil health and carbon sequestration. Biochar, a solid carbon-rich material derived from biomass through pyrolysis in oxygen-limited conditions, holds promise as a solution to agricultural challenges. The controlled pyrolysis process converts organic waste from forestry and agriculture into biochar, resembling charcoal and offering analternative to crop burningin India. The production of biochar is influenced by factors such as processing temperature, heating rate, reactor pressure, and biomass composition. The potential of biochars extends beyond soil enhancement, asitisstudied for its roleincombating climatechange, promoting water conservation, enabling renewable energy production, and serving as a component for sustainable agriculture. With its multifaceted benefits, biochar emerges as a valuable asset in addressing agricultural and environmental challenges. Watermelon, a key cucurbitcrop prevalent in India and tropical and subtropical regions, originated in Africa. Requiring temperatures above 25 °C to thrive, its fruit, known as a pepo,is highly nutritious. Lycopene, a major carotenoid, reduces the risk of cardiovascular diseases. Phytochemicals present in watermelon contribute to its health benefits, showcasing anti-cancer and antioxidant characteristics.

Materials and Methods

A field trial was undertaken at the College of Horticulture, Dapoli, during *Rabi* season 2022 and analytical work was done at the PG laboratory of Department of Soil Science and Agricultural Chemistry and instant facilities were available from Central Instrumentation Centre (CIC), Department of Soil Science and Agricultural Chemistry.

During the investigation, three various biochars such as ricehusk biochar (RHB), coconut husk biochar (CHB) and are canuthusk biochar (AHB)wereprepared. In experiment 14 treatments in which a combination of two different levels of these biochars (2 and 4 t ha^{-1}) and two levels of RDF (100%and 75%) laid in RBD design with three replications werestudied. The treatment details were T1- RDF (150:50:50) N:P2O5: K2O kg ha^{-1}, T2 -100% RDF + CHB (2 ton ha^{-1}), T3-75% RDF + CHB (2 ton ha^{-1}), T4 -100% RDF + CHB (4 tonha^{-1}), T5-75% RDF + CHB (4 ton ha^{-1}), T6- 100% RDF +RHB (2 ton ha^{-1}), T7-75% RDF + RHB (2 ton ha^{-1}), T8-100% RDF + RHB (4 ton ha^{-1}), T9 -75% RDF + RHB (4 tonha^{-1}), T10-100% RDF + AHB (2 ton ha^{-1}), T11-75% RDF +AHB(2tonha^{-1}),T12-100%RDF+AHB(4tonha^{-1}),T13-75% RDF + AHB (4 ton ha^{-1}), T14-Absolute control (RHB-Ricehusk biochar,CHB-Coconuthuskbiochar,AHB-Arecanuthuskbiochar)andFYM@15tonha^{-1}appliedto all treatments. Weigh to feach fruit was taken and fruit yield per kg was calculated during harvesting. Characterization of biochars was done which recorded the alkaline pH of biochars RHB (9.34), CHB (9.05) and AHB (9.38) and electrical conductivity about 0.321dSm^{-1}in RHB, 0.143dSm^{-1}in CHB and 0.289dSm^{-1}in AHB. The total carbon content found in biochars was 83.54% (RHB), 74.50% (CHB) and 80.20% (AHB). Similarly, nitrogen, phosphorus and potassium percentages found in biochars were RHB (0.182%, 0.153%, 0.15%), CHB (0.156%, 0.077%, 0.13%) and AHB (0.166%, 0.103%, 0.14%) respectively. The experimental soil was sandy loamintexture, moderately acidic in nature, very high level of organic carbon, medium in nitrogen availability, low in phosphorus availability and high content of potassium in soil making ideal for watermelon cultivation. Ayeshavariety of watermelon was used for investigation. Methodology used for analysis of soil carbon poolsare as given in Table 1.

Table1: Methodology used for soil carbon pools

Sr.No.	Soil Carbon Pools	Method	Reference
1.	Soil organic carbon	Walkleyand Black's Wetoxidation method	Jackson(1973) [2]
2.	Water Soluble Carbon (WSC)	0.1NK2Cr2O7andH2SO4method	Chio *et al.*(1986)[1]
3.	Soil Inorganic Carbon(SIC)	Drycombustion method	Tiessenand Moir,(1993)[3]
4.	Labile Carbon (LC)	H2SO4Method	Chan *et al.* (2001)[4]
5.	Soil Total Carbon (TC)	Drycombustion method	Tiessenand Moir,(1993)[3]
6.	Microbial biomass carbon	Chloro form fumigation method	Vance*etal.*(1987)[5].

Results and Discussion

The results of the influence of various crop residue biochar on soil carbon pools i.e., soil organic carbon (OC), water soluble carbon (WSC), labile carbon (LC), microbial biomass carbon (MBC),in organiccarbon (IC) and total carbon (TC) atharvestunderwatermeloncroppresentedinTableNo.2and3.

The changes in soil organic carbon of soil were due to the influence of different levels of recommended dose of fertilizers with various cropr esidue biochar. The result srevealed that anincreasing rate of biochars application influenced soil organic carbonconsiderably. Soilorganiccarbon ranged from

14.11 to 17.16 g kg^{-1} at harvest. During the harveststage, the maximum organic carbonvalue was 17.16 g kg^{-1}in treatment T8, which comprised100% RDFwith 4 t ha^{-1} of RHB. This value was on parwith treatmentsT4containing 100% RDF+ 4tha^{-1} of CHB) at 16.80 g kg^{-1},T5 containing 75% RDF + 4 t ha^{-1} of CHB at 15.93 g kg^{-1}, T9consisting 75% RDF + 4 t ha^{-1} of (RHB) at 16.49 g kg^{-1}, T12containing 100% RDF + 4 t ha^{-1} of AHB at 16.97 g kg^{-1}, andT13consisting75%RDFwith4tha^{-1}ofarecanuthuskbiochar (AHB) at 16.34 g kg^{-1}. The lowest organic carbonvalue at harvest was 14.11 g kg^{-1}, found in treatment T14, which served as the absolute control.

Application of biocharand FYM along with in organic fertilizers significantly improved soil organic carbon content. After the addition of biochar, organic carbon fractions within the soil also increased significantly. The increase in carbon fractions might be due to the application of biochar, RDF along with FYM and native soil organic matter status of soil(Shilpa,2019)[8]. Increase in soil organic carbon was observed might be due to the placement of biochar directly with the raised beds where the root rhizosphere ecology was in fluenced. Water soluble carbon affected positively by application of biochar, RDF and FYM. Application of 100% RDF alongwith 4 t ha^{-1} of rice husk biochar (T8) resulted in a higherwater-soluble carbon (WSC) content and it was at par withtreatments T4 (100% RDF + 4 t ha^{-1} of coconut husk biochar)at 81.82 mg kg^{-1}, T5 receiving 75% RDF + 4 t ha^{-1} of coconut husk biochars (CHB)at 80.62mgkg^{-1},T9consisting 75% RDF+ 4 t ha^{-1} of rice husk biochar (RHB) at 81.58 mg kg^{-1}, T12containing100%RDF+4tha^{-1}of arecanut husk biochar (AHB) at 81.96mgkg^{-1},andT13receiving 75%RDF+4tha^{-1}of arecanut husk biochars AHB at 80.63mgkg^{-1}.WSCranged from54.85mgkg^{-1}to80.85mgkg^{-1}atharvestand lowest WSC at 53.76 mg kg^{-1} found in absolute control. WSC is considered as the most sensitive indicator of labile organic matter and carbon within the soil. As the organic carbon improved it led to an increase in water soluble carbon which might be due to more carbon added into the soil and there was a conversion of organic carbon from one form to another formby the processes of decomposition, microbial transformationas well as enzymatic transformation. Sandhu *et al.*, (2017) [7]recorded application of corn stover biochar@ 10mg ha^{-1}increased WSC. Labile carbon pool significantly affectedby applicationofbiochar. The highest labile carbon (351.98 mg kg^{-1}) was foundin treatment T8 receiving 100% RDF along with 4 t ha^{-1} RHB at harvest stage. But statistically treatment T8 receiving 100%RDFalongwith4tha^{-1}RHB was found at parwith T4 (348.75 mg kg^{-1}) and T12 (353.05 mg kg^{-1}) treatments in which4 ton of CHB and RHB with 100 percent RDF was applied respectively. Labile carbon was also a sensitive indicator of soil quality. Labile carbon has a rapid turnover rate and it is sensitive to microbial attack, easily oxidisable and sensitive tochanges occurring in soil organic carbon. Application of biochar, FYM and inorganic fertilizers showed significantly higher labile carbon than control. This might be due to higher labile compounds being added by biochars rates into the soil (Tirol *et al.* 2004) [10]. Arun Kumar *et al.*, (2019) [9] found labile carbon was positively affected by the application of biochar. Biochar application improved microbial population which leads to improvement in MBC. Application of Treatment T8,which received 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB), exhibited higher microbial biomass carbon (279.88 mg kg^{-1}) and was at part otreatmentsT4,whichconsistedof100%RDFwithcoconut husk biochar (CHB) at 4 t ha^{-1} (268 mg kg^{-1}), T9containing 75% RDF with RHB at 4 t ha^{-1} (266.92 mg kg^{-1}),and T12receiving 100% RDF with areca nut husk biochars (AHB) at 4 t ha^{-1} (274.18 mg kg^{-1}). The absolute control, represented by treatment T14, showed the lowest value of microbial lbiomass carbon (200.55mgkg^{-1})attheharveststage. Microbial biomass carbon (MBC) measures biologicalactivity and carbon contained in living components of soilorganic matter within the soil. In the present investigation, itwas found that due to a considerable increase in microbial population after addition of biocharinsoil as it improves chemical and physical properties within soil such as pH, CEC,porosity,waterholding capacity, and surface area which ledto increased MBC.Hale *et al.*,(2015)[11]concludedthatmicrobialbiomasscarboninsoilincreasesaftertheapplication of biochar which might be due to properties ofbiochar such as large surface area and high porosity which provide the best habit at formicrobes by maintainingwaterandair.Biocharitselfactsasagoodcarbonsourceforthe growth of microbes (Fowles2007)[6]. Soil inorganic carbon at harvest did not differ significantly. The highest value of soil in organic carbon was recorded about 1.56 g kg^{-1} at harvest of watermelon. The lowest value of soilinorganic carbon was recorded in treatment (T14) which was absolutecontroland foundtobe 1.22 gkg^{-1}.At the harvest of watermelon, the highest total carbon of soilwasrecorded(18.72gkg^{-1}) intreatment T8,which consistedof 100% recommended dose of fertilizer (RDF) along with 4 tha^{-1} of rice husk biochar (RHB). It was at par with treatmentsT4with 100%RDFand4tha^{-1}ofcoconuthusk biochar(CHB)(18.30g kg^{-1}),T5with 75% RDF and4tha^{-1}ofcoconut husk biochar (CHB)(17.39 g kg^{-1}), T9 with 75%RDFand4tha^{-1}ofricehuskbiochar(RHB)(17.97gkg^{-1}),T12with 100% RDF and 4 t ha^{-1} of areca nut husk biochar(AHB) (18.50 g kg^{-1}), and T13with 75% RDF and 4 t ha^{-1} ofareca nut husk biochar (AHB) (17.81 g kg^{-1}). The absolutecontrolshowedthe lowest total carbon (15.33gkg^{-1}) atharvest. Total carbon content in soil was significantlyincreased after the application of biochar and RDF along withFYM. There was a significant improvement in soil organiccarbon which led to an increase in TC. This might be due totheincreasedlevelofbiocharandRDFalongwithFYMwhich increased the carbon status in the soil which was due tothe high carbon content present in biochar. The functional group spresentin biochars such asphenolic and carbonyl carbon helped to adsorb organic compounds.

Table2:Effectofbiocharson soil carbon poolsunderwatermelon cropatharveststage

Tr.No.	Treatmentdetails	SoilOrganiccarbon (g kg^{-1})	aterSolubleCarbon(WSC) (mgkg^{-1})	LabileCarbon(LC)(mgkg^{-1})
T1	RDF(150:50:50) N:P2O5: K2O kgha^{-1})	14.16	60.23	279.33
T2	100%RDF+CHB(2tha^{-1})	15.54	70.51	326.54
T3	75%RDF +CHB (2t ha^{-1})	14.75	69.75	316.44
T4	100%RDF+ CHB(4tha^{-1})	16.80	81.82	348.75
T5	75%RDF+CHB (4tha^{-1})	15.93	80.62	338.47
T6	100%RDF+RHB(2tha^{-1})	15.73	72.73	334.15
T7	75%RDF+RHB (2tha^{-1})	15.23	70.59	323.33
T8	100%RDF+RHB(4tha^{-1})	17.16	82.24	358.22
T9	75%RDF+RHB (4tha^{-1})	16.49	81.58	346.00
T10	100%RDF+AHB(2t ha^{-1})	15.64	71.55	331.33
T11	75%RDF +AHB (2tha^{-1})	15.03	69.67	321.00
T12	100%RDF+AHB(4t ha^{-1})	16.97	81.96	353.05
T13	75%RDF+AHB (4tha^{-1})	16.34	80.63	342.00
T14	Absolutecontrol	14.11	53.76	268.81
	S.E. (±)	0.43	3.26	4.15
	CD(P=0.05)	1.25	9.46	12.05
InitialValues		14.00	52.11	270.01

Table3: Effectofvariousbiocharson soilcarbonpoolsunderwatermelon cropatharveststage

Tr.no.	Treatmentdetails	Microbialbiomasscarbon(MBC)(mgkg^{-1})	Soilinorganiccarbon(IC) (g kg^{-1})	TotalCarbon(TC)(g kg^{-1})
T1	RDF(150:50:50) N:P2O5: K2O kgha^{-1})	208.75	1.25	15.41
T2	100%RDF+CHB(2tha^{-1})	245.84	1.41	16.75
T3	75%RDF +CHB (2t ha^{-1})	223.05	1.35	16.10
T4	100%RDF+ CHB(4tha^{-1})	268.00	1.50	18.30
T5	75%RDF+CHB (4tha^{-1})	257.73	1.46	17.39
T6	100%RDF+RHB(2tha^{-1})	253.42	1.44	17.17
T7	75%RDF+RHB (2tha^{-1})	231.96	1.40	16.63
T8	100%RDF+ RHB (4tha^{-1})	279.88	1.56	18.72
T9	75%RDF+RHB (4tha^{-1})	266.92	1.48	17.97

T10	100%RDF+AHB(2t ha^{-1})	250.29	1.42	17.06
T11	75%RDF +AHB (2tha^{-1})	229.53	1.39	16.42
T12	100% RDF + AHB (4 t ha-1)	274.18	1.53	18.50
T13	75% RDF + AHB (4 t ha-1)	261.32	1.47	17.81
T14	Absolute control	200.55	1.22	15.33
	S.E. (±)	4.47	0.08	0.46
	CD (P=0.05)	13.00	NS	1.34
InitialValues		184.12	1.15	15.15

Yield of watermelon

The result revealed that treatment T8 containing 100% RDF +RHB4tha^{-1}recordedthehighestfruityield(48.85tha^{-1})This value was statistically at par to treatments T12 receiving100% RDF with AHB 4 t ha^{-1} (48.58 t ha^{-1}), T4containing100% RDF with CHB 4 t ha^{-1} (48.58 t ha^{-1}). T5containing75% RDF with 4 t ha^{-1} of coconut husk biochar (47.25 t ha^{-1}),T9consisting of 75% RDF with 4 t ha^{-1} of rice husk biochar(47.60 t ha^{-1}), T12 containing 100% RDF with 4 t ha^{-1} of arecanut husk biochar (48.58 t ha^{-1}), and T13comprising of 75%RDF with 4 t ha^{-1} of areca nut husk biochar (47.35 t ha^{-1}), while significantly exceedingremainingtreatments. The lowest fruit yield was observed in treatment (T14) absolutecontrol was (19.01 t ha^{-1}). The yield of crops depends on theproduction and mobilization of carbohydrates, intake of waterandnutrientsfromthesoil. It is alsoaffected by theenvironmentduringgrowth. Theapplicationofbiocharshowed an increase in fruit yield of watermelon as comparedto control. Itmay be due tointake of nutrients through acombinationofbiochar,FYMandinorganicfertilizers(Shilpa, 2019)[8].

Table4: Effectofvariouscropresiduebiocharonyield ofwatermelon

Tr.No.	Treatmentdetails	Fruityield(tha^{-1})
T1	RDF(150:50:50) N:P2O5: K2O kgha^{-1}	29.00
T2	100%RDF+CHB(2tha^{-1})	37.32
T3	75%RDF+CHB (2tha^{-1})	35.36
T4	100%RDF+CHB(4tha^{-1})	48.48
T5	75%RDF+CHB (4tha^{-1})	47.25
T6	100%RDF+RHB(2tha^{-1})	39.50
T7	75%RDF+RHB (2tha^{-1})	37.24
T8	100%RDF+RHB(4tha^{-1})	48.85
T9	75%RDF+RHB (4tha^{-1})	47.60
T10	100%RDF+AHB(2t ha^{-1})	38.30
T11	75%RDF +AHB (2tha^{-1})	36.48
T12	100%RDF+AHB(4t ha^{-1})	48.58
T13	75%RDF +AHB (4tha^{-1})	47.35
T14	Absolutecontrol	19.01
	S.E. (±)	0.68
	CD(P=0.05)	2.04

Conclusion

The application of variousrates of different biocharalong with ino rganic fertilizers recorded enhanced soil carbon pools aswell as yield of watermelon crop in lateritic soils of Konkan. It was concluded that application of 100% RDF along with RHB (4tha^{-1}) significantly improved soil carbon pools such assoilorganic carbon, soil total carbon, water soluble carbon, labilecarbon and microbial biomass carbon. Yield of watermelon crop also positively affected by biochar application. The application inorganic fertilizers combined with biochars which help to achieve multiple benefits of carbonsequestration, environment protection.

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PP: 18 Utilizing *Prosop is juliflora* Invasion as a Charcoal Feedstock to Enhance Livelihoods in Tribal Hamlets of Sathyamangalam Tiger Reserve, Tamil Nadu: A Successful Framework

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Abstract: This case study explores an innovative approach to improving the livelihoods of indigenous tribal communities within the Sathyamangalam Tiger Reserve (STR) in Tamil Nadu, India, by converting the invasive plant species *Prosopisjuliflora* into biochar. Effective removal of *P. juliflora* trees to improve Tiger reserve habitat parts like, BhavaniSagar range by Tamil Nadu Biodiversity Conservation and Greening Project (TBGP) funded by Japan International Co-operation Agency (JICA) from 2011-2012 to 2018-2019. The project highlights the dual objectives of addressing ecological issues related to the invasive *P. juliflora* and creating sustainable economic opportunities for tribal communities who traditionally rely on forest resources for their survival. Biochar production from *P. juliflora* biomass presents a promising solution to these intertwined challenges, offering both ecological and economic benefits to the STR and its inhabitants.

Introduction

The Sathyamangalam Tiger Reserve, part of the biodiversity-rich Western Ghats, is home to various indigenous communities whose livelihoods are intricately tied to the forest ecosystem. However, *P. juliflora*, introduced to India for soil stabilization and afforestation in arid regions, has become a significant environmental threat. Rapidly growing and highly competitive, *P. juliflora* outcompetes native flora, reducing biodiversity, disrupting local ecosystems, and limiting available resources for indigenous tribes (Maheshnaik*et al.,* 2018). Though invasive, *P. juliflora* is characterized by its high lignin and calorific content, which makes it an ideal candidate for biochar production. Biochar obtained useful for multiple beneficial applications, including soil enrichment, water retention, and carbon sequestration.

Wood as feedstock for charcoal

P. juliflora firewood is bulky and expensive to transport as it is a low value product. Conversion to charcoal reduces the weight and increase the energy and economic value of the product. Charcoal is consumed mostly in urban areas in restaurants, bakeries, small-scale iron works, and for parching and popping food grains like corn and rice for snacks. Charcoal is often produced at a considerable distance from the point of consumption. In the southern districts of Tamil Nadu, charcoal manufacturing from *P. juliflora* forms an integral part of daily activity of a large part of the rural population. Revenue earned from charcoal manufacture plays a vital role in rural livelihoods of these areas. To produce 1 kg charcoal, approximately 6-9 kg *P. juliflora* wood is required, depending on the method used.

Objectives

This study aims to assess the feasibility of biochar production from *P. juliflora* as a sustainable livelihood source for tribal communities within STR. Specifically, it evaluates the potential of biochar production to control the spread of *P. juliflora*, reduce carbon emissions through sequestration, enhance soil quality, and generate income for the local tribal population. Additionally, it examines the necessary processes and infrastructure, community training, and market opportunities required for successful biochar production.

Material and Methods

The methodology involved site selection, community engagement, and hands-on training in biochar production. Tribal hamlets within the STR were identified as pilot locations, and community meetings were held to discuss the economic and environmental benefits of biochar production. Partnerships were formed with local NGOs, forest authorities, and community organizations to ensure sustained engagement.

1. **Harvesting and Processing**: Tribal communities were guided in sustainable harvesting methods to prevent further spread of *P. juliflora*. Harvested wood was then pyrolyzed in small, low-cost kilns specially designed for remote, rural settings.
2. **Biochar Production and Training**: Portable pyrolysis units were introduced, and community members received training on operating and maintaining the kilns, emphasizing traditional methods adapted to produce high-quality biochar.
3. **Application and Evaluation**: The biochar produced was applied to local farmlands to test its impact on soil health and crop yield. Its chemical properties were analyzed to assess its suitability for various agricultural applications, including soil pH balancing, nutrient retention, and water management.
4. **Market and Economic Assessment**: A market analysis was conducted to identify potential buyers for biochar and related products. Training sessions included discussions on basic marketing, pricing, and customer outreach strategies to support the commercialization of biochar within and beyond local markets.

Results and Discussion

1. **Environmental Benefits**
    - **Control of *Prosopisjuliflora***: The project successfully demonstrated that converting *P. juliflora* into biochar not only controls the spread of this invasive species but also contributes to ecological restoration by removing biomass from the ecosystem.
    - **Carbon Sequestration**: Biochar production locks carbon into a stable form, contributing to carbon sequestration and offering a sustainable approach to offsetting carbon emissions within STR.
2. **Economic Impact on Tribal Communities**
    - **Income Generation**: Biochar production offered tribal communities an alternative income source. Initial sales of biochar products, including briquettes and soil amendments, revealed strong market interest both locally and regionally.
    - **Job Creation and Community Empowerment**: The biochar units created direct employment opportunities, particularly for women and young adults in the community, strengthening local economic resilience.
3. **Agricultural Benefits**
    - **Soil Quality Improvement**: Application of biochar significantly improved soil structure and nutrient retention, leading to better crop yields. Additionally, biochar’s ability to maintain soil moisture levels reduced irrigation requirements, which is particularly valuable in the semi-arid conditions of STR.
    - **Enhanced Crop Productivity**: Trials showed improved growth rates and productivity in crops cultivated on biochar-amended soils, benefiting local food security.

This case study demonstrates that biochar production from *P. juliflora* is both environmentally and economically viable for tribal communities in STR. By transforming a problem - *P. juliflora* invasion - into a resource, the project presents a holistic model for community development and ecological management (Sivakumar*et al.,* 2018). The initial training and market development provided the skills and infrastructure needed for local community members to manage biochar production independently. Moreover, partnerships with NGOs and governmental bodies have ensured that the project aligns with broader conservation and community livelihood improvement goals ((Maheshnaik*et al.,* 2023; Ramasubramanian S and Officer, 2010).

Challenges and Limitations

While promising, the project encountered several challenges, including:

- **Initial Investment**: Although pyrolysis units are relatively low-cost, initial funding was required. Support from NGOs and government programs was essential to cover these initial expenses.
- **Market Development**: Establishing a stable market for biochar products was challenging. Local demand was strong, but consistent sales required broader awareness and acceptance of biochar products.
- **Sustained Training Needs**: Continued technical and business training is essential to maintain production quality and community engagement, ensuring that biochar production remains sustainable and profitable.

Recommendations

For future expansion, the study recommends:

1. **Capacity Building**: Continuous training programs are needed to build community skills in production and marketing.
2. **Policy Support**: Government incentives and grants could accelerate the adoption of biochar production, helping more tribal communities to replicate this model.
3. **Market Development Initiatives**: To ensure steady demand, partnerships with agro-industries and local agricultural agencies should be strengthened.
4. **Entreprenerd opportunities:** Vast opportunities are available for start-ups and cottage industries in the *P. juliflora* value added products like biomass power, briquette making, charcoal, biochar, activated carbon, wood gasification, cut wood market and Prosopis gum.

Conclusion

This case study illustrates the potential of biochar production from *P. juliflora* as a transformative approach for tribal communities in the Sathyamangalam Tiger Reserve. The project offers a dual benefit by converting an ecological challenge into a sustainable livelihood solution, providing tribal communities with a source of income while supporting environmental conservation. With adequate support in training, market development, and policy alignment, biochar production from *P. juliflora* could become a scalable, sustainable model for community-based resource management in similar forested and semi-arid regions.

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PP: 19 Enhancing rice defense: Biochar soil amendment and its role in induced resistance against yellow stem borer, *Scirpophagaincertulas* Walker

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Abstract: The impact of biochar on rice variety TN-1 and its induced resistance against yellow stem borer (YSB) was studied at the Agricultural Research Station, Gangavathi, in 2021. Results showed that 8% biochar significantly enhanced plant growth parameters, including height, tillers, and chlorophyll levels, while reducing YSB infestation. Biochar-treated plants exhibited prolonged larval development, higher larval mortality, and increased resistance due to elevated phenol and tannin content. The study also observed increased enzyme activity (peroxidase, catalase, and SOD) and nutrient levels, highlighting biochar's potential for improved plant growth and pest resistance.

Introduction

Over 1,400 insect species attack rice, with 20 being major pests in India. The yellow stem borer (YSB) is the most destructive, causing up to 87.66% yield loss if left uncontrolled. Its resistance to insecticides highlights the need for alternative methods like biochar, a carbon-rich material derived from organic matter, which improves soil health and may reduce pest damage. Biochar's role in enhancing plant defenses against pests, particularly YSB, is promising, but limited research exists on its effects on chewing insect pests. This study explores biochar's potential in boosting rice resistance biochemically.

Materials and Methods

The investigation was conducted at the Agricultural Research Station, Gangavathi, Karnataka, India, during 2021-22. Commercial biochar was added to soil at concentrations of 0%, 2%, 4%, 6%, 8%, and 10%, with the TN-1 rice variety planted in pots. Yellow stem borer (YSB) larvae were released on the plants to assess the effects of biochar on plant growth, pest damage, and biochemical changes. Plant height, tiller number, stem diameter, and trichome density were measured, along with larval development time, mortality, and fecundity. Soil nutrients and biochemical parameters like phenols, tannins, proteins, and enzymes were analysed to understand biochar's role in enhancing resistance against YSB.

Results and Discussion

The study revealed that biochar significantly improved rice plant growth parameters, with 8% biochar (T4) yielding the best results. Plant height increased to 67.02 cm by 60 days after transplanting (DAT), and tiller count reached 11.03 per hill. Stem diameter peaked at 0.98 cm, trichome density at 90.17 trichomes/cm², and SPAD chlorophyll values at 61.83. Biochar also reduced yellow stem borer damage, with the lowest dead heart percentage (1.10% at 20 DAT) and minimal stem tunnelling (6.03 cm). Additionally, larval development was delayed, mortality increased, and biochemical defenses like phenol, tannin, and lignin content were enhanced.

This study explored the effects of biochar on rice growth and resistance to the yellow stem borer (YSB). Biochar enhanced plant height, tiller number, stem diameter, and leaf chlorophyll content, linked to increased nutrient availability. The high silicon content in biochar boosted trichome density, reduced stem borer damage, and prolonged larval development time, while increasing larval mortality (Ashrith*et al.*, 2020 and Ahmad *et al.*, 2019). Biochemical changes, including elevated phenol, tannin, and protein levels, were observed, further strengthening plant defenses (Abbas *et al.,* 2017; Yang *et al.*, 2017 and Li *et al.*, 2007).

However, excessive biochar raised soil alkalinity, potentially limiting nutrient absorption. Overall, biochar improved plant resilience and nutrient uptake but requires careful management for optimal results.

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PP: 20 Perception of Farmers towards Sugarcane Residue Management and the Potential of Biochar Production as a Sustainable Solution

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Abstract: The present study was conducted in Belagavi and Bagalkot districts of Karnataka during 2022-23 by employing *Ex-post facto* research design and simple random sampling technique constituting a total sample size of 120 sugarcane farmers. The perception index was highest for ‘residue burning facilitates land preparation and planting in time’ (84.67). Traditional residue management practices, particularly open burning, lead to environmental degradation, air pollution, and loss of valuable nutrients. In contrast, biochar production, which involves the pyrolysis of sugarcane residue into a stable carbon-rich substance, has emerged as a promising, sustainable alternative.

Introduction

A wide variety of crops are grown on a large portion of the land in India's many agroecological regions, and a sizable amount of agricultural residue is left in the field after harvest. The materials that are left in the agriculture field after the harvest of the crop are known as crop residues. The residue includes stalks, leaves, stems, seedpods, etc. Sugarcane (*Saccharumofficinarum L.*) is the country's most important commercial crop. It is one of the most valuable cash crops. Around 12 Mt of sugarcane residue is generated annually in India. One hectare of sugarcane typically produces ten tonnes of residue. Traditionally, the residue is burnt in-situ which results in nutrient loss, organic carbon depletion, and greenhouse gas emissions.Experts have recommended various methods of sugarcane residue management such as bedding materials for animals, livestock feed, soil mulch, bio manure and compost production and biochar production etc. However, recent studies have shown that converting sugarcane residues into biochar through pyrolysis can be a more sustainable alternative. Hence the present study was conducted to understand the perception of sugarcane farmers towards residue management and biochar production.

Material and Methods

The study was conducted in Belagavi and Bagalkot districts of Karnataka during 2022-23, using an Ex-post facto research design and simple random sampling. Total sample size was 120 sugarcane farmers. Data was collected through personal interview using a pre-tested schedule. Perception scale developed by Choudhary (2022) was used to measure the variable. To know the awareness among the farmers about biochar from the farmer’s point of view, a list of statements was prepared after extensive review of literature, consulting scientists and based on experience gained during pre-testing in non-sample area.

Results and Discussion

The perception index was highest for ‘residue burning facilitates land preparation and planting in time’ (84.67), this perception suggested that some sugarcane growers believe that burning crop residues before planting helps clear the fields quickly. It was noticed that ‘high price of machinery used for crop residue management’ had the perception index of 84.33, indicated that farmers are concerned about the cost of machinery required for effective crop residue management (CRM). This could be a barrier as majority of the sugarcane growers are small and medium farmers who might find it challenging to invest in expensive equipment. Majority of them perceived that ‘crop residue management is time consuming practice and labour intensive’ (83.67) as shortage of labour resources was main concern. However, the perception index for ‘loose residue creates a micro-environment to pathogen infection in the field’ was 62.50, sugarcane growers perceived that leaving crop residues on the field could foster conditions conducive to the growth and spread of plant pathogens which may affect the next crop yield. ‘Lack of knowledge about modern techniques of crop residue management practices’ (47.67), some sugarcane growers perceived that they are not aware about the various techniques of crop residue management. This gap in knowledge is due to the continuation of traditional practices or a reliance on familiar methods.

Awareness level of the farmers about biochar

An insight into the Table 1 indicated that 25.00 per cent of the farmers having heard of biochar as a method for managing agricultural waste, indicating a basic level of awareness about the term and its potential applications in agriculture. Further 15.83 per cent of the farmers were aware of the potential benefits of biochar in improving soil fertility and increasing crop yields. Very few (5.00%) of the farmers knew about where to purchase biochar indicates a significant barrier to adoption. Even if farmers are aware of the potential benefits of biochar, their ability to access it remains a major challenge. This could be due to a lack of local suppliers, high costs, or logistical barriers in rural areas. Additionally, it suggests that biochar is not yet integrated into the broader agricultural supply chains in the region, limiting its accessibility.On a more positive note, 22.50 per cent of the farmers expressed interest in learning more about how to produce and use biochar. This indicated a significant potential for increasing adoption if targeted education and training programs were introduced.

Table 1. Awareness level of the farmers about biochar
(n=120)

Statement	f	%
I have heard of biochar as a method for managing agricultural waste.	30	25
I am aware that biochar can improve soil fertility and increase crop yields.	19	15.83
I know where I can obtain or purchase biochar for use in my farming practices.	6	5
I would be interested in learning more about how to produce and use biochar.	27	22.50

Conclusion

The perception of farmers toward sugarcane residue management is influenced by a combination of environmental, economic, and social factors. However, given the numerous benefits of this technology as well as to reduce the ill effects of crop residue burning, it is crucial to raise awareness among sugarcane growers about the different residue management practices.While, biochar offers significant benefits for soil health and climate change mitigation, its adoption is constrained by lack of knowledge, high initial costs, lack of technical expertise, and market uncertainty. To promote the widespread use of biochar as a sustainable residue management solution, it is essential to provide targeted training, financial incentives, and access to biochar markets. Policymakers and agricultural institutions must work closely with farmers to overcome these barriers and highlight the long-term benefits of biochar for both the environment and farm productivity.

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PP: 21 Biochar Composite Fertilizers for sustainable agriculture: an overview

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Abstract: Increasing food demand, loss of applied fertilizers and declining soil productivity necessitate excessive chemical fertilizer use, which is uneconomical and harms soil biota. Application of biochar, a carbon-rich product derived from thermal decomposition of organic materials under controlled oxygen (pyrolysis), restores soil organic carbon thereby improves soil health. Biochar composite fertilizers improve soil physical properties, nutrient use efficiency along with carbon sequesteration. BCFs are produced via pre- or post-pyrolysis treatment, with the latter being more common. Post-pyrolysis involves physicochemical techniques like mixing, coating, microwave processing and infiltration. BCFs offer great potential for enhancing soil fertility, boosting yields and minimizing environmental impact.

Key words: Soil health, organic carbon, carbon sequesteration, nutrient use efficiency

Introduction

Fertilizers use inefficiency, evidenced by leaching, volatilization losses from fertilized farmlands, necessitates higher fertilizer applications to meet crop demands. However, excessive use of fertilizers, notably urea, leads to environmental impacts.Biochar, with its high porosity and specific surface area, is well-known for enhancing nutrient retention in soil and improving crop nutrient utilization. Therefore, exploring the potential of fertilizer-enriched biochar to reduce reliance on conventional fertilizers is crucial.

Materials and Methods

Preparation of biochar- blended urea

BU was prepared from urea blended with maize biochar and organo- mineral binders. First, the urea-biochar mixture and the bentonite-carboxy methyl cellulose sodium mixture were thoroughly homogenized separately. Then, these mixtures were combined, and during pelleting in a disc granulator, wood vinegar diluted 200 times was sprayed onto the granules to moisten them. The mixture was pelleted to form aggregated pellets, with sepiolite added to the initial particles, continuing granulation for about 1 hour. Finally, wood vinegar diluted 100 times was sprayed, and chitosan was applied as a coating before drying the pellets at 60 °C for 3 hours (Shi *et al*., 2019).

Field experiment design

The field experiment was carried out on a farm located in Kangbo village (31°35′N, 120°55′E), Gulitownship, Changshu municipality, Jiangsu, China. In the study, Conventional Urea (CU) and Biochar Urea (BU) were tested at two levels of N supply for wheat. Form of urea (CU vs. BU) was taken as the primary factor, while the N application rate (conventionally high level vs. reduced level) was considered a secondary factor. The five treatments included a null (CK) without N fertilization, 265 kg N ha^{-1} of CU and BU (CU_{HN} and BU_{HN}, respectively) and 186 kg N ha^{-1} of CU and BU (CU_{LN} and BU_{LN}, respectively).Each treatment was performed in four replicates and the 20 treatment plots were arranged in a randomized block design.

Results and Discussion

Grain yield

It was observed that the total biomass and grain yield were both higher under the CU and BU treatments compared with CK. The grain yield was 6.37 t $ha^{-1}$and 7.06t ha^{-1} at HN for CU and BU respectively, 5.25t ha^{-1} and 6.79 t ha^{-1} at LN for CU and BU respectively. BU significantly increased grain yield by 13% and 38%respectively, at HN and LN level in comparison with CU. Higher yields with BU may be due to continuous supply and higher uptake of N along with greater allocation of nutrient to the grains which was 19% and 55% respectively, at HN and LN level in comparison with CU.

Nutrient Use Efficiency

There was an increase in PFPN of 2.4 and 8.3 kg grain kg^{-1} N under BU compared with CU at the HN and LN rates, respectively. Similarly, a 13% and 38% increase in AEN was observed under BU compared with CU at the HN and LN levels, respectively(Fig. 1). Similar results were found with release-controlled urea by Zheng *et al*. (2016).

The increase in plant NUE with BC compared to CU may be attributed to reduced N losses, improved N plant uptake, a significant increase in grain N allocation helping protein synthesis in wheat grains further leading to yield improvement.

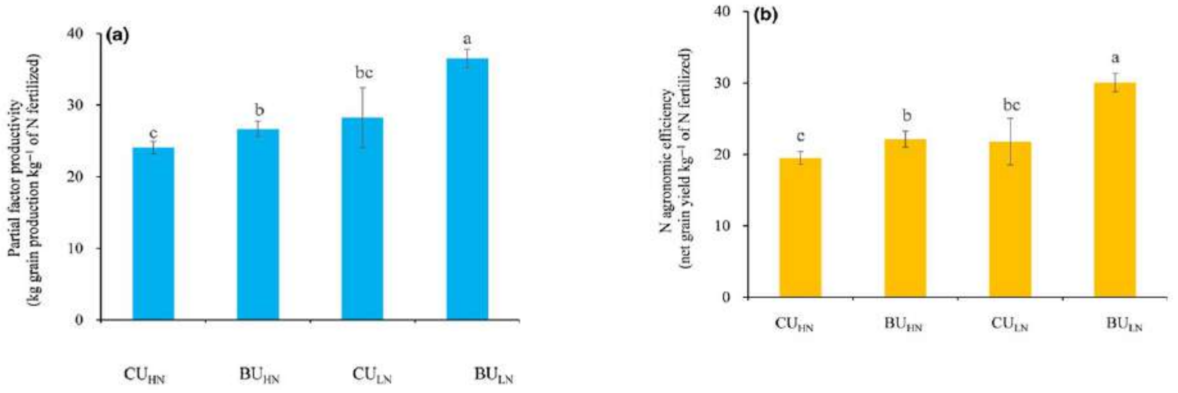

Fig.1. Partial factor productivity (a) and agronomic use efficiency (b) of N fertilization under the treatments.

Conclusion

It can be concluded that BU demonstrated a synergistic improvement in wheat productivity by 13% and 38% and plant N use by 2.4 and 8.3 kg grain kg^{-1} N over CU at HN and LN levels respectively.

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PP: 22 Characterization of Cotton Stalk Biocharin Comparison with Farm Yard Manure

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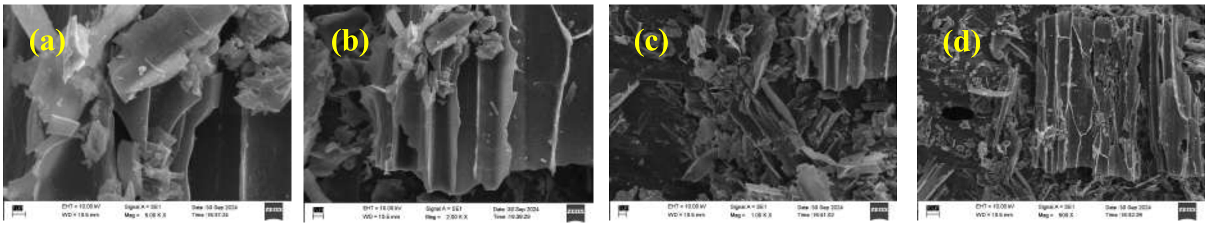
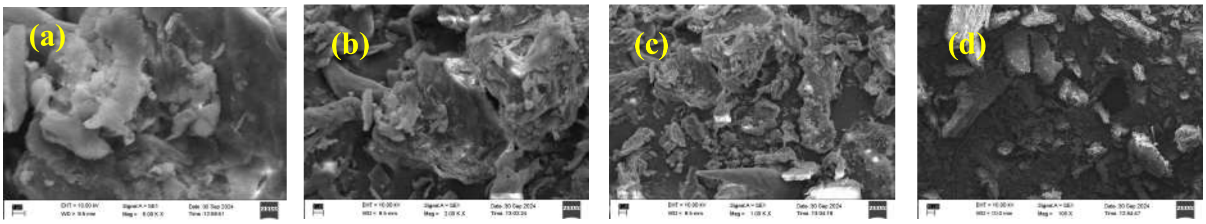
Abstract: Biochar produced from the cotton stalks through open pit pyrolysis method was characterized for various physico-chemical and biological properties and compared withthe Farm yard manure. The biochar exhibited superior properties, including higher porosity (70.13%), water holding capacity (231%) than FYM. Spectral analysis revealed biochar's complex carbon structure with different functional groups and higher stability that support nutrient retention when compared to FYM. Further, the surface morphology study revealed that biochar had thin sheet like structure with better-defined pores while FYM had irregular morphological surface area consisting of less number of pores. FYM offers rich microbial population, which contribute to organic matter decomposition and nutrient cycling. Although biochar lacks an inherent microbial community, it is presumed that it can support soil's native microflora due to its porous structure, water and nutrient retention when it is incorporated into the soil.

Key words: Biochar, Carbon, Characterization, FYM

Biochar produced from the cotton stalks through open pit burning method was characterized for various physico-chemical and biological properties and compared with the Farm Yard Manure which was collected from Farm Dairy unit of ARS, Bheemarayanagudi. The analysis data revealed distinct differences in their properties (Table 1). The biochar had lower densities when compared to FYM and thus possessed higher porosity (70.13%) than FYM (67.46%) which favours better soil aeration and reduced compaction in biochar amended soils. Further, the biochar had a maximum water holding capacity of 231%, which is far superior than FYM (193.4%). The property which supports better soil water retention and nutrient holding capacity, enhancing conditions for root growth and microbial activity in biochar amended soils.



Cotton stalkbiochar



Farm Yard Manure

Figure 1: Scanning electron microscope (SEM) imageof cotton stalk biochar and FYM samples

Further, figure 1, the surface morphology of biochar and FYM samples revealed that biochar had thin sheet like structure with best pores development and better-defined pores which more favourable in retention of nutrients and water (Sahoo *et al*. 2021) and pores size was small but number of pores was higher compared to FYM, the imaging was done at 5.00 K X (a), 2.00 K X (b) 1.00 K X (c) and 500 X (d) resolution time and with a scale of the image was 1 µm, 2 µm, 3 µm and 10 µm, respectively whereas in FYM had irregular morphological surface area which consisting of less number of pores, the imaging was done at 5.00 K X (a), 2.00 K X (b) 1.00 K X (c) and 100 X (d) resolution time and with a scale of the image was 1 µm, 2 µm, 3 µm and 30 µm, respectively (Zaitun*et al.*, 2022).

Table 1.Physico-chemical and biological properties and elemental composition of biochar and FYM

Parameters	Biochar	FYM
Physical Properties		
Bulk density (Mg M^{-3})	0.20	0.34
Particle density (Mg M^{-3})	0.68	1.07
Porosity (%)	70.13	67.46
MWHC (%)	231	193.4
Chemical properties and elemental composition		
pH (1:20; w/v)	9.05	6.65
EC (1:20; w/v, dS m^{-1})	2.50	0.94
Total Carbon (%)	63.55	16.82
Total Nitrogen (%)	1.12	0.90
Total Hydrogen (%)	1.74	2.61
Total Phosphorus (%)	0.23	0.18
Total Potassium (%)	0.52	0.42
Total Sulphur (%)	0.50	0.26
C/N Ratio	56.74	18.68
H/C Ratio	0.33	1.86
Total Zn (mg kg^{-1})	32.24	15.42
Total Fe (mg kg^{-1})	120.12	97.71
Total Mn(mg kg^{-1})	7.45	6.92
Total Cu (mg kg^{-1})	16.58	8.26
Biological properties		
Bacteria (No. ×10^{6} CFU g^{-1} soil)	-	5
Fungi (No. ×10^{3} CFU g^{-1} soil)	-	2
Actinomycetes (No. ×10^{4} CFU g^{-1} soil)	-	3

On the other hand, biochar has an alkaline pH (9.05) while FYM had near-neutral pH (6.65). Thus, biochar's alkaline nature stresses for being cautious to use it in already alkaline soils to prevent nutrient lock-out. On the contrary, it may be helpful to neutralize acidic soils and may improve nutrient availability in acidic conditions. However, biochar also has a higher electrical conductivity (EC, 2.50 dSm^{1}) when compared to FYM(0.94 dSm^{1}), indicating more soluble ions that could contribute to short-term nutrient availability but may pose issues in saline soils. The total carbon content of biochar (63.55%) is significantly higher than that of FYM (16.82%), making biochar an effective long-term soil carbon reservoir, enhancing soil organic carbon levels and promoting soil fertility over time. Though biochar has a higher nitrogen content (1.12% vs. 0.90% in FYM), which benefits immediate nitrogen availability, biochar's higher carbon-to-nitrogen (C/N) ratio (56.74 vs. 18.68 for FYM) and FYM higher H/C ratios (1.86 vs. 0.33 for biochar) it means biochar decomposes more slowly, releasing nutrients over a longer period. Additionally, biochar contains higher levels of phosphorus (0.23%) and potassium (0.52%) than FYM (0.18% phosphorus and 0.42% potassium), offering valuable sources of these essential nutrients. Sulfur content is also greater in biochar (0.50%) than in FYM (0.26%), which can support plant protein synthesis.

Biochar contains significantly higher levels of micronutrients Zn, Fe, Mn, and Cu (32.24, 120.12, 7.45 and 16.58 in biochar vs 15.42, 97.71, 6.92 and 8.26 in FYM) compared to FYM, which can contribute to improved soil fertility over the long term and which play roles in enzyme activation and plant metabolic processes.

The EDS spectrum shows that the biochar particles and FYM are enriched with variable composition of elements (weight %) such as C (76.85), O (19.05), Mg (1.64), Ca (2.46) and C (62.16), O (29.85), Si (4.71), Cu (3.29).The biochar had a peculiar characteristics which improving soil properties by supplying carbon, magnesium and calcium in higher quantity when compared to FYM.

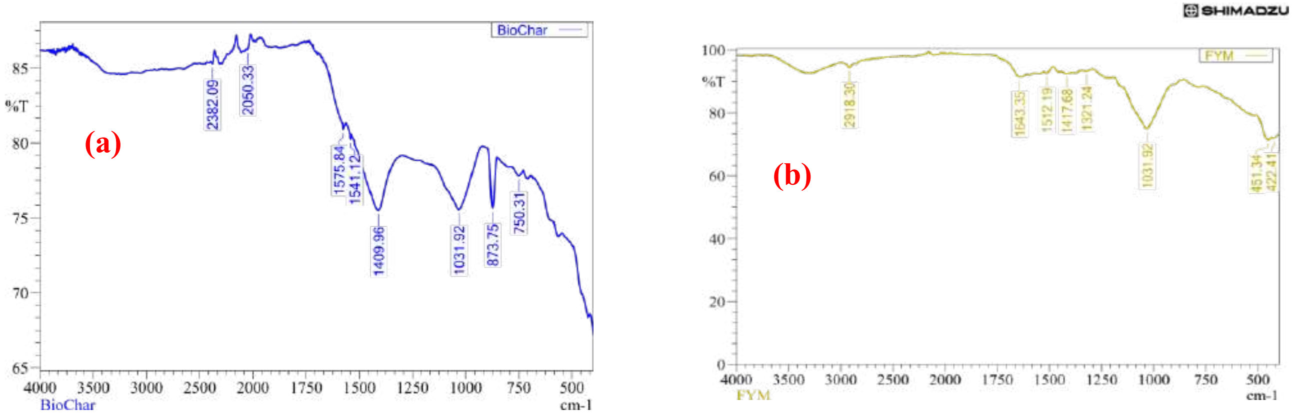


Figure 2: Fourier Transform Infrared Spectroscopy (a) Cotton stalkbiochar(b) Farm Yard Manure

The results of functional groups present in biochar and FYM analyzed from Fourier transform infrared spectroscopy (FTIR) are presented in Figure 2. The figure 2(a) indicates that the absorption peaks for cotton stalk biochar range from 750.31 to 2382.09 cm^{-1}. Notably, the bands between 750.3 and 873.75 cm^{-1} indicate the presence of free methyl groups (C-H) and alkaloids, suggesting a complex carbon structure, potentially enhancing the stability of biochar in soil. The peak at 1031.92 cm^{-1} may be attributed to alcohols, ethers, or C=O stretching, indicating functional groups that can facilitate soil microbial activity. Additional peaks, particularly at 1409.96 cm^{-1}, represent saturated ketones (C=O) and C-O-H bonds, which could enhance biochar's ability to retain nutrients. The presence of amides, alkenes, and alkynes (1541.12, 1575.84, 2050.33, and 2382.09 cm^{-1}) adds to its chemical complexity, suggesting that biochar can adsorb a variety of organic and inorganic compounds, making it a strong candidate for long-term soil amendment.

The figure 2(b) indicates that the FYM spectra, spanning 422.41 to 2918.30 cm^{-1}, display functional groups associated with organic materials that are important for nutrient cycling. Peaks at 1321.24 and 1417.68 cm^{-1} correspond to C-H and N-O stretching, implying the presence of nitrogen-containing compounds and aromatic rings, which are characteristic of organic matter decomposition. The peak at 1512.19 cm^{-1} indicates C=C stretching in aromatic rings, suggesting the presence of stable organic structures that could improve soil structure. A strong peak at 1031.92 cm^{-1}, associated with C-O and C-O-C stretching, indicates polysaccharides or cellulose, which could enhance soil aggregation. The peak at 1643.35 cm^{-1}, likely related to C=O stretching in amides or carboxylic acids, suggests the presence of protein decomposition products, beneficial for soil fertility. Finally, the peak at 2918.30 cm^{-1}, indicative of C-H stretching in aliphatic compounds, points to biodegradable organic matter that can improve microbial biomass in the soil.In comparison, cotton stalk biochar exhibits a more complex carbon structure with a variety of functional groups, making it more stable and effective for long-term soil carbon storage and nutrient retention than FYM (Viveket *al*., 2022).

Biologically, FYM offers a rich microbial population, including bacteria, fungi, and actinomycetes, which contribute to organic matter decomposition and nutrient cycling. Although biochar lacks an inherent microbial community, it can support soil's native microflora due to its porous structure, water and nutrient retention when it is incorporated into the soil.

It is concluded that the characterization of cotton stalk biochar and FYM samples showed distinct variations in physico-chemical and biological properties. Biochar possessed unique surface morphology with varied functional groups, high porous structure that favours more water and nutrient retention capacity when compared to FYM. However, biologically the biochar seems to be inert material due to lack of inherent microflora. However, it can support soil's native microflora in amended soils through its porous structure, high surface area by enhancing good soil aeration, water and nutrient retention in biochar amended soils.

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PP: 23 Impact of biochar application to soil on the plant growth and soil properties

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ABSTRACT: A field experiment isconducted to study the effect of biochar (produced from cotton feedstock) application on soil at Hunehadagali sub-watershed Kalaburagi, during *kharif* 2024. The experiment was laid out in Randomized Complete Block Design with six treatments *viz.,* absolute control, recommended dose of fertilizer, 50 % RDF + Biochar @ 2t/ha, 50 % RDF + Biochar @ 4t/ha, 100 % RDF + Biochar @ 2t/ha and 100 % RDF + Biochar @ 4t/ha replicated four times. Observations on physical properties (bulk density, particle density, porosity, maximum WHC), chemical properties (pH, EC, total carbon, macro and micro nutrients) of soil and growth parameters (plant height, primary branches per plant, SPAD and LAI) were recorded in all the treatments at 30 days intervals. The results revealed that application of biochar to soil increased the carbon content and nutrients (N, P, K, S, Ca, Mg, Fe, Zn, Mn, Cu and B) besides contributing to an increase in aggregate stability, water retention and PAWC and improved in soil bulk density. The improved soil physical and chemical properties had desirable effect on plant growth and development like plant height (45.25, 77.80 and 151.50 cm), primary branches per plant (3.91, 7.36 and 9.30), SPAD (28.06, 42.19 and 44.90) and LAI (2.06, 3.24 and 4.38) at 30, 60 and 90 DAS, respectively with 100 % RDF with 4 t/ha bio char compared to recommended dose of fertilizer plot.

Keyword: Biochar impact, soil application, physical, chemical properties and plant growth

Introduction

Biochar is a carbon-rich, porous material created by the thermal decomposition of biomass, such as plant residues, agricultural waste, or wood, under controlled, oxygen-limited conditions. This process, known as pyrolysis, involves heating the biomass to high temperatures in the absence or near absence of oxygen, which prevents complete combustion. The outcome is a stable form of charcoal with a well-structured network of pores, known as biochar.

Biochar, a stable carbon-rich material, enhances plant growth and boosts crop yields by fostering microbial activity. It is a black, highly porous, lightweight, fine-grained substance with a large surface area. The properties of biochar, such as its impact on microbial activity, nutrient and mineral binding, and soil water holding capacity (WHC), are influenced by the physical structure, pore size, and surface area, which in turn depend on the type of feedstock used during its production (Tomczyk *et al.,* 2020).

Pigeonpea holds a significant position in India's rainfed agriculture. It is an essential component of various agro-ecologies across the country, often intercropped with cereals, pulses, oilseeds, and millets. As the second most important pulse crop after chickpea, pigeonpea is cultivated over approximately 4.42 million hectares, which accounts for about 14.5% of the total area under pulses. The crop yields around 2.86 million tonnes, contributing 16% to the total pulse production, with a productivity rate of approximately 707 kg/ha. Primarily, it is consumed as dry split dal across the country, though various parts of the pigeonpea plant have several other uses. (Sameer *et al.*,2014)

Materials and Methods

A field experiment was conducted during the *kharif* 2024 at the Hunehadagali sub-watershed (17.317415°N latitude, 76.658627°E longitude, and an altitude of 468 meters above mean sea level)in Kalaburagi, which is located in the North Eastern Dry Zone of Karnataka. The experiment was conducted in Randomized Complete Block Design with six treatments: T1 – Absolute control, T2 – Recommended dose of fertilizer (RDF), T3 – 50% RDF + Biochar @ 2t/ha, T4 – 50% RDF + Biochar @ 4t/ha, T5 – 100% RDF + Biochar @ 2t/ha, and T6 – 100% RDF + Biochar @ 4t/ha, all replicated four times. The recommended dose of fertilizer for pigeonpea (25:50:125 kg N: P_2O_5: K_2O) was applied at the time of sowing. Fertilizers, including nitrogen, phosphorus, and potassium, were supplied through diammonium phosphate (DAP), while farmyard manure (FYM) was incorporated into the soil at a rate of 6 t/ha. The sowing of pigeonpea was carried out on July 6, 2024.

The soil at the experimental site was characterized by a clay texture and slightly alkaline pH of 8.10. It exhibited a low electrical conductivity of 0.2 dS m^{-1}, indicating low salinity. The soil had a low organic carbon content of 0.42%, which suggests limited nutrient availability from organic matter. In terms of essential nutrients, the soil was deficient in available nitrogen, with a concentration of 210 kg ha^{-1}, while phosphorus was at a medium level of 87 kg ha^{-1}. However, the soil had a high concentration of available potassium, measuring 790 kg ha^{-1}high in available calcium (17.2 meq/100g soil), high in available Magnesium (8.7 meq/100g soil), medium in available sulfur (15 kg ha^{-1}), high in available Zinc (5.79 kg ha^{-1}), low in available Iron(0.55 kg ha^{-1}), high in available Copper (1.45 kg ha^{-1}) and Low in available Manganese (0.45 kg ha^{-1}). These properties provide a context for understanding the nutrient status of the site and may influence the response of crops or plants grown in this environment.

Results and Discussion

Biochar is a thermally modified biological material with a range of distinct properties. Typically, biochar is rich in minerals and exhibits an alkaline pH (around 10.21), along with high porosity and a large surface area. Due to its stability, biochar can act as a long-term carbon store, potentially lasting for several hundred years.

The growth attributes of pigeonpea, as influenced by biochar applications, were assessed at 30 days after sowing. The data in Figure 1 show that growth parameters, such as plant height (45.25 cm), number of primary branches per plant (3.91), secondary branches per plant, SPAD (28.06) and leaf area index (2.06), were significantly higher with the 100% RDF and 4 t/ha biochar application compared to the recommended dose of fertilizer plot.These values were also on par with the treatment of 100% RDF and 2 t/ha biochar, where plant height was 44.72 cm, the number of primary branches per plant was 3.89, SPAD was 27.69, and leaf area index was 2.02. The 50% RDF with 4 t/ha biochar treatment resulted in a plant height of 44.07 cm and a SPAD value of 27.39.

At 60 days after sowing, the 100% RDF and 4 t/ha biochar application recorded significantly higher plant height (77.8 cm), number of primary branches per plant (7.36), secondary branches per plant (1.43), SPAD (44.9), and leaf area index (4.38), compared to other treatments. However, primary branches per plant (7.1) and SPAD (44.23) were on par with the 100% RDF and 2 t/ha biochar treatment. The observed improvements in growth attributes can be attributed to the beneficial effects of biochar, which is known to enhance soil health and productivity. According to Brtnicky*et al.*(2021) and Joseph *et al.* (2021)biochar offers a wide range of benefits, including improved soil properties, increased soil protection and water retention, enhanced nutrient content and sequestration, promotion of soil organism health, and improved plant growth, biomass production, and crop yields.

Table.1: Characteristics of Biochar produced from cotton stalk

Sample name	pH (1:10)	EC (1:10)	P (%)	K (%)	C (%)	H (%)	N (%)	S (%)	C/N ratio	BD (g/cc)	MWHC (%)	Ash (%)
Biochar (Cotton)	10.21	13.OO	O.32	0.43	6O.88	1.78	1.34	0.46	45.43	O.22	252.23	14.00

Table.2: Characteristics of soil

pH	EC (dS m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
8.1	0.2	0.42	210	87	790	15

Table.3: Characteristics of soil contd….

Ca (meq/100g soil)	Mg (meq/100g soil)	CaCo$_3$ (%)	B (kg/ha)	Zn (kg/ha)	Fe (kg/ha)	Cu (kg/ha)	Mn (kg/ha)
17.2	8.7	14	0.29	5.79	0.55	1.45	0.456

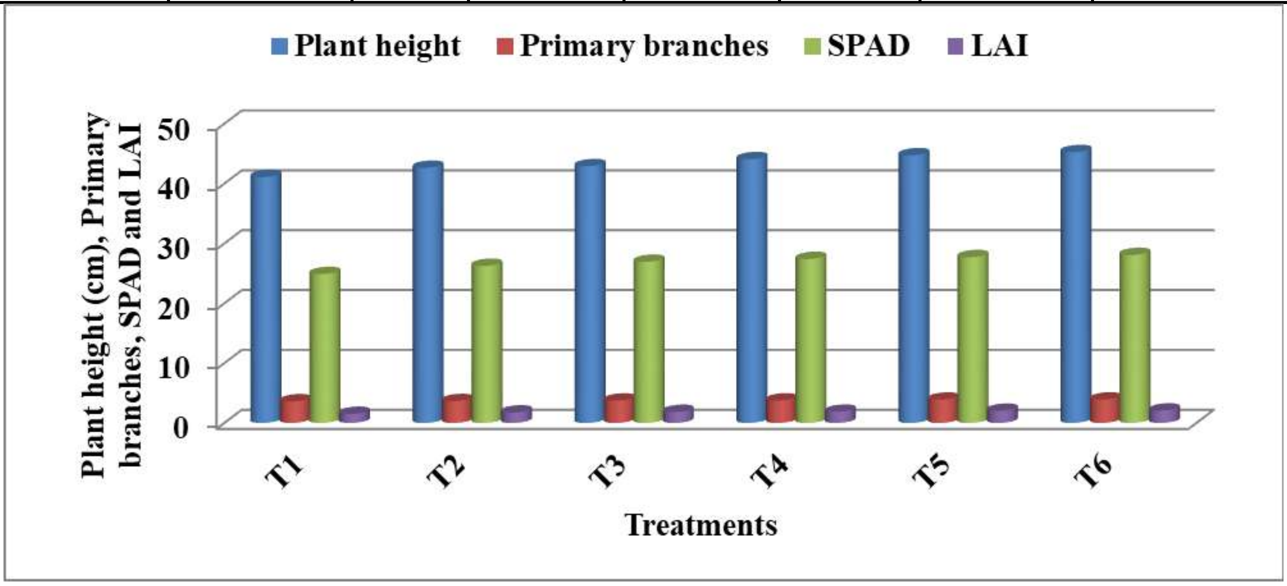

Fig.1: Plant height (cm), Primary branches, SPAD and LAI at 30 DAS

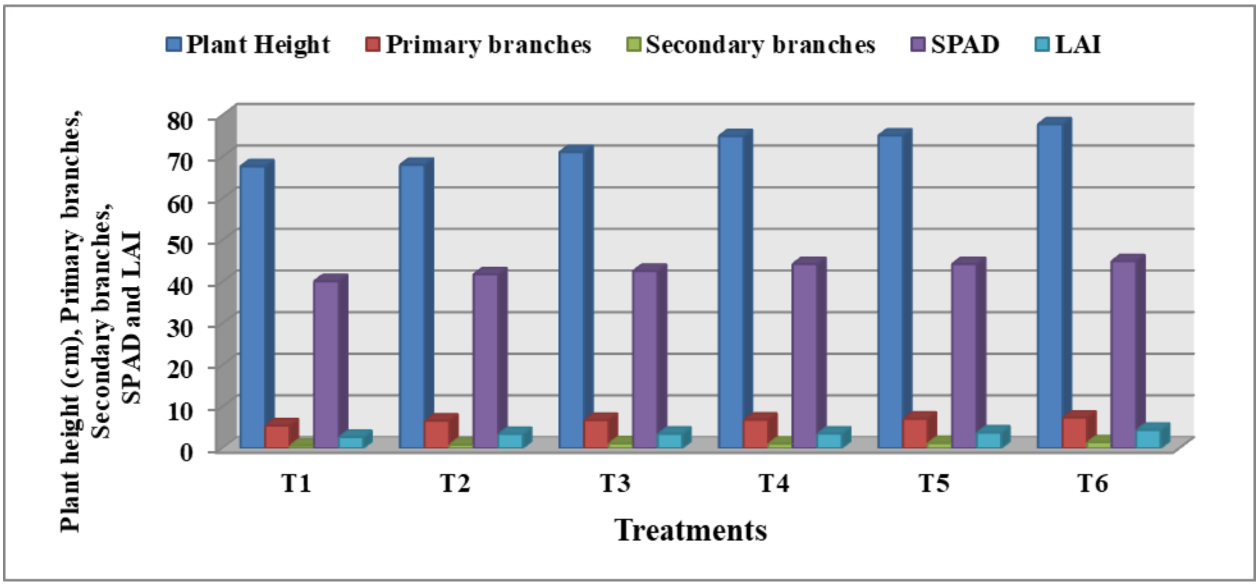

Fig.2: Plant height (cm), Primary branches, Secondary branches, SPAD and LAI at 60DAS

Physical properties of biochar applied field

The physical properties of cotton stalk biochar applied field produced underopen pit conditions are given in Table 1.

The results of the keen cup studies on bulk density (BD) and total porosity of the biochar applied field are depicted in Table 4. The cotton stalk biochar resulted in decrease in BD and increase in total porosity of soil. Bulk density and total porosity values ranged from 1.49 to 0.855 gg/cc and 30.07 to 59.11 %, respectively. Lowest BD of 0.855 gg/cc and maximum total porosity of 59.11 % is recorded for the biochar applied filed, respectively. Total porosity and BD were inversely correlated. The decrease in BD of biochar with increase intemperature could be due to greater proportion of biochar particles with smaller particle size distributions (Kim *et al*., 2012)

Table 4: Physical properties of soil

Treatments	BD (gg/cc)	Porasity (%)	Max WHC (%)
T1	1.49	30.07	22.6
T2	1.15	39.26	23.4
T3	1.07	47.75	29.7
T4	1.04	51.10	36.5
T5	0.89	53.44	42.6
T6	0.85	59.11	47.3

Table 5: Soil water content by TDR

Treatments	Soil depth (cm)						
	10	20	30	40	50	60	70
T1	10.41	16.77	8.02	8.41	13.12	12.03	
T2	12.31	10.68	22.35	28.83	11.37	1.42	5.65
T3	4.56	8.25	37.7	9.61	14.82	14.12	25.41
T4	18.1	9.27	18.88	15.91	12.46	11.18	9.92
T5	22.38	24.57	21.38	14.47	13.01	12.14	8.33
T6	19.88	23.3	18.6	20.22	14.74	10.32	12.87

Conclusion

Use of biochar in agricultural systems is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve the soil quality. Further, several studies across the world have established that biochar application increases conventional agricultural productivity and mitigate GHG emissions from agricultural soils. The initial outcomes of the present study reveal that biochar application helps in improving soil health and crop productivity. However, to promote the application of biochar as a soil amendment and also as a climate change abatement option, research, development and demonstration on biochar production and application is very vital.

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PP: 24 Field Application of Bio-char Trough Tractor Drawn Subsoiler

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Abstract: The field application of biochar was conducted at R.A.R.S field, College of Agriculture, Vijayapur using Tractor drawn five tynesubsoiler. The five tynesubsoiler was operated in loamy soil of pigeonpea harvested field using Mahindra Arjun Novo 605 DItractor as the prime mover for field operation of the subsoiler. The subsoiler was operated for 26 hours in loamy soil to check the rate and quality of work. The operating speed of the subsoiler was ranged from 2.14 to 3.02 kmph. The rate of work was found to be 0.30 to 0.41 ha/h at operating speed of 2.14 to 3.02 kmph. Quality of work *viz.,* depth of cut and soil inversion were ranged from 36.00 to 40.00 cm and 78 to 81%, respectively. Field efficiency of the machine was found to be 72.32 to 75.43%. The required draft force was ranged from 854.90 to 931.50 kgf. Fuel requirement of the tractor to draw the subsoiler was ranged from 4.03 to 4.63 l/h. The hourly percentage wear of shovel and blade on weight basis was recorded as0.11 to 0.15% and 0.11 to 0.15%, respectively. Overall performance of the subsoiler was found satisfactory.

Key words: Biochar, Tractor drawn implements, Subsoiler

PP: 25 Biochar as a carbon sequestration agent and its role in abiotic stress mitigation

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Abstract: Climate concerns, driven by the escalating impacts of global warming and climate change, are threatening ecosystems, biodiversity, and agricultural productivity worldwide. As temperatures rise and extreme weather events intensify, there is an urgent need for effective strategies to mitigate greenhouse gas emissions and build resilience in agricultural systems. Biochar, a stable carbon-rich material derived from the pyrolysis of organic biomass, offers a promising solution to two of the most pressing environmental challenges of the 21st century: greenhouse gas emissions and climate-change-induced abiotic stress in agriculture. As a carbon sequestration agent, biochar is capable of storing carbon in a highly stable, solid form, locking it into soils for hundreds to thousands of years. This feature makes it a potentially transformative technology for mitigating atmospheric CO_2 concentrations and reducing the severity of climate change. Concurrently, biochar has demonstrated significant potential in improving soil health and enhancing agricultural resilience to a wide range of abiotic stresses, thus contributing to climate adaptation. Despite these benefits, several research gaps remain, particularly in terms of understanding the long-term effects of biochar on soil microbial communities, its variability across different climates and soil types, and the broader environmental and economic impacts of large-scale biochar application. Future research is needed to refine biochar production methods, improve its application strategies, and explore its full potential as a tool for both carbon sequestration and climate change adaptation in agricultural systems. Biochar holds significant potential as a multifaceted tool for climate change mitigation and adaptation. By acting as a carbon sink and improving soil resilience, biochar contributes to both reducing greenhouse gas concentrations and enhancing agricultural sustainability in the face of climate-induced abiotic stress.

Keywords: Biochar, Carbon sequestration, Climate change, Abiotic stress.

PP: 26 Use of Biochar in Potato Cultivation

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All India Co-orinated Research Project on Potato
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Abstract: Potato (*Solanum tuberosum* L.) is one of the important commercial vegetable grown for its underground starchy tubers. It is the prime food crop addressing in food security in developing countries after wheat, rice and maize. The reduction in potato tuber yield is mainly attributed to reduction in soil organic matter, soil erosion, landslides, depletion of soil nutrients through leaching or surface runoff. Therefore maintenance of soil fertility is critical for getting maximum yield and its productivity. In recent years many studies have focused in assessing various soil management practices including the use of biochar as soil amendment to improve soil fertility and condition vis-a-vs crop productivity. Currently, very little biochar is being used in potato cultivation due to fact that its value in terms of crop response and soil health benefits are inadequately quantified. In this regard many researchers were studied to know the effect of nutrient loaded biochar application in potato. These results shown increased growth, yield and quality parameters through application of biochar along with recommended dose inorganic fertilizers by way of improving fertilizers use efficiency and physico-chemical-biological properties of soil. Hence use of biochar helps in sustainable production in long run by increasing soil carbon sequestration, fertility and productivity in potato. Hence this paper, aims to report influence of biochar in potato cultivation

Theme III:
Carbon Credits and Market Mechanisms
Inivited/Oral Presentation

IP: 27 Carbon credits potential in Indian Agriculture to Regenerate Soil and Enhance the Farmers' Income: an Overview and Policy framework

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Abstract: The influence of carbon dioxide (CO_2) emitted due to anthropogenic and natural processes increases due to ~ 420 ppm (part per million) concentration in the atmosphere. As developed countries came to Glasgow with a commitment to providing US$100 billion a year for developing countries.Significant reductions are required to limit greenhouse gas (GHG) emissions by 2030 to achieve net zero emissions. The Asian agriculture sector may be a key player in the negative carbon (C) sink for the green planet. After the United States of America, India has the second-largest area of arable land, ~ 165 million hectares (Mha). It includes 46 60 different soil types and exposure to all 15 major climates. The Indian agriculture sector has nature-gifted climatic parameters and classification of soils to cultivate 3-4 crops in a year with diverse cropping systems. In contrast, most parts can produce only one crop in Western countries yearly. Hence, Indian Agriculture farmers can play a significant role in C farming to CO_2 removal from the atmosphere and conserve plants and enhance the above and below-ground C pool.Moreover, Advanced cropping techniques reduce emissions, improve crop yield, restore damaged soils, and lessen pollution by lowering erosion and fertiliser runoff, cleaning surface and groundwater, and boosting microbial activity and soil biodiversity. When land is managed toC, capture rates rise, vital ecosystem services like waterand air quality, agricultural resilience increase, and climate change lessens. Along with worldwide initiatives like the "4 per 1000" Initiative, Global Soil Partnership, and regional public-private partnership projects on C credits for long-term sustainability, national governments and other agencies should strive towards C farming.Sustainable business practices and the use of environmentally friendly technology result in C credits that may be exchanged. As a result, it reduces GHG emissions while fostering a vibrant, profitable market. This chapter focuses on offsetting the rise in CO_2 concentrations in the atmosphere, a system of buying and selling C-credit has been developed under the United Nations framework.The C credit system was created as a "market-oriented approach" by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations. C credits are being traded, making them a “climate currency” that follows the same supply and demand rules as fiat money.The framework is based on strong regulations, technical support, public-private partnerships, quantification methodology, and creative finance methods that eventually enable land managers to execute real-world, practical solutions effectively.

Keywords: Cropping systems; Carbon credit; CO_2; innovative technologies; Incentives; Farmers

The United Nations (UNs) has been organizing climate change conferences under the title "Conference of the Parties" (COP) since 1995. To meet the 1.5°C objective, emissions of global greenhouse gases (GHGs) would have to be decreased by 50% from the current levels by 2030and to the net zero level by 2050 (IPCC, 2022). The Paris Agreement, established during COP21, aimed to limit the global average temperature increase to below 2°C, ideally to 1.5°C, to mitigate the effects of climate change. This landmark global climate accord was adopted by 197 parties at COP21 in Paris on December 12, 2015 (UNFCCC, 2023). The agreement calls for member countries to work diligently towards capping temperature rises, with their efforts being reviewed and assessed every five years. To further encourage countries, the Paris Agreement advocates for enhancing their carbon (C) reduction commitments through their Nationally Determined Contributions (NDCs).Before COP26, extensive planning meetings and one-on-one dialogues were conducted.World leaders from 193 nations gathered at COP27 in Egypt to debate and strategize the implementation of bold commitments for reducing GHG emissions(UNFCCC, 2022).Based on International Carbon Action Partnership (ICAP) research, many countries and regions establish net-zero climate objectives and enshrine these commitments in high-level political declarations and/or legal provisions (Cheye, 2023). The European Union (especially France, Germany, Spain, Sweden), the United Kingdom, South Korea, and New Zealand are among those that have enacted or are presently debating on net zero legislation. The three top climate emitters(China, the United States, and Japan) have made significant political commitments (Visual Capitalist, 2022). At the COP15 in Copenhagen in 2009, developed countries pledged to mobilize US$ 100 billion annually by 2020 to support climate action in developing nations. This commitment was made in the context of significant mitigation actions and transparency in implementation. This goal was formally established at COP16 in Cancun. At COP21 in Paris, the commitment was reiterated and extended to 2025. While reducing the emission of GHGs, the aim was to mobilize US$ 100 billion annually by 2020 for climate action in developing countries within the context of meaningful mitigation actions and transparency on implementation. Thus, developed countries made a collective commitment at the United Nations Framework Convention on Climate Change (UNFCCC, 2023) to contribute these funds. At COP26, Parties welcomed new financial commitments made to the Adaptation Fund (totalling over US$ 350 million) and the Least Developed Countries Fund (LDCF) (totalling over US$ 600 million), which will help vulnerable people build resilience to the worsening effects of climate change (UNFCCC, 2023). In COP27 in Egypt in 2022, developing nations, particularly India, proposed a new objective of global climate finance, also known as the New Collective Quantified Goal on Climate Finance (NCQG). It emphasizes the need for billions of dollars because of the rising costs of combating and adapting to climate change (The Economic Times, 2022).

Participants at COP26 made new financial commitments to assist developing nations in reaching this aim. Funding for adaptation will also be supported by new regulations for the global C trading systems ("Article 6") approved at COP26 (UNFCCC, 2023). Pricing C efficiently can motivate market players to lower emissions or enhance C capture, utilization, and storage (CCUS). They can boost CCUS by increasing the cost of generating C or funding projects that would lower or eliminate emissions. This system is distinguished because national currency exchange rates are linked to C costs. To meet the COP26 commitments, the Indian government passes the Energy Conservation (Amendment) Bill, 2022in the Lok Sabhato facilitate the achievement of COP-26 goals and to introduce concepts such as mandated use of non-fossil sources and C credit trading to ensure faster decarbonisation of the Indian economy.The Union Government or any authorised agency may issue “carbon credit certificates” to registered enterprises for reducing C emissions under Section 14 of the Bill, 2022 (The Energy Conservation Bill, 2022). The Global Soil Partnership (GSP) collaborates with regional public-private partnership projects to focus on C credits, aiming for long-term sustainability. Carbon credits are produced using environmentally friendly technologies and sustainable business practices.

Consequently, it lowers GHG emissions while promoting a thriving, lucrative industry. Within the framework of the UN, a C credit trading system has been established to mitigate the rise in atmospheric carbon dioxide (CO_2) concentrations.The UN's Intergovernmental Panel on Climate Change (IPCC) developed the C credit system as a "market-oriented approach" (Chuang *et al.,* 2019). Reducing atmospheric CO_2 concentration of more than 420 ppm in 2023 would typically involve several strategies, including trading C credits. Businesses can earn C credits by investing in projects that offset emissions, such as reforestation, conservation agriculture, or renewable energy initiatives. These credits represent a quantifiable reduction in CO_2 and contribute to global sustainability goals (Meena *et al.,* 2023). Since C credits are exchanged, they are regarded as a "climate currency" subject to the laws of supply and demand. Strong rules, technical assistance, public-private partnerships, quantification techniques, and innovative financing strategies form the framework's foundation and allow land managers to implement real-world, successfully workable solutions.

Measurement, Reporting, and Verification (MRV) are crucial components in the C credit process. Accurate and transparent MRV systems ensure the credibility of emission reduction claims. Rigorous data collection, robust reporting mechanisms, and independent verification by accredited entities are essential to validate and quantify the real impact of Coffset projects, promoting accountability and trust in the C credit market. C farming towards C footprint mitigation ensures ecosystem health and environmental sustainability.

Accurately quantifying C credits attributable to soil C sequestration in C offset markets constitutes a multifaceted methodological endeavour subject to ongoing refinement. The complexity of deriving C credits from soil C sequestration necessitates comprehensively examining the employed methodologies. This entails dissecting the core scientific theories that inform these methods, understanding how they translate into practice, and recognizing the inherent limitations of these processes. This exploration aims to unravel the intricate tapestry of approaches, from theoretical models to practical applications, and identify potential barriers that impede accurate C credit computation. The important methodologies used for estimating C credits include empirical model-based estimations, field-based direct measurements, and remote sensing and geospatial analyticaltechniques that form the cornerstone of soil C credit calculation while also considering the economic, policy, and technological dynamics that shape the valuation and verification processes within the C market infrastructure. Althougheach method has temporal and spatial variability challenges in soil C stock assessments, the implications of methodological uncertainties and adopting conservative baselines mitigate the risks of C credit overestimation.

Direct C estimation techniques are comparatively more accurate. Using this approach to regenerate the soil C stock. It involves collecting soil samples at various depths from multiple locations within a project area to account for spatial variability and then directly analysing them in a laboratory to determine their OC content. This approach provides highly localized data but is less practical for larger-scale projects due to its high cost and labour requirements.

Therefore, the present article aims to address GHG emissions and their mitigation through C-credit monetization. The concept of a C currency under the UN and various exchange plans is increasingly recognized as essential for global decarbonization efforts (The Economic Times, 2022). The specific objective of the article is to cover monetizing C credits in agriculture to benefit Indian farmers.The Ministry of Power (Cabinet order no.: CG-DL-E-30062023-246859 Dated June 28, 2023) and the Ministry of Environment, Forests, and Climate Change (MoEF & CC) have Developed (Cabinet order no.: CG-DL-E-27062023-246825 Dated June 27, 2023) and adopted the green credit program. The Ministry of Power refers to C credits directly linked with carbon-di-oxide (CO_2) equivalent removed from the environment, while the MoEF& CC mentions green credits. GoI’s notified on October 12, 2023 (CG-DL-E-13102023-249377) and elaborated the earlier notification related to the green credits by the MoEF & CC, which included afforestation, efficient water management, including treatment and reuse of wastewater, promotion of natural and regenerative agricultural practices, restoring degraded lands, improving soil health and focus on nutrition. A special mention was made of mangrove conservation and restoration, among others. Details of how green credits will be earned, monitored, quantified, etc., will be duly worked. It is also important to mention that C and green credits are different entities, but converting green credits to C credits and their valuation is possible but is still to be worked out. Considering the uncertainty associated with the C credit market, farmers and other stakeholders must have some minimum assured price linked to C/green credits. Given the importance of the C credit program, this article primarily focuses on the practical methods and policies for C credit in the Indian context. Along with outlining the problems, future roadmap, and methods, the article also offers suggestions for the C credit-based policy formulation in Indian agriculture. In the long-term,implementing this program would enhance the country's defences against climate change and encourage net zero emissions targeted by India through adopting negative C emission agriculture. It may also promote the "Sustainable Development Goals" of the Agenda 2030 of the UNs.

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IP: 28 Biochar Research: Bridging the gap between Agricultural Challenges and Market Opportunities

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Abstract: MASH utilizes thermo chemical processes to convert agricultural waste into valuable products like bio-oil, hydrogen, and electricity. One of the key byproducts of this process is biochar. Biochar can be added to soil to enhance plant growth, improve water retention, and increase nutrient availability. Through over 33 field trials conducted across various crops, MASH has demonstrated the potential of biochar to improve agricultural productivity, even under adverse conditions, where biochar improved soil health and boosted crop yields in both organic and inorganic setups. However, despite these positive results, biochar doesn’t always deliver immediate commercial benefits in the first season, especially given its bulk input and associated costs. This creates a challenge for market adoption, as farmers may be hesitant to invest in a product that doesn't show a quick return on investment. To bridge this gap, MASH is introducing an innovative solution through contract farming. we are innovating in the financial model around it to make it an appropriate match Biochar, as an investible commodity, offers long-term value both for the environment and agricultural productivity, and MASH is committed to helping farmers transition to more sustainable practices.

IP: 29 Biochar and bio-oil production using crop residues and voluntary carbon credits - A case study

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Abstract: Cotton, pigeonpea and paddy are the important crops of Yadagir district. The residues of these crops are currently burnt *in situ* by the farmers that causes environmental pollution. Production of biochar is an efficient way of converting waste into wealth. Biochar addition to soils results in carbon sequestration improves soil health and increases crop yields. An effort was to collect residues of crops such as cotton, pigeonpea and paddy during summer 2024 to produce biochar and bio-oil. Biochar was produced using soil pit, Kon Tiki and pyrolysis methods. The biochar so produced was offered to Circonomy Pvt Ltd, Singapore for obtaining voluntary carbon credits.

Key words: Biochar, bio-oil, Kon Tiki, soil pit, pyrolysis methods, voluntary carbon credits.

OP: 30 Carbon budgeting, energy analysis and economics of nutrient management practices in sugarcane

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Abstract: A field experiment was carried out at Agriculture Research Station, Sankeshwar Karnataka, India during 2020-21 and 2022-23. The experiment was laid out in split plot design consist of two main plots and four sub plots. Main plot treatments are methods of application and sub plot treatments were of time and split application of recommended dose of nitrogen and potassium. Among method application, band application recorded significantly higher energy parameters and carbon efficiency, yield and net returns. In time of and split application, RDN+RDK applied at six splits (Basal 10% remaining at 45, 75, 90,120 and 150 DAP in equal splits) recoded significantly higher energy parameters and carbon efficiency, yield and net returns. Pooled results indicated that, interactions of band application of RDN+RDK at six splits (Basal 10% remaining at 45, 75, 90,120 and 150 DAP in equal splits) recorded significantly higher cane yield (146.3 t ha^{-1}) and significantly higher net returns of Rs 3,00,654 ha^{-1} with B; C ratio of 3.58.Similar trend was observed in output energy, net energy and energy productivity and carbon efficiency.

Introduction

Sugarcane is a perennial grass cultivated commercially over 90 countries. Sugarcane is mainly used for sugar production. It is also used for livestock feeding andproducing ethanol as a biofuel. However, the capability of sugarcane crop being C4 plant to sequestrate carbon into plant and soil is of great importance. Sugarcane is a C4 plant having high efficiency of utilising solar radiation and consuming more amount of CO_2duringphotosynthesis.Certaininterventionshelpful in enhancing CO_2capture by the nutrient management practices, which will directly help to increase the yield and largely contribute to the carbon sequestration.

Material and Methods

A field experiment was carried out at Agriculture Research Station, Sankeshwar Tq Hukkeri Dist Belagavi, Karnataka, India during 2020-21 and 2022-23.The experiment was laid out in split plot design consist of two main plots and four sub plots. Main plot treatments are method of application of fertilizer *viz*., M_1: Broadcasting in farrow and M_2: Band application. Sub plot treatments were of time and split application of fertilizes *viz*., S_1: Recommended dose of nitrogen (RDN) + recommended dose of potassium (RDK) in five splits (basal 10% remaining at 45, 75, 90 and 120 DAP in equal splits), S_2: RDN + RDK in six splits (Basal 10% remaining at 45, 75, 90,120 and 150 DAP in equal splits), S_3: RDN + RDK in seven splits (Basal 10% remaining at 45, 75, 90,120,150 and 180 DAP in equal splits) and S_4: Recommended dose and schedule of nutrient applications (10 % N basal, 20% N at 50 DAP, 30% at 90 DAP and 40% N at 120 DAP. Sugarcane cultivar SNK 09227 was planted at 135 cm row spacing. Recommended dose of fertilizer was 250:75:190 N, P_2O_5, K_2O kg ha^{-1}. The soil was medium black clay in texture had low in soil available nitrogen, medium in available P_2O_5 and high in available K_2O.

Energy parameters *viz.,* output energy, net energy, energy ratio, energy productivity and specific energy were calculated as suggested in Devasenapathy *et al.* (2009). Total carbon input was calculated by considering total input energy and the formula (1 MJ=0.02015 kg C, West and Marland (2002). Carbon output was calculated by biomass X 0.4. Carbon efficiency was calculated by carbon output/carbon input and carbon sustainability index was calculated by carbon output – carbon input/carbon input. (Lal, 2004 and Lal *et al.,* 2020).

Results and Discussion

Yield

Pooled results indicates that, among method of application, band application of fertilizers recorded significantly higher cane yield (131.1 t ha^{-1}) compared to broadcasting in furrows (123.5 t ha^{-1}). Band application of fertilizers ensured the higher availability of nutrients within the rhizosphere.The application of recommended dose of nitrogen (RDN) + recommended dose of potash (RDK) in six splits (S_2) recorded significantly higher cane yield (142.5 t ha^{-1}). The next best treatment was the application of RDN + RDK in seven splits (S_3) which recorded plant crop cane yield of 131.9 t ha^{-1}. Higher cane yield was recorded for interactions. Among the interaction M_2S_2 *i.e.*, band application of RDN+RDK at six splits (146.3 t ha^{-1}) recorded significantly higher cane yield as compared to other interactions.Interaction effect of correct method of application along with time of application in split doses led to higher nutrient availability and lower wastage of nutrients.

Economics

Among the method of application, band application recorded significantly higher net returns (Rs 2, 88,431 ha^{-1}) and B: C ratio of 3.24. Application of RDN+RDK at six equal splits recorded significantly higher net returns (Rs 2, 90,882 ha^{-1}) and B; C ratio (3.52). In interactions, M_2S_2 *i.e.,* band application of RDN+RDK at six equal splits recorded significantly higher net returns of Rs 3,00,654 ha^{-1} with B; C ratio of 3.58.

Table 1.Yield and economic parameters of sugarcane cultivation under different nutrient management practices. (Pooled data)

Treatments		Cane yield (t ha^{-1})	Net returns (₹ ha^{-1})	BC Ratio
Main plot (2) – Method of application				
M_1	Broadcasting	123.5 b	237983 b	3.09 b
M_2	Band Placement	131.1 a	258431 a	3.24 a
	S. Em. ±	1.38	3944	0.03
Sub plot (4) – Time and Split application of fertilizers				
S_1	RDN + RDK in 5 splits	120.5 ab	228939 ab	3.00 ab
S_2	RDN + RDK in 6 splits	142.5 a	290882 a	3.52 a
S_3	RDN + RDK in 7 splits	131.9 ab	259629 ab	3.23 ab
S_4	RDF (N in 4 splits)	114.3 b	213662 b	2.90 b
	S. Em. ±	3.53	10071	0.09
Interaction (M X S)				
M_1S_1		117.7 de	221859 de	2.95 de
M_1S_2		138.6 ab	281109 ab	3.46 ab
M_1S_3		128.9 b-d	252864 b-d	3.20 b-d
M_1S_4		108.5 e	196524 e	2.74 e
M_2S_1		123.3 b-e	236019 b-e	3.05 b-e
M_2S_2		146.3 a	300654 a	3.58 a
M_2S_3		134.8 a-c	266394 a-c	3.26 a-c
M_2S_4		120.1 c-e	230799 c-e	3.07 c-e
	S. Em. ±	5.00	14242	0.12

Energy parameters

Band application recorded significantly higher output energy (6,95,095 MJ), net energy (6,21,810 MJ), energy ratio (9.48), energy productivity (1.79 Kg MJ^{-1}) and lower specific energy (0.56 MJ kg^{-1}). Application of RDN+RDK at six equal splits recorded significantly higher output energy (7,55,515 MJ), net energy (6,82,376 MJ), energy ratio (10.3), energy productivity (1.95 Kg MJ^{-1}) and lower specific energy

(0.51 MJ kg^{-1}). In interactions, M_2S_2 *i.e.,* band application of RDN+RDK at six equal splits recorded significantly higher output energy (7,75,920 MJ), net energy (7,02,661 MJ), energy ratio (10.59), energy productivity (2.0 Kg MJ^{-1}) and lower specific energy (0.50 MJ kg^{-1}).

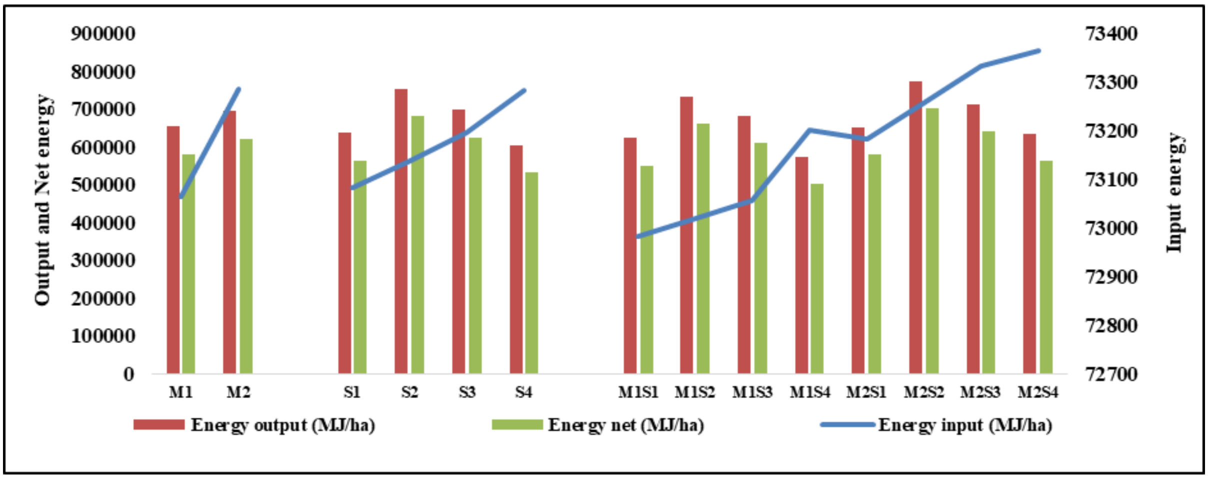

Fig 1. Input, output and net energy of sugarcane cultivation under different nutrient management practices.

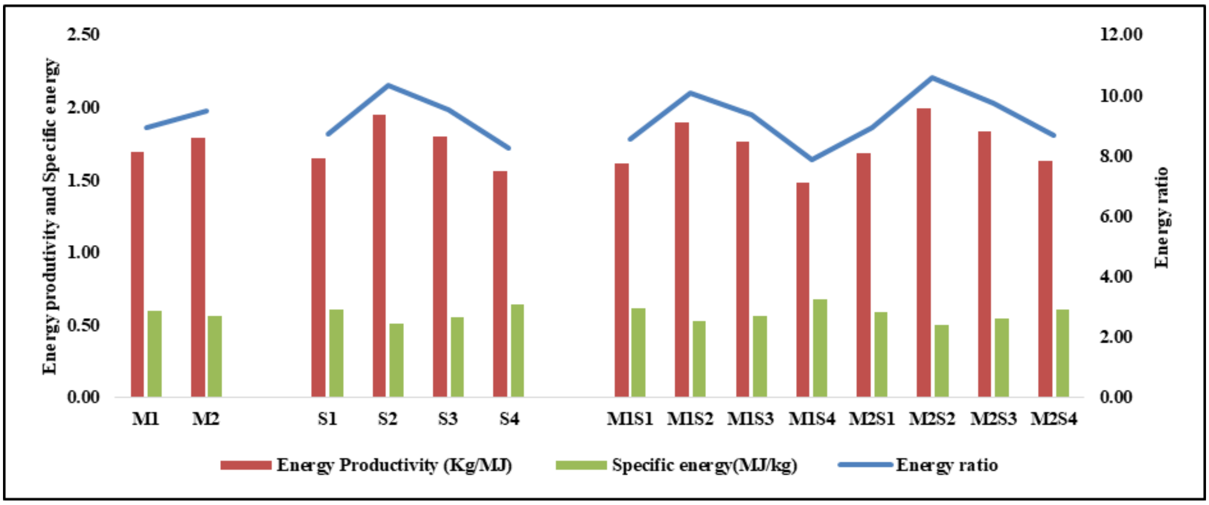

Fig 2. Energy productivity, specific energy and energy ratio of sugarcane cultivation under different nutrient management practices.

Carbon budgeting

Band application recorded significantly higher carbon output (52.5 t ha^{-1}), carbon sustainability index (34.5) and carbon efficiency (35.5). Application of RDN+RDK at six equal splits recorded significantly higher carbon output (57.0 t ha^{-1}), carbon sustainability index (37.6) and carbon efficiency (38.6). In interactions, M_2S_2 *i.e.,* band application of RDN+RDK at six equal splits recorded significantly higher carbon output (58.6 t ha^{-1}), carbon sustainability index (38.7) and carbon efficiency (39.7).

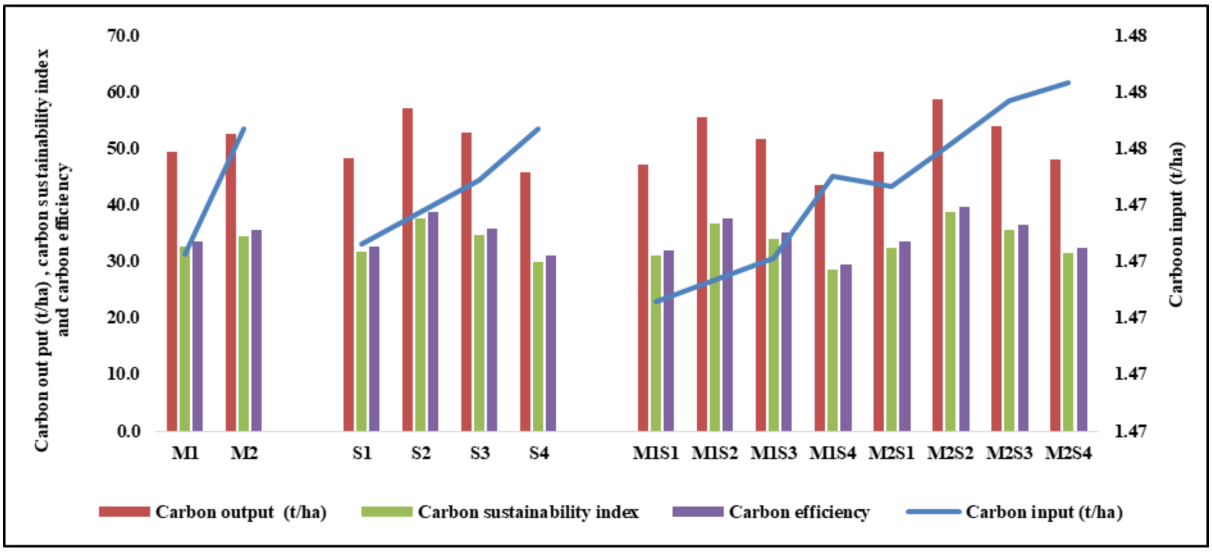

Fig 3. Carbon input, carbon output, carbon efficiency and carbon sustainability index of sugarcane cultivation under different nutrient management practices.

Conclusion

Band application of RDN+RDK at six splits (Basal 10% remaining at 45, 75, 90,120 and 150 DAP in equal splits) found to be effective for higher sugarcane productivity,economic returns and resource use efficient nutrient management practice.

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OP: 31 Long term effect of different production systems on fractions, indices and sequestration potential of carbon in surface soils of Vertisol

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Abstract: An understanding of the dynamics of soil organic carbon (SOC) as affected by production systems is imperative for maintaining soil productivity and mitigating global warming. Results of a long-term experiment (10years) under rainfed Maize- Chickpea cropping system was analyzed to determine the effects of organic, integrated, in-organic and RPP systems on SOC fractions, stocks, lability indices and sequestration potential. Results revealed that organic carbon, total carbon, permanganate oxidisable C (POX-C) and microbial biomass carbon(MBC) were significantly higher (6.7,19.0, 0.321 & 0.228 g kg^{-1}, respectively) in 100 per cent organic treatment compared in-organic. The highest carbon stock (12.76 $Mgha^{-1}$), carbon management index CMI (141.1) and carbon sequestration potential CSP (0.196 t/ha/yr) were recorded in treatment receiving 100 per cent N supplementation through organic sources compared to that receiving through inorganic sources. The active pool {(very labile C (VLC) + labile C (LC)} constituted about 21.6 per cent of total carbon and passive pool { less labile C (LLC) + non labile C (NLC)} represented 79.2 per cent of total carbon.

Keywords: carbon fractions, carbon stock, sequestration potential, production systems

Introduction

Increasing global soil organic carbon (SOC) stock through CO_2 sequestration is one of the ways that could enable a reduction of global warming. This will also ensure soil productivity and global food security. In croplands, optimum SOC levels can be managed through crop rotation, fertility maintenance including use of mineral fertilizers and organic manures, conservation tillage methods, and other cropping system components. To better understand the mechanisms by which C is lost or stabilized in soil, the SOC stock is separated into labile pool and recalcitrant pools. Microbial biomass C(MBC), oxidizable organic C, $KMnO_4$ oxidizable C ($KMnO_4$-C) are some of the important labile pools used as soil quality indicators as they are likely to be more sensitive to management practices than SOC. The SOC is considered to be comprised of small labile or active pool with relatively high turnover rate, which greatly influences nutrient cycling for maintaining soil quality and productivity and a large recalcitrant or passive pool with slower turnover rates, which is important from carbon sequestration point of view.

Material and Methods

The present study on "*Long term effect of different production systems on fractions, indices and sequestration potential of carbon in surface soils of Vertisol*" was carried out at Organic Farming Research Institute (OFRI), MARS, UAS, Raichur, Karnataka since from 2012-13 under rainfed situation at a fixed location using Pigeonpea as a sole test crop. But during current season of 2020-21, Maize-Chickpea cropping system was followed on a fixed location. Experiment consisted of 4 treatments, which were replicated five times and laid out in RCBD design. The treatments were: T_1: 100% N through organics, T_2: Integrated N management (50 % N through organics & 50 % N through inorganics), T_3: 100% N through inorganics and T_4: Recommended Package of Practice (RPP) (100 % RDF + FYM @ 7.5 t ha^{-1}). The treatment wise composite soil samples at harvest of crop were collected from of 0-15 cm depth which was analyzed for different parameters. The different fractions of carbon, lability indices, C stock and carbon sequestration potential were determined in soil by following the procedures as outlined in Chan *et al.,* 2001, and Blair *et al.* (1995).

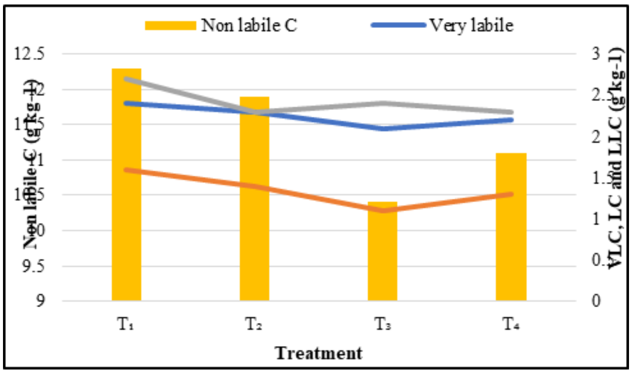
Results and Discussion

The present experiment was aimed to assess the effect of long-term application of organic, inorganic and integrated sources of nutrients on soil organic fractions, lability pools, carbon stock and sequestration potential in soil.

The initial organic carbon content of soil (during 2012-13) was 5.8 g kg^{-1} and it was increased to 6.7 g kg^{-1} in the surface layer under 100 per cent organic treatment showing 15.5 per cent increase in organic carbon content over a period of 9 years. While, its content declined to 5.3 g kg^{-1} under 100 per cent inorganic treatment. Among the different production systems, the highest total carbon, permanganate oxidisable carbon and microbial biomass carbon were recorded with application of 100 per cent organics (T$_1$) (19.0, 0.321 and 0.228 g kg^{-1}, respectively) followed by integrated sources of nutrients (17.9, 0.291 & 0.214 g kg^{-1}, respectively) and the lowest was in inorganic treatment (16.0, 0.278 & 0.171 g kg^{-1}, respectively) receiving recommended dose of fertilizer. The increase in soil organic carbon content of soils under organic farming is attributed to the cumulative effect of carbonaceous materials such as organic residues, root biomass and root exudates which contribute to soil organic carbon which acted as carbon and energy source for microbes and fermented organics in a quick buildup of microflora and fauna (Ramesh *et al.,* 2009). Total carbon was allocated into different oxidisable C fractions in the order of NLC>LLC>VLC>LC constituting about 65.3, 12.9, 13.9 and 7.7 per cent, respectively. The active pool (VLC + LC) constituted about 21.6 per cent of total carbon and passive pool (LLC + NLC) represented 79.2 per cent of total carbon.

Table 1: Effect of different production systems on fractions, stock and lability indices of carbon in soil

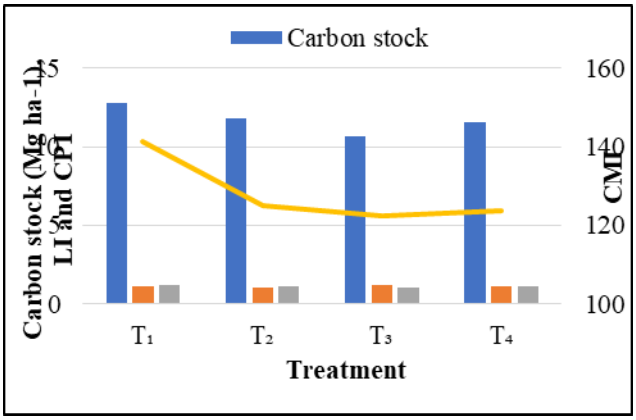
Treatment	SOC	TOC	SIC	POX-C	MBC	Carbon stock	CSP	LI	CPI	CMI
	g kg^{-1}					Mg ha^{-1}	t/ha/yr			
T$_1$: 100% organic	6.7	19.0	4.9	0.321	0.228	12.76	0.196	1.15	1.23	141.4
T$_2$: Integrated	6.0	17.9	5.5	0.291	0.214	11.79	0.043	1.08	1.16	125.2
T$_3$: 100% inorganic	5.3	16.0	6.0	0.278	0.171	10.65	-0.087	1.18	1.04	122.3
T$_4$: RDF + FYM	5.9	16.9	5.7	0.284	0.197	11.57	0.022	1.13	1.10	123.7
SEm±	0.24	0.41	0.15	0.02	0.03	0.34	0.04	0.01	0.02	0.99
CD@5%	0.73	1.25	0.47	0.05	0.09	1.06	0.09	0.02	0.05	3.05



The data on carbon stocks as influenced by different production methods are presented in Table 1 and Fig. 1.The soil organic carbon stock ranged from 10.65 to 12.76 Mg ha^{-1} and CSP from 0.196 to – 0.087 t/ha/yr.The increase in SOC stock, CSP and improvement in CMI might be attributed to addition of greater amount of carbon inputs through different organic sourceswith use of organics alone or in combination with in-organics over sole application of inorganic fertilizers.

Conclusion

Based on the results of long-term (over 10 years) application of organics, inorganics and their integration in a black soil, it is inferred that supplementation of N through organic sources alone or in combination with inorganic fertilisers can maintain the soil sustainability compared to treatment receiving recommended dose of fertilizer alone.



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Theme III:
Carbon Credits and Market Mechanisms
Poster Presentation

PP: 32 Indian Agricultural Potential for Capturing Atmospheric CO_2 and Monetizing Carbon Credits: an Overview and Policy Framework

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Abstract: The influence of carbon dioxide (CO_2) emitted due to anthropogenic and natural processes increases due to ~ 420 ppm (part per million) concentration in the atmosphere. As developed countries came to Glasgow with a commitment to providing US$100 billion a year for developing countries.Significant reductions are required to limit greenhouse gas (GHG) emissions by 2030 to achieve net zero emissions. The Asian agriculture sector may be a key player in the negative carbon (C) sink for the green planet. After the United States of America, India has the second-largest area of arable land, ~ 165 million hectares (Mha). It includes 46 of the 60 different soil types and exposure to all 15 of the world's major climates. The Indian agriculture sector has nature-gifted climatic parameters and classification of soils to cultivate 3-4 crops in a year with diverse cropping systems. In contrast, most parts can produce only one crop in western countries yearly. Hence, Indian Agriculture farmers can play a significant role in C farming to CO_2 removal from the atmosphere and conserve plants and enhance the above and below-ground C pool.Moreover, Advance cropping techniques reduce emissions, improve crop yield, restore damaged soils, and lessen pollution by lowering erosion and fertiliser runoff, cleaning surface and groundwater, and boosting microbial activity and soil biodiversity. When land is managed toC, capture rates rise, vital ecosystem services like water and air quality, agricultural resilience increase, and climate change lessens. Along with worldwide initiatives like the "4 per 1000" Initiative, Global Soil Partnership, and regional public-private partnership projects on C credits for long-term sustainability, national governments and other agencies should strive towards C farming.Sustainable business practices and the use of environmentally friendly technology result in C credits that may be exchanged. As a result, it reduces GHG emissions while fostering a vibrant, profitable market. This chapter focuses on offsetting the rise in CO_2 concentrations in the atmosphere, a system of buying and selling C- credits has been developed under the United Nations framework.The C credit system was created as a "market-oriented approach" by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations. C credits are being traded, making them a “climate currency” that follows the same supply and demand rules as fiat money.The framework is based on strong regulations, technical support, public-private partnerships, quantification methodology, and creative finance methods that eventually enable land managers to execute real-world, practical solutions effectively.

Keywords: Cropping systems; Carbon credit; CO_2; innovative technologies; Incentives; Farmers

The United Nations (UNs) has been organizing climate change conferences under the title "Conference of the Parties" (COP) since 1995. To meet the 1.5°Cobjective, emissions of global greenhouse gases (GHGs) would have to be decreased by 50% from the current levels by 2030and to the net zero level by 2050(IPCC, 2022).The Paris Agreement, established during COP21, aimed to limit the global average temperature increase to below 2°C, ideally to 1.5°C, to mitigate the effects of climate change. This landmark global climate accord was adopted by 197 parties at COP21 in Paris on December 12, 2015 (UNFCCC, 2023). The agreement calls for member countries to work diligently towards capping temperature rises, with their efforts being reviewed and assessed every five years. To further encourage countries, the Paris Agreement advocates for enhancing their carbon (C) reduction commitments through their Nationally Determined Contributions (NDCs).Before COP26, extensive planning meetings and one-on-one dialogues were conducted.World leaders from 193 nations gathered at COP27 in Egypt to debate and strategize the implementation of bold commitments for reducing GHG emissions(UNFCCC, 2022).Based on International Carbon Action Partnership (ICAP) research, many countries and regions establish net-zero climate objectives and enshrine these commitments in high-level political declarations and/or legal provisions(Cheye, 2023). The European Union (especially France, Germany, Spain, Sweden), the United Kingdom, South Korea, and New Zealand are among those that have enacted or are presently debating on net zero legislation. The three top climate emitters(China, the United States, and Japan) have made significant political commitments (Visual Capitalist, 2022). At the COP15in Copenhagen in 2009, developed countries pledged to mobilize US$ 100 billion annually by 2020 to support climate action in developing nations. This commitment was made in the context of significant mitigation actions and transparency in implementation. This goal was formally established at COP16 in Cancun. At COP21 in Paris, the commitment was reiterated and extended to 2025. While reducing the emission of GHGs, the aim was to mobilize US$ 100 billion annually by 2020 for climate action in developing countries within the context of meaningful mitigation actions and transparency on implementation. Thus, developed countries made a collective commitment at the United Nations Framework Convention on Climate Change (UNFCCC, 2023) to contribute these funds. At COP26, Parties welcomed new financial commitments made to the Adaptation Fund (totaling over US$ 350 million) and the Least Developed Countries Fund (LDCF) (totaling over US$ 600 million), which will help vulnerable people build resilience to the worsening effects of climate change (UNFCCC, 2023). In COP27 in Egypt in 2022, developing nations, particularly India, proposed a new objective of global climate finance, also known as the New Collective Quantified Goal on Climate Finance (NCQG). It emphasizes the need for billions of dollars because of the rising costs of combating and adapting to climate change (The Economic Times, 2022).

Participants at COP26 made new financial commitments to assist developing nations in reaching this aim.Funding for adaptation will also be supported by new regulations for the global C trading systems ("Article 6") approved at COP26 (UNFCCC, 2023). Pricing C efficiently can motivate market players to lower emissions or enhance C capture, utilization, and storage (CCUS). They can boost CCUS by increasing the cost of generating C or funding projects that would lower or eliminate emissions. This system is distinguished because national currency exchange rates are linked to C costs. To meet the COP26 commitments, the Indian government passes the Energy Conservation (Amendment) Bill, 2022in the Lok Sabhato facilitate the achievement of COP-26 goals and to introduce concepts such as mandated use of non-fossil sources and C credit trading to ensure faster decarbonisation of the Indian economy.The Union Government or any authorised agency may issue “carbon credit certificates” to registered enterprises for reducing C emissions under Section 14 of the Bill, 2022 (The Energy Conservation Bill, 2022). The Global Soil Partnership (GSP) collaborates with regional public-private partnership projects to focus on C credits, aiming for long-term sustainability. Carbon credits are produced using environmentally friendly technologies and sustainable business practices.

Consequently, it lowers GHG emissions while promoting a thriving, lucrative industry. Within the framework of the UN, a C credit trading system has been established to mitigate the rise in atmospheric carbon dioxide (CO_2) concentrations.The UN's Intergovernmental Panel on Climate Change (IPCC) developed the C credit system as a "market-oriented approach"(Chuang *et al.,* 2019). Reducing atmospheric CO_2 concentration of more than 420 ppm in 2023 would typically involve several strategies, including trading C credits. Businesses can earn C credits by investing in projects that offset emissions, such as reforestation, conservation agriculture, or renewable energy initiatives. These credits represent a quantifiable reduction in CO_2 and contribute to global sustainability goals (Meena *et al.,* 2023). Since C credits are exchanged, they are regarded as a "climate currency" subject to the laws of supply and demand.Strong rules, technical assistance, public-private partnerships, quantification techniques, and innovative financing strategies form the framework's foundation and allow land managers to implement real-world, successfully workable solutions.

Measurement, Reporting, and Verification (MRV) are crucial components in the C credit process. Accurate and transparent MRV systems ensure the credibility of emission reduction claims. Rigorous data collection, robust reporting mechanisms, and independent verification by accredited entities are essential to validate and quantify the real impact of C offset projects, promoting accountability and trust in the C credit market.C farming towards C footprint mitigation ensures ecosystem health and environmental sustainability.

Therefore, the present article aims to address GHG emissions and their mitigation through C-credit monetization. The concept of a C currency under the UN and various exchange plans is increasingly recognized as essential for global decarbonization efforts (The Economic Times, 2022). The specific objective of the article is to cover monetizing C credits in agriculture to benefit Indian farmers.The Ministry of Power (Cabinet order no.: CG-DL-E-30062023-246859 Dated June 28, 2023) and the Ministry of Environment, Forests, and Climate Change (MoEF& CC)have Developed (Cabinet order no.: CG-DL-E-27062023-246825 Dated June 27, 2023) and adopted the green credit program. The Ministry of Power refers to C credits directly linked with carbon-di-oxide (CO_2) equivalent removed from the environment, while the MoEF & CC mentions green credits. GoI's notified on October 12, 2023 (CG-DL-E-13102023-249377) and elaborated the earlier notification related to the green credits by the MoEF & CC, which included afforestation, efficient water management, including treatment and reuse of wastewater, promotion of natural and regenerative agricultural practices, restoring degraded lands, improving soil health and focus on nutrition. A special mention was made of mangrove conservation and restoration, among others. Details of how green credits will be earned, monitored, quantified, etc., will be duly worked. It is also important to mention that C and green credits are different entities, but converting green credits to C credits and their valuation is possible but is still to be worked out. Considering the uncertainty associated with the C credit market, farmers and other stakeholders must have some minimum assured price linked to C/green credits. Given the importance of the C credit program, this article primarily focuses on the practical methods and policies for C credit in the Indian context. Along with outlining the problems, future roadmap, and methods, the article also offers suggestions for the C credit-based policy formulation in Indian agriculture. In the long-term,implementing this program would enhance the country's defences against climate change and encourage net zero emissions targeted by India through adopting negative C emission agriculture. It may also promote the "Sustainable Development Goals" of the Agenda 2030 of the UNs.

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PP: 33 Growth, Volume and Carbon sequestration study of *Pongamiapinnata* provenances in blackgram based agroforestry system

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Abstract: The present investigation was conducted to study growth, and volume and Carbon sequestration study of *Pongamiapinnata* provenances along with blackgram based agroforestry system. The experiment was conducted during *kharif* 2019-20 and 2020-21 in "T" block, Agroforestry experimental fields of University of Agricultural Sciences, Dharwad campus which is located at 15° 26' North latitude and 75° 0' East longitude, with an elevation (altitude) of 678 m above mean sea level. The plantation of *Pongamiapinnata* with ten different provenances was planted in the year of 2016 *kharif*. *Pongamiapinnata* provenance's growth and volume observations were recorded. Two years blackgram was grown in between *Pongamia* tree rows and various observations like tree height (m), tree girth (cm), canopy cover (sq.m.), number of branches, stem volume (m^{-3}), total biomass (kg $tree^{-1}$), carbon stock (tonnes $tree^{-1}$) and carbon dioxide (tonnes $tree^{-1}$) at regular intervals.*Pongamiapinnata* provenancestwo years pooled data indicates highest growth and volume obtained in treatment (T_1) RAK-1 + blackgram followed by (T_9) RAK-9 + blackgram which is on par with (T_6) RAK-7 + blackgram. Lowest values recorded in (T_8) RAK-9 + blackgram which is on par with (T_4) RAK-4 + blackgram.

Introduction

Pongamiapinnata L. known as pongamia or kerung, belongs to family Fabaceae which is medium size, an evergreen tree having short trunk and dispersing crown. The trees are planted for shade purposes and grown as an ornamental tree. It is also a nitrogen fixing tree which produces seeds containing 30-40% oil. It is a high-speed growing; deciduous, glabrous, trunk of diameter up to 60 cm, bark is smooth, grey in colour. Its leaves are imparipinnate, sometimes shiny, young, pinkish red, glossy and deep green when mature. Its many parts are used for timber, fuel production, medicinal and industrial purposes (Alam*et al.,* 2011). A Pongamia tree can sequester 767 kg of carbon over 25 years. It has a higher carbon sequestration potential than other trees like mahua and neem. Pongamia trees have several benefits for restoring degraded land. Studies have shown five-year-old pongamia plantations having carbon sequestration potential of around 13.43 tons per ha (Bohre *et al.* 2014; Edrisi and Abhilash 2016). It can also be part of climate change mitigation strategies as it has a high carbon sequestration potential (Prasad, 2021), and be an alternative source of protein and vegetable oil as Terviva®, an American based agricultural technology company, has patented methodologies to use Pongamia as a source of plant protein for human and animal consumption and to refine its crude oil into food-grade vegetable oil. They also claim that the production can be carbon-negative which can have a huge impact on food-security in the future. Black gram (*Vigna mungo* (L.)Hepper) is a fast-growing erect, herbaceous annual legume reaching 30-100 cm height with a well-developed taproot, and its stems are diffusely branched from the base. Black gram differs from green gram (*Vignaradiata* (L.) R. Wilczek) with a distinct bright yellow corolla, while green gram is pale yellow. Black gram pods are erect, whereas pods are pendulous for green gram. A black gram is more pubescent than a green gram, and a white hilum is visible in the seed. Besides the potential benefits of tree-based intercropping systems, interactions within agroforestry systems can be beneficial, neutral, or unfavourable (Ong, 1996). Competitive interactions should be avoided to properly design and manage intercropping systems and maximize tree-based systems' potential benefits (Thevathasan *et al.,* 2004). The studies of interactions in agroforestry systems necessitate the evaluation of several complex processes, including plant competition (*i.e.*, for light, water, and nutrients), those related to soil conservation, soil fertility, allelopathy, pests and diseases, and microclimatic modifications (Rao *et al*., 1998). In recent days Pongamia tree is popular for various benefits and the objective of the present study is to explore the influence of ten Pongamia provenances.

Material and Methods

After 35 days of black gram sowing, various observations on *Pongamia* were recorded. Tree height (m.) was measured with ravi multi meter and observations were recorded in meter. Tree girth (cm.) was measured at breast height with tree calliper. Mathematical model was developed for the measurements of biomass by considering Diameter at Breast Height (DBH) and the girth at DBH at approximately 1.3 meter. The tree having diameter above 7.5 cm were treated as trees. Techniques, such as clinometers, wooden pole, and considering the height of the near building to the tree were implemented according to the situation where the trees were grown. The height of the tree was calculated by considering the angle between the tree top and eye view at breast height angle (α). Further crown area, tree volume and number of tree branches were also recorded. Number of branches is most important character of tree which is direct indicator of tree health and growth. Number of branches proves its potential to increase the yield and direct and indirect benefit to the ecology and mankind. The biomass was estimated from allometric relations between the tree diameter at DBH and tree biomass. Corbon stock and carbon dioxide in ponagmia is calculated by values of three height, girth, and tree biomass.

Results and discussion

Pongamiaprovenaces (Rahuri Karanja1 1 to 9) and (DPS-1 Dharwad Pongamia Selection-1) growth and volume observations were recorded along with tree height, tree girth, canopy cover and number of branches for two years. Pooled data recorded(Table 1) maximum tree height, tree girth, canopy cover and number of branches in treatment (T1) RAK-1 + black gram (3.66 mt, 18.85 cm , 3.03 sqmt and 29.85) respectively. Lowest values recorded in (T8) RAK-9 + black gram (2.25 mt, 12.40 cm, 1.95 sqmt and 18.30) which is on par with (T4) RAK-4 + black gram (2.23 mt, 12.45 cm, 1.91 sqmt, and 18.50) respectively.Stem volume (m^{-3}) is function of a tree's height, basal area, shape, and depending on definition, bark thickness. It is therefore one of the most difficult parameters to measure, because an error in the measurement or assumptions for any one of the above factors will propagate to the volume estimate.The stem volume (m^{-3}) of *Pongamiapinnata* provenances as influenced by the blackgram is intercrop for two years is recorded . Pooled data recorded maximum (Table 1.) stem volume (m^{-3}) in treatment (T_1) RAK-1 + blackgram (0.0353 m^{-3}) followed by (T_9) RAK-9 + blackgram (0.0289 m^{-3}) followed by (T_6) RAK-7 + blackgram(0.0271 m^{-3}). Lowest stem volume was recorded in (T_8) RAK-9 + blackgram (0.095 m^{-3}) followed by (T_4) RAK-4 + blackgram (0.097 m^{-3}). Two years pooled data(Tabl 2.) recorded maximum total biomass in treatment (T_1) RAK-1 + blackgram (0.0328 tonnes tree^{-1}) followed by (T_9) RAK-9 + blackgram (0.0269 tonnes tree^{-1}) and (T_6) RAK-7 + blackgram (0.0252 tonnes tree^{-1}). Lowest tree total biomasswas recorded in (T_8) RAK-9 + blackgram (0.0089 tonnes tree^{-1}) followed by (T_4) RAK-4 + blackgram (0.0090 tonnes tree^{-1}). Maximum carbon stock in tonnes tree^{-1} was recorded in (T_1) RAK-1 + blackgram at (0.0169 tonnes tree^{-1}) followed by (T_9) RA10 + blackgram (0.0138 tonnes tree^{-1}) and (T_6) RAK7 + blackgram (0.0130 tonnes tree^{-1}), lowest carbon stock in tonnes tree^{-1} recorded in followed by(T_4) RAK-4 + blackgram (0.0046 tonnes tree^{-1}) and (T_8) RAK-9 + blackgram (0.0045 tonnes tree^{-1}) reapectively. Pooled data on carbon dioxide in tonnes tree^{-1} there was no significant difference between treatments was noticed during both the years (2019 and 2020) respectively. Carbon dioxide in tonnes tree^{-1} was recorded in (treatment no 1.) RAK-1 + blackgram at (0.0214) followed by (T_6) RAK7 + blackgram (0.0199) and (T_9) RA10 + blackgram (0.0162), lowest carbon dioxide in tonnes tree^{-1} recorded in (T_4) RAK-4 + blackgram (0.0044).

Table 1 : Tree growth and volume values of *Pongamiapinnata*provenances

Treatments	Pooled data for the year 2019 and 2020				
	Tree height(mt.)	Tree girth (Cm)	Canopy cover (Sq.mt)	Number of branches	Stem volume (M^3)
T_1 – RAK-1 + Blackgram	3.66	18.85	3.03	29.85	0.0353
T_2 – RAK-2 + Blackgram	2.92	16.40	2.62	23.30	0.0211
T_3– RAK-3 + Blackgram	2.94	15.70	2.56	23.80	0.0193
T_4 – RAK-4 + Blackgram	2.23	12.45	1.91	18.50	0.0097
T_5 – RAK-6 + Blackgram	2.68	15.20	2.32	20.65	0.0166
T_6 – RAK-7 + Blackgram	3.28	17.55	2.83	25.20	0.0271
T_7 – RAK-8 + Blackgram	2.66	15.95	2.37	21.40	0.0186
T_8 – RAK-9 + Blackgram	2.25	12.40	1.95	18.30	0.0095
T_9 – RAK-10 + Blackgram	3.26	17.80	2.81	25.75	0.0289
T_{10} – DPS-1 + Blackgram	2.67	14.80	2.35	21.20	0.0162
S. Em (±)	0.32	0.57	0.31	0.90	NS
C. D. (5%)	0.93	1.67	0.92	2.60	0.007

Table 2 : Tree total biomass, carbon stock and carbon dioxide of *Pongamiapinnata*provenances

Treatments	Pooled data for the year 2019 and 2020		
	Total biomass (Tonnes tree^{-1})	Carbon stock in tonnes tree^{-1}	Carbon dioxide in (tonnes tree^{-1})
T_1 – RAK-1 + Blackgram	0.0328	0.0169	0.0620
T_2 – RAK-2 + Blackgram	0.0196	0.0101	0.0372
T_3– RAK-3 + Blackgram	0.0179	0.0094	0.0343
T_4 – RAK-4 + Blackgram	0.0090	0.0046	0.0168
T_5 – RAK-6 + Blackgram	0.0154	0.0080	0.0293
T_6 – RAK-7 + Blackgram	0.0252	0.0130	0.0478
T_7 – RAK-8 + Blackgram	0.0173	0.0088	0.0325
T_8 – RAK-9 + Blackgram	0.0089	0.0045	0.0167
T_9 – RAK-10 + Blackgram	0.0269	0.0138	0.0508
T_{10} – DPS-1 + Blackgram	0.0150	0.0077	0.0283
S. Em (±)	NS	NS	NS
C. D. (5%)	0.007	0.006	0.012

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PP: 34 Carbon trading and its opportunities in the Agriculture sector – An Indian agriculture point of view

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Abstract: India updated its Nationally Determined Contribution (NDCs) to the United Nations Framework Convention on Climate Change (UNFCC) in August 2022. The updated NDC includes 50 per cent cumulative electric power installed from non-fossil fuel-based energy sources and an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through forest and tree cover by 2030. The updated NDC target also aims to reduce the emissions intensity of its Gross Domestic Product (GDP) by 45 per cent from 2005 levels by the year 2030. It also talks about propagating a healthy and sustainable way of living, including (through) a mass movement for LiFE – 'Lifestyle for Environment' as a key to combating climate change. The Energy Conservation (Amendment) Bill, 2022 was passed by Parliament which mandates the exploration and use of non-fossil fuel energy sources and the creation of a national carbon market. The Bill is also futuristic in achieving the target of net zero emission by 2070. The agriculture sector plays a significant role in carbon trading because it has the potential to both emit and sequester carbon. Agricultural activities such as tilling, fertilizer use, and livestock production can release greenhouse gas into the atmosphere. On the other hand, practices such as agroforestry, conservation tillage, and soil carbon sequestration through various methods including biochar preparation and its use can remove carbon from the atmosphere and store it in the soil. As for as Indian agriculture is concerned there is an ample scope and opportunities to start carbon farming. There is also a need to create awareness among farming communities on the benefits of the adoption of improved agricultural practices and participation in carbon markets. This paper mainly highlights some important aspects on the same as for as Indian agriculture is concerned.

Key words: Carbon source, agriculture practices, carbon dioxide,carbon sequestration, carbon trading

Introduction

Carbon trading is a market-based system that aims to offer financial incentives to persuade enterprises to lessen their environmental footprint. In contrast to voluntary offsets, which allow consumers to pay to offset their carbon impact, carbon trading is a legally binding scheme. Carbon trading in the agricultural sector refers to the buying and selling of carbon credits that are generated by practices that reduce greenhouse gas emissions or increase carbon sequestration on farms and other agricultural lands. The concept of carbon trading in the agricultural sector is seen as a way to provide financial incentives for farmers to adopt environmentally friendly practices, which can help to mitigate the effects of climate change.

Material and Methods

A carbon credit represents successful emission reductions through practices that enable the removal of carbon in the atmosphere. Carbon credits in agriculture require practice changes that limit farm emissions or store carbon in the fields or both. On specifications, these are the qualities of carbon credits: One carbon credit corresponds to one metric ton of carbon dioxide. Genuine carbon credits are generated with careful measurement, reporting, and verification (MRV) procedures. Once carbon credits are generated, carbon credit producers can sell them to buyers looking to offset their emissions, usually to businesses or even individuals. Carbon credits are traded at carbon markets for sellers and buyers.

Brief background

It's 1997 during Kyoto, Japan, in the United Nations Framework Convention on Climate Change (UNFCCC). There, the world's nations agreed carbon credits were a good way of reducing the emission of CO_2 and other greenhouse gases. Later, in 2001 in Germany, 191 countries ratified the protocol, including Japan, Australia, Canada or France. The United States didn't. Among other issues, the protocol mandated that 37 industrialized nations plus the UE cut down their emissions. For the first time, the idea of a cap-and-trade system and a carbon credits market were brought to the table. Furthermore, according to the Kyoto Protocol Reference Manual, parties can add or deduct from their initial assigned amount, thus raising or lowering the level of their allowed emissions over the commitment period, by trading Kyoto units with other parties. These additions and subtractions took under the Kyoto mechanisms of emissions trading, joint implementation or the clean development mechanism. These mechanisms allowed the parties flexibility to meet their commitments by allowing them to take advantage of lower-cost emission reductions outside their territories. Later, in 2015 at the Paris Agreement, a new set of policies implemented during 2020 onwards. One of the differences is that developing countries are also setting reduction targets, and not only developed nations. One of the goals is to extend the reach and deepen the integration of carbon markets. Because by linking various trading schemes to a global carbon market will likely stabilize prices and, as a consequence, create more options to reduce carbon emissions.

The two main ways of pricing carbon: According to the World Bank, there are 2 main cornerstones of carbon pricing: emissions trading systems (ETS) and carbon taxes. The first, also known as a cap-and-trade system, caps the total levels of carbon and other GHG emissions. It works as a system where caps are increasingly reduced every year and where businesses with low emissions can sell the allowances they didn't spend to others who spend more than they were allowed to. This creates the supply and demand of the carbon market. On the other hand, carbon taxes set a direct price on carbon as they establish a tax rate on GHG emissions. Contrary to the cap and trade system, with carbon taxes, the emission reduction outcome is not pre-defined. Furthermore, there are also other indirect ways to price carbon such as taxing fossil fuels or removing fossil fuel subsidies. Trade policies where tariffs on solar or wind-generated electricity are reduced, or renewable portfolio standards where the electric grid has to be a mix with a minimum share of clean energy, are also alternative ways of pushing carbon emissions out.

How much is a carbon credit worth?

According to the Carbon Fund, a carbon credit is an instrument that represents ownership of one metric tonne of carbon dioxide equivalent (using CO_2 as a unit to measure different greenhouse gases) that can be traded, sold or retired. In this way, if a business is regulated by a cap-and-trade system, it will have the benefit of allocating, trading, selling or holding a carbon credit if it managed to keep its emissions below the top limit. On the other hand, if a business has used more than what it has been allocated with; it will need to purchase a credit to be in compliance or to pay heavy fines instead. Therefore, carbon credits turn into a tradable asset that allows measuring a reduction in polluting greenhouse gas emissions.

According to the World Economic Forum, the number of permits in the market is limited, since the total amount is an attempt to match the reduction target. At the start of a trading phase, emission licenses can either be bought at auction or allocated to businesses for free. As time goes by, the number of available licenses diminishes which contributes to putting pressure on the participating businesses to reduce their emissions and to invest in cleaner production alternatives. The goal is that in the long term the price of new and cleaner technologies decreases while innovation increases.

How do farmers get carbon credits?

Carbon credits are produced from different methods and industries. For carbon credits in agriculture, it can be generated from any of these five sources:

1. Managing peat lands
2. Agro-forestry
3. Maintain and enhance soil organic carbon on mineral soils
4. Livestock and manure management
5. Nutrient management on cropland and grasslands

For crop producers, in particular, credits are generated by shifting to carbon farming practices that enhance soil health and contribute to climate change mitigation by storing carbon in the soils. However, adopting carbon farming practices is just one step in the process to generate carbon credits in agriculture (IPCC, 2020).

Main steps to generate carbon credits in agriculture:

The steps listed below vary from one carbon program to another. There could be more or less same depending on requirements (Sun *et al*., 2015).

1. Begin by finding the right carbon program**:** Carbon farming takes commitment and engagement with the right partner from the start can impact the success of the endeavor. A good place to start is to connect with a carbon program provider that can guide you through with the right tools, expertise, and support. The right voluntary carbon credit program encourages farmers to implement certain agronomic practices designed to improve soil health, reduce greenhouse gas emissions, and/or enhance soil carbon sequestration. This should be collaborative, taking into consideration that each farm is unique and doesn't just default to rigid guidelines applied to all participating farms regardless of individual conditions. This stage is usually kicked-off with initial consultations to manage results and expectations. Once the farmer and the carbon program provider agree to the terms, the carbon credit program provider oversees the next steps hereafter to guide the farmer accordingly. The eAgronom Carbon Programme is the only carbon farming manager that offers payments at the start of the carbon program to help farmers manage outcomes and profits at an early stage.
2. Conducting an initial assessment of the farm: Carbon farming is a science-based approach to agriculture that deals with measurements and understanding data to get to know how change can be implemented best with verifiable results. As a nature-based solution to climate change, it is imperative to generate credits based on robust assessment. Different measurements are conducted at different stages of the engagement, but it is typically done at the start by gathering baseline information to understand the current condition of the farm. Gathering initial data on a farm can include the following:
   a) 3-5 years of historical farm data about crops grown, farm practices, yields, diesel usage, rate of fertilizer application, etc.
   b) Soil sampling

Setting the baseline for the farm is important because it guides what carbon farming practices are appropriate for the farm as well as measuring progress to properly account for carbon credits.

3. Designing a carbon farming practice plan: Upon assessment, the carbon program will recommend a set of agronomic practices which will enable the farmer to improve soil health, reduce greenhouse gas emissions, and enhance soil carbon sequestration, which subsequently leads to the generation of carbon credits. All farms are different and should have a custom carbon farming practice plan based on their

baseline assessment and goals. Expert agronomists will guide the crop producers on how to implement carbon practices. Here are 10 examples of carbon farming methods to implement in the field.

1. Reduced fertilizer application (use of bio-fertilizers, green manures, nano-fertilizers etc)
2. Reduced tillage (zero tillage, minimum tillage, conservation tillage etc)
3. Improved residue management (In-situ decomposition of sugarcane crop residues)
4. Eliminating bare fallows
5. Increased production of cover crops
6. Sowing companion crops
7. Agro-forestry
8. Improved task efficiency
9. Improved water management (DSR in paddy cultivation, alternatively alternate row irrigation in maize and cotton, 80% cut-off irrigation in wheat and chickpea etc).
10. Fuel-use efficiency (using solar operated machines).

4. Applying practice changes on the farm and recording data:After setting the guidelines and a practice to implement on the farm to achieve carbon credits, the next step is for the land manager to carry out the plan in the fields. Each carbon farming practice will have different requirements and will depend on actual conditions. It's worth highlighting how important proper data-keeping and tracking is at this stage. The aim is to achieve results through practice changes. And having measurable information guides in understanding how each practice contributed to successfully generating carbon credits. Or perhaps, when it's not working as originally planned, it's good to have data to review the practices that need to be amended or improved. Measurement, reporting, and verification are vital in generating carbon credits. Recording data can be tedious. But without it, it will be hard to tell if there's real carbon reduction or removal that happened. The eAgronom Carbon Programme provides an MRV system for the farmer to support farm management and track the progress of the practice changes. It's easy-to-use software which can be combined with other technologies such as remote sensing for a more robust data collection.

5. Verifying the results:This step makes sense of all the data gathered from practice changes applied on the farm to determine how it developed since setting the baseline data at the start. Calculations can include the amount of total CO_2 removals or reductions generated by the farm. The process of checking and verifying the farmer's data can be conducted by the carbon program provider or an independent verification body**.**

6. Earn certified carbon credits in agriculture: Following verification comes the issuance of carbon credits**.** Carbon credits are traded in a carbon market where buyers actively look for high-impact projects to complete their own emission reduction goals. Successfully trading carbon credits in agriculture results in a new revenue stream for farmers. It's worth noting that the prices of carbon credits change, and at the moment, they can trade anywhere between $10-90. The carbon credit market is expected to grow to reach a total value of up to $3.5 billion at the end of 2025.

Examples of carbon trading in India:

1. Jindal Vijayanagar Steel: Yearly it will be ready to sell $225 million worth of saved carbon. This was made possible since their steel plant uses the Corex furnace technology which prevents 15 million tones of carbon from being discharged into the atmosphere.

2. Powerguda in Andhra Pradesh: The village in Andhra Pradesh was selling 147 tonnes equivalent of saved carbon dioxide credits. The company has made a claim of having saved 147 MT of CO_2. This was done by extracting bio-diesel from 4500 Pongamia trees in their village.
3. Handia Forest in Madhya Pradesh: In Madhya Pradesh, it is estimated that 95 very poor rural villages would jointly earn at least US$ 300,000 every year from carbon payments by restoring 10,000 hectares of degraded community forests.

Challenges Associated with carbon trading in Agriculture:

1. Trade-off between income and carbon sequestration: The trade-off between the expected additional revenue from adopting a carbon abatement practice and its impact on crop yield is another challenge.
2. A farmer will adopt a carbon abatement practice if he expects that revenue from the sale of carbon credits would compensate for the loss in crop yield, if any, due to its adoption.
3. Such a trade-off may act as a disincentive to the large-scale adoption of carbon abatement practices.
4. Difficulty of accurately measuring and verifying carbon sequestration: This is due to the complex nature of the carbon cycle in soils and the difficulty of distinguishing the effects of specific farming practices from other factors such as weather and soil type.
5. Higher administrative and transaction costs: The existing agrarian structure in Indian agriculture is dominated by small landholdings usually differing in their cropping pattern and the adoption of carbon abatement farm practices.
6. Thus, reaching out to such a huge number of smallholders means higher administrative and transaction costs for buyers of the carbon credits.
7. Complex Regulations: The regulatory framework for carbon trading in India is complex and not yet fully developed, making it difficult for farmers and other stakeholders to participate in carbon markets.
8. Lack of accurate and consistent data: There is a lack of accurate and consistent data on carbon sequestration by agricultural practices, making it difficult to quantify and trade carbon credits.
9. Limited Demand: There is currently limited demand for carbon credits from the agriculture sector, making it difficult for farmers and other stakeholders to find buyers for their credits.
10. Lack of Awareness: Many farmers and other stakeholders in India lack awareness of the opportunities and benefits of carbon trading, and how to participate in carbon markets**.**

Reduction of greenhouse gas emissions: Adopting carbon abatement farming practices can help to sequester carbon in the soil, which can contribute to the reduction of

Soil Health Improvement: Many carbon abatement farming practices, such as conservation tillage and agroforestry, can improve soil health, which can result in increased crop yields and

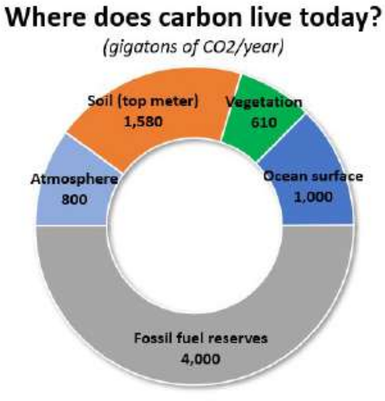
sustainable land-use practices: Carbon offset projects can provide an incentive for farmers to adopt sustainable land-use practices, which can help to conserve natural

Promote biodiversity: Some carbon abatement farming practices, such as agroforestry, can also help to promote biodiversity and support the survival of wild

Creating jobs and income-generating opportunities: It can also promote rural development, by creating jobs and income-generating opportunities in rural areas, and by supporting the

Additional Revenue: Participating in carbon offset projects can provide farmers with additional revenue through the sale of

Carbon Trading Opportunities in the Agricultural Sector (IPCC, 2017)



Sources: Dr. Terry McCosker, CarbonLink: https://carbonlink.com.au; University of Arizona's Hydrology and Atmospheric Sciences: atmo.arizona.edu

The-complex-world-of-carbon-credits

(Houghton *et. al*., 2022)

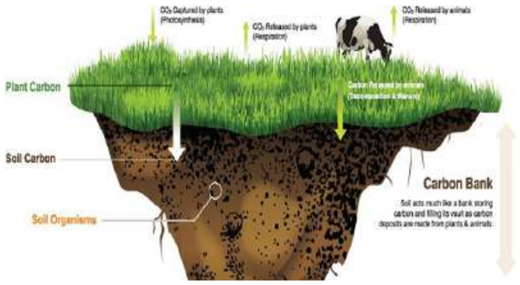
2030 Targets for sustainable food production

Reduce by 50% the overall use and risk **of chemical pesticides** and reduce use by 50% of more hazardous **pesticides**

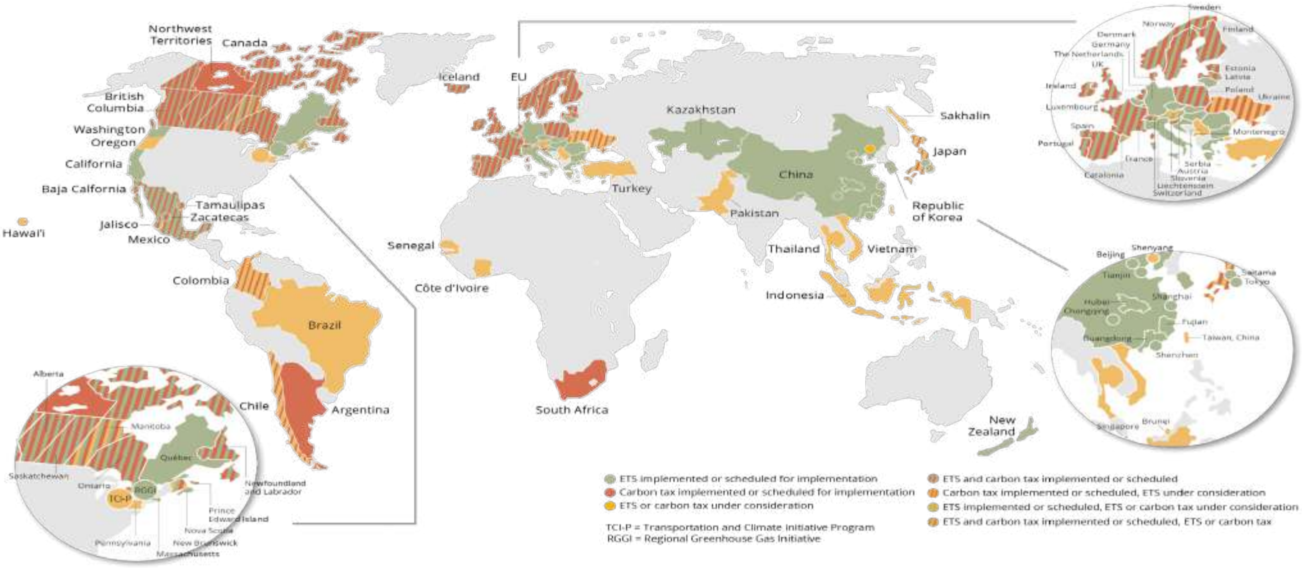
Reduce **nutrient losses** by at least 50% while ensuring no deterioration in soil fertility; this will reduce use of **fertilisers** by at least 20 %

Reduce sales of **antimicrobials** for farmed animals by 50%

Achieve at least 25% of the EU's agricultural land under **organic farming** and a significant increase in **organic aquaculture**



(Han *et. al*., 2022)



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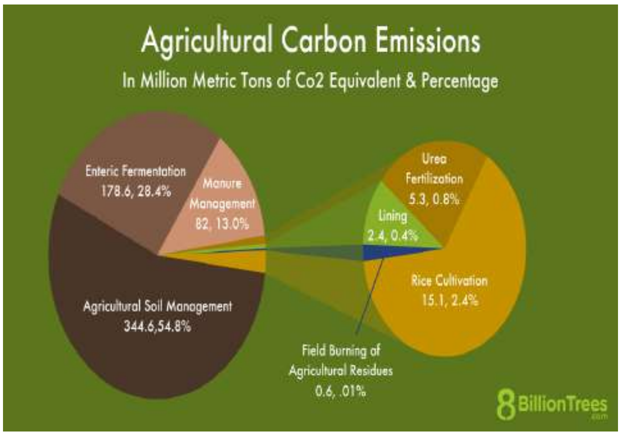

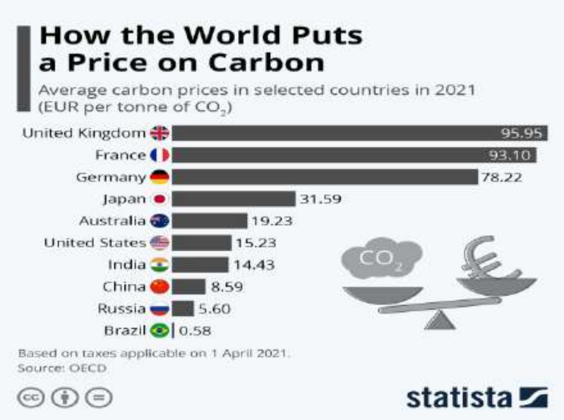

(Zhao *et. al*., 2016)

Conclusion

Apart from carbon credits, there are many ways farmers can leverage carbon farming to their advantage. And it goes without saying that successfully generating high-quality carbon credits in agriculture needs commitment. Finding the right carbon program can provide the needed tools and guidance throughout the process**.** The first step towards creating a market for sequestered carbon is to evolve a transparent process of quantification and verification of additional carbon generated by different farm practices. Artificial intelligence and remote sensing offer scope for assessing the quantum of sequestered carbon. Further, for an individual farmer, the process of selling carbon credits in the voluntary carbon market is tedious. Nonetheless, their participation in carbon trading can be facilitated by collectives such as FPOs and cooperatives that can organize farmers to adopt carbon abatement practices and sell the accrued carbon credits on their behalf. A few agro-techs companies, for example, Bhoomitra and Nurture farm, organize farmers through intermediaries tofacilitate their participation in voluntary carbon markets.

Finally, there is a need to create awareness among farming communities on the benefits of the adoption of improved agricultural practices and participation in carbon markets.

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Theme-IV :
Regenerative Carbon-Neutral Farming Systems
Invited/Oral Presentation

IP: 35 Building resilience with regenerative agriculture: Catalyzing soil carbon for green economic growth

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Abstract: Climate change poses significant challenges to agricultural systems worldwide, underscoring the urgent need for functional farming practices. Regenerative agriculture, as an emerging paradigm, offers a holistic approach to restoring resilience, revenue, ecosystem services such as improving soil health, and mitigating climate impacts through soil carbon sequestration and trade.

This lecture explores the transformative potential of regenerative practices in building resilience within farming systems. By adopting functional strategies, regenerative practices, bio-circularity, and soil carbon catalysts. These systems not only enhance soil carbon stocks and improve soil health but also drive green economic growth through carbon credit, green water management, and sustainable land use strategies.

Key takeaway of the talk include: (1) **Soil Carbon as a Cornerstone:** Unlocking the potential of soils as a major carbon sink to mitigate greenhouse gas emissions. (2) **Biochar Integration in Carbon Sequestration:** Enhancing soil fertility and carbon stability while contributing to circular bio-economies. (3) **Green Water in Drylands:** Evaluating green water budgets and enhancing on-farm water and in-soil moisture storage capacities to revive spring sheds. (4) **Catalyzing Green Economic Growth:** Unlocking opportunities in carbon trading markets and improving resource use efficiency to enhance income streams for farmers. (5) **Policy and Technology Synergies:** Leveraging AI-driven solutions, evidence-based case studies, and policies to facilitate the widespread adoption of regenerative practices and biochar trade mechanisms.

The discussion will feature real-world trends, living labs, and success stories of farmers adopting regenerative methods, illustrating their positive impacts on soil health, crop productivity, and environmental sustainability. This presentation will provide actionable insights for researchers, practitioners, and policymakers to advance carbon-neutral farming systems. Emphasis will be placed on the critical role of crop residues and activated biochar in regenerative agriculture as pathways to achieving sustainable development goals, ecological restoration, and fostering an inclusive green economy.

Keywords: Regenerative Agriculture, Soil Carbon Sequestration, Biochar, Green Water Management, Carbon Neutral Farming, Agro ecosystems

IP: 36 Bibliometric Insights into Biochar Research: Leveraging Biotechnology for Advancing Carbon-Neutral Agriculture

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Abstract: This bibliometric analysis explores the role of biotechnology in advancing biochar production, carbon sequestration, and carbon trading for carbon-neutral agriculture. Based on 4,103 PubMed publications (2006–2024), it highlights trends driven by climate change awareness and biochar's potential for carbon storage, soil enhancement, and environmental remediation. Emerging biotechnological applications, such as microalgae-derived biochar for water treatment, showcase innovation at the intersection of carbon capture and sustainability. Advances in pyrolysis technology and biochar's integration into carbon credit markets are also significant. With China leading global research, India and other nations focus on soil fertility, heavy metal detoxification, and climate resilience.

Introduction

Biochar, a carbon-rich solid derived from the pyrolysis of biomass, is an innovative solution to global agricultural challenges. It enhances waste management, water conservation, and climate change mitigation. Biochar's adoption aligns with sustainable practices that improve soil productivity, reduce greenhouse gas emissions, and enable carbon sequestration, contributing to environmental and food security(Chauhan *et al.*, 2024). This bibliometric analysis of biochar research reveals scientific advancements, applications, and global impact, offering insights into emerging trends and innovations in biotechnology for researchers, policymakers, and industry leaders working to address soil degradation, waste management, and climate change.

Material and Methods

A bibliometric analysis was conducted using 4,103 references retrieved from PubMed and organized with EndNote X9. Data analysis tools and R Programming were used to assess the trends in biochar research. The study focused on biochar's growth, emerging themes such as pyrolysis, soil amendment, and carbon sequestration, as well as the role of biotechnology in advancing biochar applications.

Results and Discussion

Biochar research has significantly increased since 2014 (Figure 1), driven by climate change awareness and its potential for carbon storage, soil enhancement, and greenhouse gas mitigation(Itam *et al.*, 2024). Key themes include biochar's role in improving soil fertility, microbial activity, and nutrient cycling. There has been a shift toward integrating biochar with other technologies for pollution control and resource optimization. China leads global research, with significant contributions from Pakistan, Australia, and India. Journals like Science of the Total Environment, Chemosphere, and Bioresource Technology highlight biochar's impact on environmental safety and resource management.

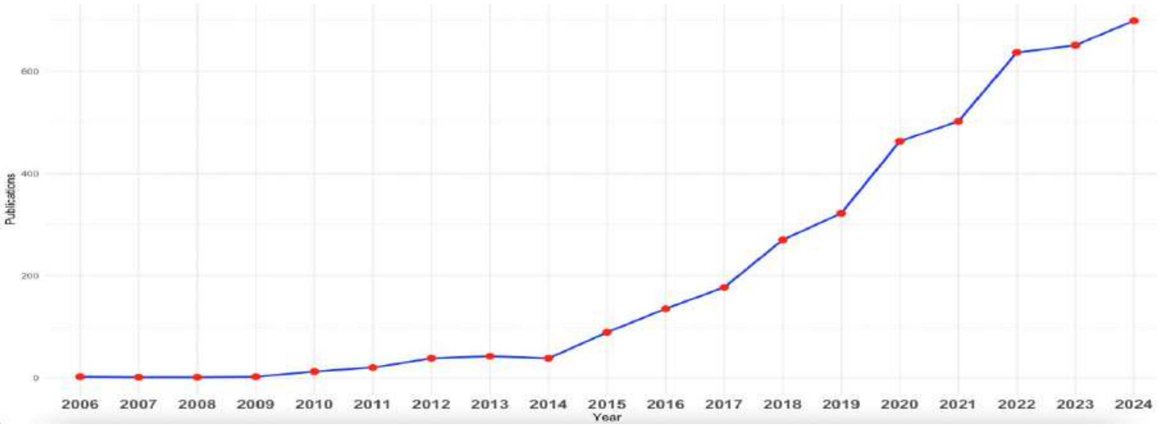

Figure 1. Trends in the number of publications on biochar research (2006–2024)

Biotechnology has revolutionized biochar production, particularly through the development of biochar from microalgae, focusing on carbon sequestration and environmental remediation. Genetic engineering, including CRISPR-Cas9(Chang *et al.*, 2020), enhances algal strains to improve biochar yields (Badiefar *et al.*, 2023). Engineered microalgae are also used in phycoremediation to remove heavy metals and treat wastewater, offering sustainable pollution solutions. Biotechnology also aids in creating biochar-based fertilizers and soil amendments that boost soil health and crop productivity, with biochar stimulating plant growth hormones like auxins and brassinosteroids to improve agricultural efficiency.

Innovations in biochar production, such as advanced pyrolysis techniques (slow, fast, catalytic, and microwave-assisted), have improved biochar's quality and utility. Microalgae and cyanobacteria are valuable renewable feedstocks for biochar, addressing both waste disposal and carbon sequestration. Biochar's applications extend beyond pollution control to renewable energy, where its high surface area and graphitic structure make it suitable for supercapacitors and CO_2 adsorption. It also enhances soil properties, such as porosity and cation exchange capacity, and effectively removes heavy metals from soil and water.

Despite the advances, challenges in scaling biochar production, ensuring cost-effectiveness, and maximizing its benefits across ecosystems remain. Future research should focus on optimizing feedstock efficiency through metabolic engineering, addressing large-scale deployment gaps, and fostering interdisciplinary collaborations to drive innovation and policy development. Biotechnology-driven advancements offer significant potential for biochar in sustainable agriculture, environmental protection, and carbon management.

In conclusion, biochar research, advanced by biotechnology, has expanded its applications in carbon sequestration, soil improvement, and pollution control. While progress has been made, further efforts are needed to overcome challenges in production and cost-effectiveness to maximize biochar's potential in sustainable agriculture and climate change mitigation.

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IP: 37 Biochar for sustainable agriculture

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The first green revolution during 1970's was possible with high yielding varieties of rice and increased area under cultivation. However, excessive use of fertilizers and pesticides continuously over a period of time, with little or no application of organic manures have resulted in soil with multi nutrient deficiencies, depletion of soil organic carbon, deterioration of soil health, new pests and diseases, global climate change posing a threat to sustainable agriculture. In addition, exponential population growth, soil degradation, water scarcity, food security and nutritional security pose a threat to sustainable development. Moreover, the current unsustainable practices are enhancing the vulnerability of microbial communities are detrimental to fragile ecology and environment.

To meet these challenges, and one of the ways to increase the productivity and income per unit of scarce natural resource, is through the effective use of improved technology. It is in this context, biochar and its use in agriculture seeks to address the problem and has the potential to combat the problems in the areas of agriculture, water energy health, environment and ecosystem.

Biochar has multiple uses in a number of processes and in daily activities. Biochar can be used for water treatment, air quality, soak pits, insect repellants, food and food preservatives, medicines, cleaning and finds a huge applications in agriculture.

In the agricultural systems, biochars can be used in a number of ways like carbon sequestration and immobilization, regulation of soil temperature increased moisture retention, water conservation, retention of nutrients on the surface, adsorption of pesticides, organic contaminents and reduced heavy metal pollution, soil microbial biodiversity etc., Since the details of preparation of biochar using different feedstocks, processes involved in biochar production, storage of biochars have a definite influence on the properties of biochar, the properties of biochar which have a definite influences on the soil properties are presented in this lecture.

The physical properties of biochar i.e., particle size, bulk density porosity, surface area, hydrophobicity, water holding capacity have a beneficial effects in improving the physical properties like reducing bulk density in sandy soils, increase in soil moisture retention, lessening of hardening of soil increased CEC of soils and in reclamation of problem soils.

Most of the biochars reported is in literature have alkaline pH, high electrical conductivity, act as storehouse for plant nutrients. On application to soil, it reduces acidity and increases pH, retains nutrients against leaching losses, improves soil fertility, availability of nutrients, mitigates the hazardous effects of pesticides and toxic heavy metals.

Among the biological properties, application of biochar increases soil microbial respiration, increases soil biodiversity in the presence of carbon and increases population of mycorrhyzae. Biochar can be used a carrier for a number of microbial inoculants. Owing to large surface area and easy surface modifications, biochars could be used widely as adsorbents. These are low cost technology products,, their use could be regulated and their disposal is less troublesome.

However, the research work done on use of biochar in agriculture, especially under Indian conditions is scanty and not capable of arriving at any conclusive evidences. The future thrust areas for research include quality testing, standardization

- Integration of biochar production and exploration locally in likely to be more sustainable than based such conducted production.
- Role of policy makers, civil societies, mass media and other stakeholders in very important.
- Documentation of traditional biochar practices
- Formulation of strigent laws to prevent exploitation of biomass and ensure efficient use.
- Inefficient biochar technologies to be phased out and technologies by which small and marginal farmers can produce their own biochar should be encouraged
- Need to standardize biochar products for application to different types of soils , crops and cropping systems in different agroclimatic zones.
- Use of biochars as a decontaminants,, in household activities, conditioners, purifiers.
- Need to study in detail the properties of biochars obtained from different feedstocks, by different methods, effects of aging of biochars on their properties, use of biochar is non-agricultural systems, in the environmental sciences, health, energy, need to be established
- Efforts should be made to use biochar as one of the treatments in the ICAR project on Long term fertilizers effects.

Use of Biochar as a part of organic farming practices and integrated nutrient management practice in crops and cropping system.

OP: 38 Restoration of degraded lands with fruit-based systems to achieve carbon neutrality and land productivity in Semi-Arid conditions

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Abstract: Globally, 33% of the land area is degraded due to various causes. Addressing these issues is crucial for achieving COP-26 goals, such as net-zero emissions, limiting global warming to 1.5°C, and enhancing carbon (C) sequestration by 2030. A 2012–2022 study rehabilitated degraded basaltic landscapes using engineering, mechanical, and agronomic methods to establish mango, pomegranate, and coconut plantations, transforming barren land into productive systems, increasing C stocks, reducing greenhouse gas (GHG) emissions, and improving ecosystem services. The establishment phase emitted the most GHGs (67.25%), mainly from diesel use. Mango plantations had the highest emissions (31.88 Mg CE/ha) but also the largest C stock (91.29 Mg C/ha) due to enhanced biomass and soil quality. Despite high initial emissions, all systems achieved net-positive GHG mitigation, with mango plantations offering the highest potential (164.2 Mg CO2-eq./ha). Pomegranate was the most profitable, with a benefit-cost ratio of 4.95 and a land expectation value over eight years. Rehabilitating degraded lands into fruit production systems promotes carbon neutrality, ecosystem restoration, and sustainable development in semi-arid regions.

Keywords: Carbon sequestration, fruit production, land degradation neutrality, land productivity and restoration practices.

Introduction

Global agri-food systems face increasing pressure from climate change, driven by rising greenhouse gas (GHG) emissions and land degradation (IPCC, 2021). CO_2 levels have risen from 278 ppm in 1970 to 415 ppm in 2021, primarily due to fossil fuel use and deforestation. Agriculture, forestry, and land-use systems contribute 23% of global GHG emissions annually, making it the second-largest emitting sector (Pathak, 2023). With the population projected to reach 10 billion by 2050, intensive farming practices will likely increase emissions and worsen land degradation, which already affects 33% of global land, impacting three billion people and nearly half the global GDP (Potts *et al.,* 2016). In India, 30% of land is degraded, with 26 million hectares of shallow soils suffering from low fertility, erosion, and organic matter loss. Techniques like nutrient-rich pit filling and planting resilient species show promise for enhancing productivity and soil carbon (C) stocks. Integrating trees further boosts soil organic carbon (SOC), sequesters CO_2, and provides ecosystem services like C credits and oxygen (O_2).

India's COP-14 pledge to achieve land degradation neutrality by 2030 highlights the need for eco-friendly practices. Restoring degraded lands can improve crop yields, sequester CO_2, and generate C credits, despite GHG emissions from intensive practices like fertilization. Initiatives like India's GROW program aim to restore 26 million hectares by 2030, creating an additional C sink of 2.5–3 billion tonnes. Degraded lands in Asia could sequester 2,156 million tonnes of CO_2 annually and generate $214 billion in C credits (Anon., 2015). A 2012–2022 study on fruit production in degraded basaltic lands evaluated carbon sequestration, GHG mitigation, and profitability (via fruit yields, C credits, and O_2 supply), offering scalable solutions for climate resilience and land restoration.

Material and Methods

2.1 Study location details: A long-term study was initiated in 2012-13 at the Research Farm of ICAR-National Institute of Abiotic Stress Management (NIASM), Baramati, Maharashtra. The study site is located in the Deccan Plateau agro-ecological region, the area experiences a hot, sub-arid climate with an average annual rainfall of 576 mm (Harisha *et al.,* 2023). The study included fruit crops like mango (variety 'Kesar'), pomegranate (variety 'Bhagwa'), and coconut (variety 'Banawali WCT'). Pits were filled with a mix of native soil, black soil, and farmyard manure (FYM) in a 1:1:1 ratio before transplantation (2013-14).

2.2 Wood and Soil Carbon Estimation: Dried samples (leaves, stems, branches, and roots) were powdered, and carbon content was measured using the traditional ash method in a muffle furnace. Soil organic carbon (SOC) content was determined at depths of 0–5 cm, 5–15 cm, 15–30 cm, and 30–60 cm.

2.3 GHG Budgeting and net GHGs mitigation: Data on direct and indirect inputs from 2012–13 to 2021–22 were used to calculate carbon equivalents (CE). Total C output was determined by multiplying total biomass (stem, branches, leaves, stumps, coarse roots, and fine roots) by the corresponding C content. The net GHG mitigation was determined by subtracting the total C sequestered (from trees, soil, and pruned biomass) from the GHG emissions produced by inputs and operations during land transformation and fruit cultivation.

2.4 Economic Analysis: Economic performance over eight years was evaluated, with costs divided into establishment (A) and operational (B) costs. Key metrics, such as net returns, net present value (NPV) at a 12% discount rate, internal rate of return (IRR), and benefit-cost ratio (BCR), were calculated.

Results and discussion

***3.1 C footprints and GHG's mitigation potential of fruit production systems*:** Among the systems, mango showed the highest GHG mitigation potential due to its greater biomass (30.18 Mg CE / ha) and soil C stock (26.80 Mg CE / ha), surpassing coconut by 38.30% and pomegranate by 58.24%. Although pomegranate maintained relatively high biomass and soil C stocks, its potential was lower due to increased GHG emissions from fertilizer use. Overall, fruit orchards significantly enhance net C sequestration on degraded lands, ranging from 68.59 to 164.25 Mg CO_2-eq. / ha, despite initial heavy machinery use. Conversely, pomegranate was the least efficient, with lower biomass (9.61 Mg C/ha), soil C stocks (20.91 Mg C / ha), and higher emissions, leading to a 57% greater C footprint than mango and 66.66% more than coconut. These results highlight the need for improved management practices for pomegranate to enhance its C sequestration and environmental performance.

***3.2 Economic returns of fruit production systems*:** The economic evaluation of fruit production systems, considering fruit supply, carbon credit earnings, and oxygen production, highlighted pomegranate as the most profitable. Pomegranate yielded the highest net returns (60,840 USD / ha) and benefit-cost ratio (4.95), driven by substantial fruit income, moderate C credit earnings (1,030 USD/ha), and oxygen production (2,066 USD / ha). These findings demonstrate that fruit-based systems on degraded lands not only enhance farmers' income through improved yields and ecosystem services but also support sustainable land management and environmental conservation.

Conclusion

Developing sustainable systems to enhance C stocks, offset GHG emissions, and reduce C footprints is essential. The National Institute of Abiotic Stress Management has pioneered techniques like soil excavation and enrichment, successfully rehabilitating barren lands, improving fruit crop yields, and boosting carbon sequestration. Despite initial emissions, these systems achieve a net GHG benefit of 111.4 Mg CO_2-eq. / ha, demonstrating the potential of converting degraded basaltic lands into productive fruit-based systems.

Table 1. Carbon budgeting in mango, pomegranate and coconut based systems.

Crops	Carbon indicators		
	Carbon efficiency	Carbon sustainability index (CSI)	Carbon footprint (kg CE/kg biomass)
Mango	3.31b	2.31b	0.09b
Pomegranate	1.26c	0.26c	0.21a
Coconut	5.37a	4.37a	0.07b

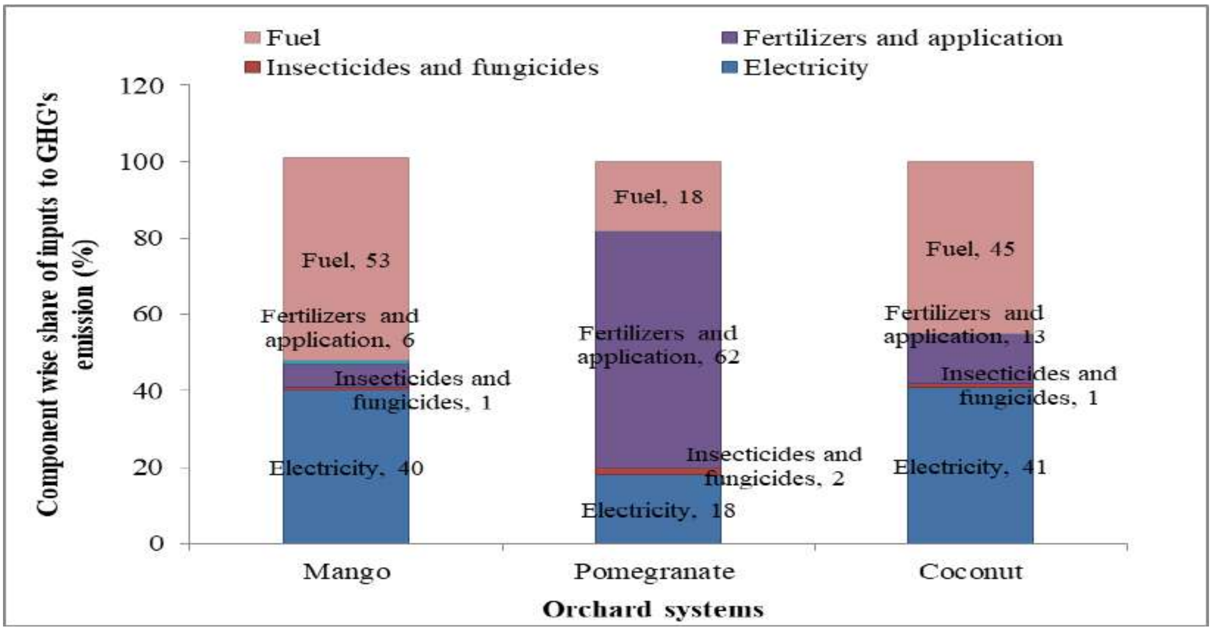

Fig. 1. Share of major inputs (%) to GHG's emission in mango, pomegranate and coconut systems.

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PP: 39 Journey of Pyrolysis from Lab-scale to Commercial scale and Development of valuable products from Paddy stubble/straw waste

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Pyrolysis is the process of thermal degradation in the absence of oxygen at desired high temperature with the production of useful products. Today there is a need for user friendly unit which is easy to install and is cost effective. The main idea behind it is to minimise agricultural waste pollution and produce useful products. Today the need of the hour is carbon rich soil. Initial studies at the University of Agricultural Sciences, GKVK, Bengaluru were conducted on a 20kg lab-scale pyrolysis unit (Fixed bed vertical pyrolyser). Raw materials used as feed stock included different agricultural wastes (red gram straw, sunflower stalks, corn cobs, Pongamia fruit husk, Calophyllum fruit husk…etc). The temperature was maintained from 300°C to 500°C and the quantity of Biochar, Biooil and Syngas produced varied based on the temperature maintained.

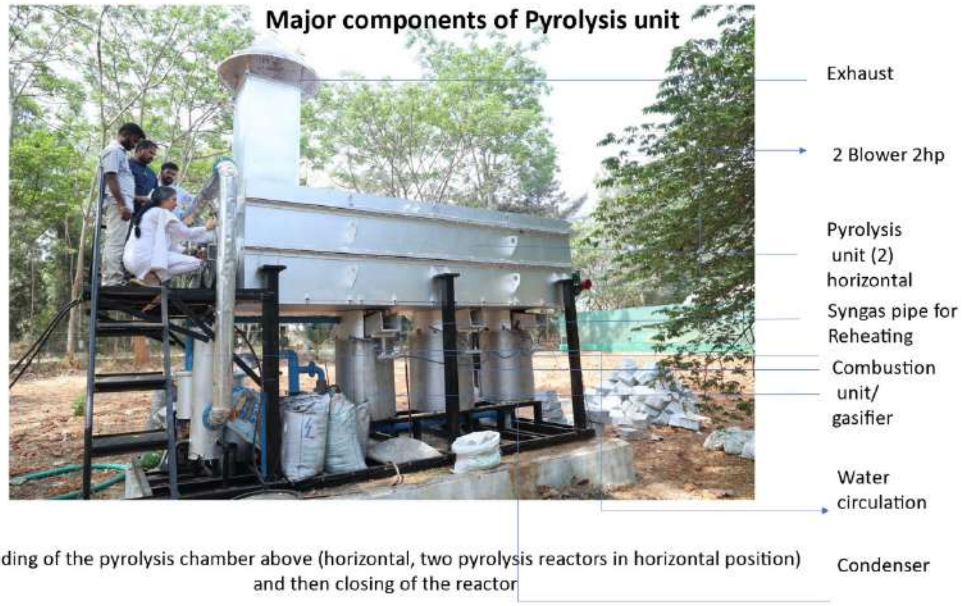
Complete proof of concept was established and the results obtained showed that for 3 kg of paddy straw waste added, maximum biochar obtained was about 1.4 kg and bioil was about 1 Litre ; temperature was maintained at 500°C.

The Department of Sceince& Technology (DST) funded GKVK to study the feasibility of Pyrolysis in field conditions and to conduct field trials of biochar. In March 2024, 500 Kg/day Pyrolysis unit was delivered to GKVK after multiple trials were conducted at the industry site in Pune

The major components of Pyrolysis unit include

- Exhaust,
- 2 Blower (2HP),
- 2 Pyrolysis chambers ,
- Syngas pipe for reheating
- Combustion Chambers (3 nos)
- Water circulation around combustion units.

The Combustion chambers power the Pyrolysis unit. Combustion chambers in turn are being powered by the syngas and the biomass feed. Syngas coming out of the pyrolysis unit in blue pipe is reheating the unit.Electricity is used, except for the blowers and water motor. Biooil and Biochar is produced. The picture below shows the major components of the 500 Kg/day Pyrolysis unit.



Feeding of the pyrolysis chamber above (horizontal, two pyrolysis reactors in horizontal position) and then closing of the reactor

Observations

Time for one run = 12 hours (1 hour feeding biomass to pyrolysis unit,
8 hours operation,
2 hours cooling,
1 hour Biochar collection).

Unit capacity = 200 kg.

Runs/Day = 2

Max capacity/day = 400 kg/day (Needs to be optimised).

Results:

Sr No	Materials/ products	1st Trial	2nd Trial
1	Biomass Rice straw filled in 2 pyrolysis unit (unit1 + unit2)	169kg (82+87kg)	188.9kg (92.4+96.5kg)
2	Briquettes used/other biomass	791 kg	766 kg
3	Oil obtained	15 L	20 L
4	Biochar production	68 kg	77kg

Conclusion

Around 35 -40% of biochar production is observed and 7 -10% of biooil is being produced and the syngas being produced is utilized in the pyrolysis process itself.

Theme-IV : Regenerative Carbon-Neutral Farming Systems

Poster Presentation

PP: 40 Experiences of ICAR Taralabalu KVK in Educating Farmers Through Establishing Demonstration Units For Carbon Sequestration

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Abstract: Carbon sequestration units in KVK campuses involve a combination of natural, agricultural, and technological methods. Agro-forestry systems increase and store carbon stocks in soil and above ground biomass, reducing vulnerability to climate change. Conservation tillage enhances soil fertility and mitigates climate change by serving as a natural carbon sink. Fruit trees contribute to carbon sequestration through above-ground biomass and below-ground soil carbon storage. Cover crops enrich soil organic carbon, while mulch protects it from microbial decomposition. IFS combines various agricultural enterprises to maximize productivity, reduce waste, and promote ecological balance. Soil amendment practices and carbon content accumulation lead to reduced soil chemical parameters and increased organic matter, resulting in increased coconut palm yields.

Introduction

ICAR-Taralabalu Krishi Vigyan Kendra, Davanagere is established under the aegis of Tararalabalu Rural Development Foundation, Sirigere and ICAR, New Delhi Since 2005. Krishi Vigyan Kendra is striving hard to make farming a comfortable and profitable venture for farming community. It is carving niche for itself in the hearts of people of Davanagere district through its committed services. Krishi Vigyan Kendra has reached 456 villages out of 810 villages through at least one or more extension activities. Carbon sequestration is a critical practice for mitigating climate change, and implementing it on a Krishi Vigyan Kendra (KVK) campus offers several environmental, educational, and operational benefits. Establishment of demonstration units related to carbon sequestration have the significant impact on the climate change mitigation strategies like carbon sink creation, promoting sustainable agricultural practices, enhancing ecosystem services like biodiversity conservation and soil health management etc.

Materials and methods

Establishing carbon sequestration units in a KVK campus involves planning and implementing a combination of natural, agricultural, and technological methods. The demonstration units pertaining to this has been established over the years. A trench of 4x4 feet is created block wise and surrounding on all four side for soil and water conservation. The demonstration units established for the carbon sequestration in the KVK campus are

Establishment of Agro-forestry system and Miyawaki Mini Forest: Establishment of Miyawaki Mini Forest ecosystem also helps in creating diverse biodiversity ecosystem in the campus.8000 plants of diverse forest species are placed since 2019.

Conservation Tillage through Natural farming: Established one acre mixed fruit orchard in the kvk campus comprising of more than 40 fruit species and 150 plants under natural farming techniques. Mixed orchard system include species like Mango, Custard Apple, Jamun, Jack fruit, Cashew, Water Apple, Rose Apple, Carambola, Ramphal, Lakshman Phal, Mangoateen, Elephent Ear Fig, Pommelo, Ber, Anola, Guava, Sapota, Hog plum, Wood Apple, Bael, Spice crops etc.

Cover Cropping: The demonstration units like Mango and Arecanut orchards are planted with green Manuring plants like Velvet Beans, Dhaincha, Sunhemp and aurogreen technology. These crops can be incorporated in the soil at the suitable time to enable the soil to get the fixed atmospheric nitrogen through root nodules.

Mulching: Mulching(both wet and dry) plays an important role in enhancing carbon sequestration in agro ecosystems by improving soil organic matter content and creating conditions favourable for carbon storage. This is continuously practiced using agricultural residues in the farm. Coconut fronds, husk, tree branches are used for mulching.

Composting: Vermicomposting and composting of Arecanut husk units have been established. The decomposed compost is used regularly for the KVK demonstration units to increase the soil fertility status.

Integrated farming system: It plays a vital role in carbon sequestration by combining diverse agricultural practices into a synergistic system. IFS integrates crop production, livestock(Dairy with 4 cows), aquaculture, agroforestry, and other enterprises to optimize resource use and increase sustainability, while also enhancing carbon storage in biomass and soils.

Biogas unit: A biogas unit contributes to carbon sequestration and climate change mitigation by capturing and utilizing organic waste to produce biogas, a renewable energy source. **Estimating Organic carbon in the soil:** Estimating the organic carbon in soil involves determining the amount of carbon present in soil organic matter (SOM). Soil organic carbon (SOC) is typically expressed as a percentage of the soil's dry weight and is a crucial indicator of soil health, fertility, and carbon sequestration potential. Walkley-Black Method (Wet Oxidation) used for estimating the same.

Results and Discussion

KVK campus Kadalivana instructional farm land fertility level was poor in the beginning. Therefore several interventions were aimed at improving the soil health status.

Establishment of Agro-forestry system (AFS) and Miyawaki Mini forest: A mini forest with 1000 plants was created within a year. Two more units were established with 3500 plants in each during the follow up years. According to Ramachandran Nair (2010), agroforestry practitioners, who are usually resource-poor farmers in underdeveloped nations, might profit by trading sequestered carbon.

Conservation Tillage through Natural farming: After planting over 40 fruit species, the one-acre orchard was farmed naturally. Only mulching and irrigation are used in the orchard, with light branch pruning. According to Gaurav Varma *et al*. (2024), conservation agriculture and organic farming can improve food security without harming the environment.

Cover cropping and Mulching: Cover crops are planted for soil cover rather than harvest. Cover crops' roots and branches break down into organic matter, replenishing soil organic carbon. Cover crop roots form soil aggregates, trapping organic carbon from microbial breakdown. Straw and crop wastes are used to mulch soil. Mulch protects soil from microbial degradation and carbon loss. According to Shivangi Singh et al. (2024), organic materials like manure, soil minerals, compost, poultry waste, leftover plant parts, biochar, and proper farming methods like mulching, planting cover crops, managing nutrients, and using mulch effectively are important.

Integrated Farming System (IFS) and Biogas Unit: It comprises of different cropping systems like intercropping and multi storied cropping systems in our KVK. Agri and Horticulture crops with small dairy unit, aquaculture pond are established. Biogas units capture methane (a potent greenhouse gas) from anaerobic digestion of organic waste, preventing its release into the atmosphere. The use of biogas as a renewable energy source offsets fossil fuel use, reducing overall carbon emissions. Integrated farming system (IFS) is an environmentally friendly method that uses products or waste from one field as input from another, according to Ananya Mishra (2023).

Estimation of Organic carbon and Productivity of perennial crops

Table 1. Details of Soil test results in KVK Farm

Sl.No	Particulars	2016	2018	2020	2022	2024
1	p^H	8.04	7.84	7.77	7.52	7.13
2	Electrical Conductivity(dSm^{-1})	1.21	0.83	0.80	0.64	0.42
3	Organic carbon (%)	0.13	0.28	0.34	0.41	0.58

The soil chemical parameters like p^H has been drastically reduced to normal from 8.04 to 7.13 because of continuous efforts of soil amendment practices and also through the accumulation of carbon content in the soil. Even the same trend was noticed with respect to salt accumulation content (1.21 to 0.42). There will be considerable increase in the organic matter in the soil which resulted in the increase in the organic carbon content of the soil. Due to this impact, the yield of coconut palms in the farm was increased from 75 nuts per palm to 182 nuts per palm per year. Mixed fruit orchard, Jack and Jamun separate plots have started bearing since two years and yet to reach economic yield levels.

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PP: 41 Effect of jeevamrutha on yield, organic carbon and major nutrient availability in soil of China aster (*Callistephuschinensis* [L.] Nees.)

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Abstract: A field experiment was conducted to study the effect of jeevamrutha on yield, organic carbon and major nutrient availability in soil of China aster (*Callistephuschinensis* [L.] Nees.)at the Department of Floriculture and Landscape Architecture, K. R. C. College of Horticulture, Arabhavi, Belagavi, Karnataka. Jeevamrutha application @ 1500 liter per hectare at an interval of 7 days (D_3F_1) was recorded significantly higher soil organic carbon content (0.85%), available nitrogen (254.20 kg/ha), available phosphorus (58.80 kg/ha), available potassium (489.08 kg/ha) and higher flower yield (8.06 t/ha) among the jeevamrutha treatments. However, integrated nutrient management was found superior to all other treatments for all the soil parameters and yield (10.76 t/ha).

Key words: China aster, jeevamrutha, dosage, frequency, nutrient availability

Introduction

The global shift towards eco-friendly agricultural practices highlights the importance of sustainable flower cultivation. The excessive use of fertilizers and pesticides in conventional farming has led to numerous challenges for farmers, making the adoption of natural farming methods crucial for improving soil health and ensuring sustainable yield. China aster (*Callistephuschinensis* [L.] Nees.)is an important flowering annual, this is one such crop that benefits from these practices. While some farmers have begun implementing natural farming techniques, the inputs they use; beejamrutha, jeevamrutha, neemastra, agniastra and brahmastra are not yet standardized. Jeevamrutha and ghanajeevamrutha, made from desi cow dung and urine are rich in macronutrients, vitamins, amino acids, growth regulators like IAA and GA and beneficial microorganisms. Regular application of jeevamrutha can enhance soil biological activity and promote mineralization. The objective of this study was to examine how jeevamrutha influences nutrient availability, specifically nitrogen (N), phosphorus (P), and potassium (K), in China aster cultivation.

Material and Methods

Present study was carried out at Kittur Rani Channamma College of Horticulture Arabhavi, Karnataka, India under the University of Horticultural Sciences, Bagalkot during *Rabi* 2020-21 and *Kharif* 2021-22 under irrigated condition. The experiment was laid out in Factorial Randomized Block Design (FRBD) with fourteen treatments (3×4+2) and three replications. Factor-A includes D_1: 500 litre/ha, D_2: 1000 litre/ha and D_3:1500 litre/ha, Factor-B includes F_1: Once in week (7 days), F_2: Once in two weeks (14 days), F_3: Once in three weeks (21 days) and F_4: Once in four weeks (30 days). There were 12 treatment combinations of dosage and frequency of jeevamrutha. These treatment combinations were compared with INM: Integrated nutrient management (50% RDN through FYM (9t/ha) + 50% RDN through inorganic fertilizer (45 kg N/ha) +120 kg P/ha + K @ 60 Kg/ha + 20t FYM/ha+ *Azospirillum* @ 2.5 kg/ha + PSB @2.5 kg/ha and RPP: Recommended package of practice (NPK @ 90:120:60 kg/ha +20t FYM/ha). Totally there were 14 treatments under the study. The soil samples were collected from each treatment for nutrient analysis after the harvest. Available nitrogen in the soil sample was determined by the alkaline potassium permanganate method. Available potassium in soil was determined by extracting with neutral normal ammonium acetate (pH 7.0) at 1:5 soil to extractant ratio and the potassium in the extract was measured using a flame photometer (Jackson, 1973). Organic carbon content in soil (%) was measured by Walkely and Black method.

Results and Discussion

Soil organic carbon promotes soil structure or tilth (physical stability). This improves soil aeration and water drainage which helps to balance nutrient uptake by the crop. In pooled data, significantly maximum soil organic carbon content was recorded in treatment D_3F_1 (0.85%). These significant changes might be attributed to the decomposition of organic matter applied in the form of mulching material and Ghana jeevamrutha. Application of liquid jeevamrutha applied at frequent intervals helps to increase the biological activity in the soil which ultimately changed the physico-chemical properties of soil. Similar results were obtained by Chaithra (2021).

Table 1. Organic carbon (%), Nitrogen, phosphorous and potassium availability (kg/ha) and yield (t/ha) in plant of China aster var. AAC-1 after harvest as influenced by dosage and frequency of liquid jeevamrutha

Treatments	OC (%)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Flower yield/ hectare (t)
D_1 F_1	0.67^{de}	243.60^{a}	44.67^{de}	452.32^{cd}	6.02^{de}
D_1 F_2	0.65^{def}	222.95^{ab}	41.40^{ef}	438.05^{de}	5.75^{e}
D_1 F_3	0.62^{ef}	177.73^{c}	39.72^{f}	383.45^{h}	5.65^{f}
D_1 F_4	0.57^{ef}	166.37^{c}	36.97^{f}	281.18^{i}	4.62^{g}
D_2 F_1	0.77^{abc}	249.54^{a}	57.19^{a}	482.56^{a}	7.11^{b}
D_2 F_2	0.70^{bc}	241.04^{a}	54.88^{ab}	457.35^{c}	5.93^{de}
D_2 F_3	0.63^{def}	176.17^{c}	53.85^{cd}	403.85^{gh}	5.82^{h}
D_2 F_4	0.62^{e}	166.25^{c}	42.10^{d}	393.82^{fg}	5.78^{h}
D_3 F_1	0.85^{a}	254.20^{a}	58.80^{a}	489.08^{a}	8.06^{a}
D_3 F_2	0.82^{a}	245.20^{a}	55.75^{ab}	450.70^{cd}	6.59^{c}
D_3 F_3	0.73^{abc}	231.93^{ab}	53.99^{ab}	434.33^{e}	6.32^{cd}
D_3 F_4	0.63^{de}	215.34^{c}	50.93^{cd}	407.00^{f}	5.83^{e}
S.Em±	**0.03**	**6.36**	**1.12**	**3.68**	**0.13**
C.D. @ 5%	**0.09**	**18.66**	**3.30**	**10.79**	**0.39**
INM	0.68	256.89	64.72	505.21	10.76
RPP	0.57	238.39	52.74	478.73	10.09
S.Em±	**0.03**	**6.76**	**1.25**	**4.00**	**0.25**
C.D. @ 5%	**0.09**	**19.65**	**3.63**	**11.63**	**0.76**

Significantly maximum available nitrogen, phosphorus and potassium was recorded in the treatments D_3F_1 (254.20, 58.80 and 489.08 kg/ha, respectively) in pooled data. When interaction treatments were compared with RPP and INM, INM was recorded highest nutrient availability than other interaction treatments (Table 1). In the present investigation, the variation in nutrient availability due to different dosages, frequency and interaction treatments of liquid jeevamrutha was estimated after harvest. The analysis revealed that jeevamrutha applied at higher dosage (1500 l/ha) with frequent interval of once in 7 days indicated more availability of nitrogen, phosphorous and potassium in soil. The increased availability of nutrients was due to enhanced population of soil micro flora resulting in increased bacteria, fungi, actinomycetes population in the soil and also might be due to increased earth worm activity in the soil which helps faster decomposition of organic matter (mulching material used in all the treatments except RPP and INM) which ultimately add the nutrients to the soil. Similar results were reported by Chaithra (2021). Comparison of interaction treatments with RPP and INM showed that, slow release of organic manures due to application of jeevamrutha in the soil helps in more nutrient availability. In spite of using chemical fertilizers, the available N was found low in NPK treated soil which might be due to leaching and volatilization losses (Prativa and Bhattarai, 2011).

Conclusion

It can be concluded that, application of liquid jeevamrutha @ 1500 litre per hectare once in 7 days recorded higher organic carbon, nutrient availability and flower yield among all other jeevamrutha treatments. However, yield in INM and RPP was found higher than the natural farming treatments. Hence, for cultivation of China aster under natural farming, application of liquid jeevamrutha @ 1500 litre per hectare once in 7 days can be recommended for farmers as an alternative to chemical farming.

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PP: 42 Evaluation of foliar spray of IFFCO Nano urea on productivity of Rice

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Abstract: Excessive use of conventional fertilizers for improving crop yields often results in low nutrient use efficiency, higher costs, soil degradation, and environmental harm. Nanotechnology promises enhanced efficiency and reduced environmental impacts due to their unique properties. Nano-N fertilizers, such as Nano urea, developed by IFFCO, India is the center of attraction these days. This study evaluated the effects of foliar application of IFFCO nano urea on rice productivity during *Kharif* 2021 and 2022 at PAU Ludhiana. Results showed that 100% recommended nitrogen dose (RDF) produced the highest grain (75.3 q/ha) and straw (91.5 q/ha) yields, while the two sprays of IFFCO nano urea with 50% basal nitrogen reduced yields by 15.3% and it was less effective than 100% RDF.

Keywords: Rice, IFFCO nano urea, Nanotechnology, Yield

Introduction

Global agricultural production has made incredible strides, but there are still a number of problems that must be tackled in order to achieve food security and environmental sustainability. To improve crop yields and feed the rapidly growing world population, conventional fertilizers are being utilized in excess and disproportionate amounts. However, excessive fertilizer application does not always result in consistently greater yields, which leads to low nutrient consumption efficiency (Yousaf *et al.*, 2017). Excessive fertilizer use can raise input costs, contribute to soil acidity, and possibly cause the release of greenhouse gases.

The goal of environmental friendly fertilizers is currently being pursued through the use of nanotechnology, which scales down the material structure to nanometer scale (0.1 to 100 nm). By delivering nutrients directly to plants and facilitating smart uptake, the use of nanotechnology-based nutrient application to plants may help to reduce the use of chemical fertilizers (Nongbet *et al.,* 2022). The current study was carried out to evaluate the effects of foliar application of IFFCO nano urea on rice productivity, during *Kharif* 2021 and 2022.

Material and Methods

A field experiment was conducted on neutral sandy loam soil low in organic carbon to evaluate the effect of foliar spray of IFFCO nano urea on rice (PR 129) at Research Farm, Department of Soil Science, PAU Ludhiana during *Kharif* 2021 and 2022. The experiment was conducted in split plot design in three replicates with four main plots and five subplots. In main plots 0, 50, 75 and 100 per cent recommended dose of nitrogen was applied to soil and the five treatments in subplots were (i) No spray, (ii) 4 ml/l nano urea spray (IFFCO RECOMMENDED PROTOCOL) (iii) 6 ml/l nano urea spray, (iv) 8 ml/l nano urea spray and (v) 2% urea foliar spray. As per IFFCO protocol (500 ml/acre in 125 liter of water) was to be sprayed twice (i) at maximum tillering and (ii) pre flowering stage. All other package of recommendations was followed to raise rice crop. The crop was harvested at maturity and grain yield and yield attributing parameters were recorded.

Results and Discussion

Graded level of nitrogen application had a significant impact on rice yield. Results revealed that, there was a significant increase in rice grain yield with increasing levels of applied nitrogen. The lowest yield was recorded in the control where no nitrogen was applied (54.3 q/ha), and the highest mean yield was recorded where 100% of recommended nitrogen was applied to soil (75.3 q/ha). Two sprays of IFFCO nano urea with 50% basal nitrogen application (61.5 q/ha) resulted in 15.3% reduction in rice grain yield when compared with 100% RDF (72.6 q/ha), the amount of nitrogen applied had a substantial impact on the straw yield as well. Highest mean straw yield (91.5 q/ha) was recorded under 100% nitrogen application treatment, Agronomic characteristics that attribute crop yield also exhibited the similar pattern. The treatment where 100% of the recommended nitrogen was applied to the soil was significantly better than all other treatments in producing higher panicle length, panicle weight, grain weight/panicle, number of grains/panicle, and 1000 grain weight the results are in accordance with Ghoneim *et al,* (2018); however, no significant influence was observed on soil characters recorded after crop harvest. Therefore, it may be inferred that the foliar application of IFFCO nano urea with 50% basal nitrogen is less productive than recommended dose of fertilizers practiced by framers.

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PP: 43 Early stage screening of *rabi* sorghum (*Sorghum bicolor* L.) genotypes under peg for drought tolerance

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Abstract: Twenty sorghum genotypes were subjected to osmotic stress by polyethylene glycol (PEG 6000) with the objective of evaluating the effects of drought stress. The results showed, increasing the osmotic potential level, germinated seed number, germination rate index, root and shoot length, shoot and root dry matter, and seedling vigor index (SVI) decreased. While, additionally the RSV 1837, SVD 1365, Basavanapada and RSV 1984 genotypes were more tolerant to stress than other genotypes. The germination response declining more rapidly with increasing osmotic potential. RSV 1837 tolerates water stress of up to 1.5 % PEG, without reducing germination of the seeds; however, the growth of shoots and roots are inhibited. Drought stress limits seed germination and early growth of seedlings.

Introduction

An alternative method to field experiments related to drought stress is to induce stress using polyethylene glycol (PEG) under controlled laboratory conditions. Polyethylene glycol has been used to simulate controlled drought stress in nutrient solution cultures. Hence the objective of the study is to screen *rabi* sorghum genotypes for early physiological characters for drought tolerance under polyethylene glycol stress.

Material and Methods

Seeds of 20 sorghum genotypes were surface sterilized for 5 minutes with sodium hypochlorite solution (2%, v/v). Later seeds were subjected to four osmotic potential levels [0.5% PEG, 1% PEG and 1.5% PEG and control] induced by different concentrations of polyethylene glycol 6000 (PEG 6000).The PEG-6000 concentrations required to obtain these values were determined by using the equation of Michel and Kaufmann (1973).

For Germination Conditions the relative humidity was close to 100% with a constant temperature of 25 °C (24-26 °C) in the light for 18 days. Seeds were considered germinated when radicle was longer than 5.0 mm. Germinated seeds were recorded every 24 h for 18 days. Seed germination percentage (%), Seedling length (cm), Seedling biomass (g) and Seedling vigour indices was calculated as per standard protocol and computed for analysis**.**

Results and Discussion

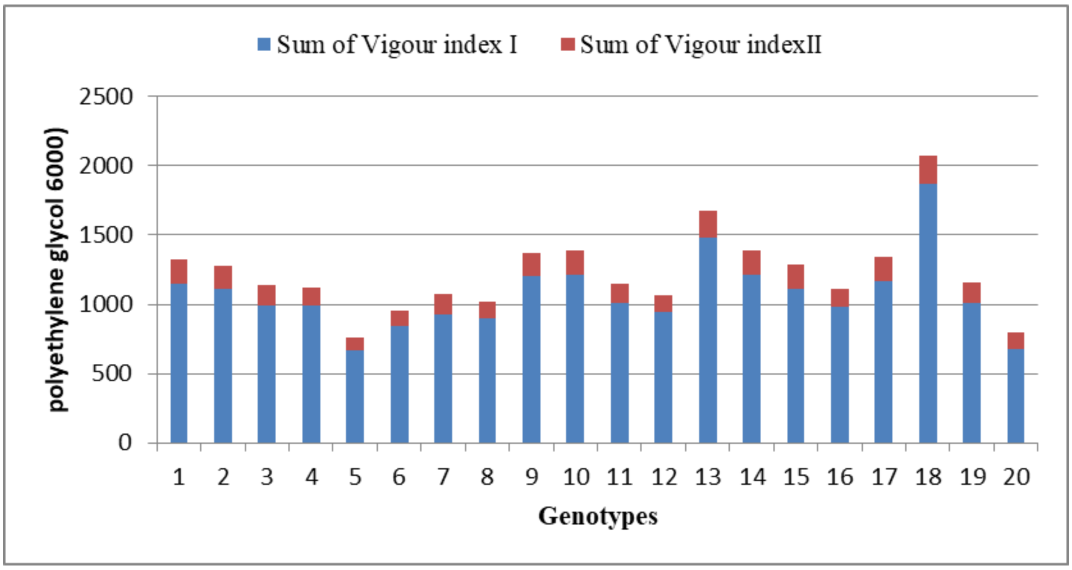
Germination process under osmotic stress condition has been studied to identify the varieties tolerant to drought. Among the osmotic levels significantly maximum mean germination percentage was recorded under 0 % PEG (87.59 %) followed by 0.5 % PEG (65.14 %), 1 % PEG (49.58 %) and at 1.5 % PEG least mean germination percentage was recorded (45.61 %). However, significantly minimum mean germination percentage was observed by the genotype PVR947 (53.90 %). Most of the morphological and physiological characters at seedling stage are affected by water stress in sorghum. Drought stress suppressed shoot growth more than root growth and in certain cases root growth increased (Bibi *et al*., 2010). Among the osmotic levels significantly maximum mean root length was observed under 0% PEG (11.78 cm) followed by 0.5% PEG (7.57 cm) and 1% PEG (5.71 cm) significantly minimum mean root length was observed under 1.5% PEG (2.75 cm). Similarly, the sorghum genotypes varied significantly for seedling length. The genotype RSV1837 showed maximum mean root length (9.70 cm) followed by the genotype SVD1365 (8.25 cm).

The mean shoot length was observed under 0 % PEG (13.91 cm), 0.5 % PEG (11.76 cm) followed by 1 % PEG (7.51 cm).The response of root growth to drought can be variable under moderate moisture stress, root growth is favoured whereas, severe drought often limits root growth (Prasad *et al*., 2008). The extent of root development is closely related to the ability of the plant to absorb water and the tolerant genotypes have higher capacity of these character. Similarly, the sorghum genotypes varied significantly for seedling length. The genotype RSV1837 showed maximum mean shoot length (12.63 cm) followed by the genotype CRS 70 (10.53cm). While significantly maximum mean seedling dry weight was observed under0 % PEG (0.20 g), 0.5 % PEG (0.14 g) and 1 % PEG (0.10 g).

Table1. Effect of osmotic stress on germination percentage and shoot length in sorghum genotypes

Genotypes	**Germination percentage (%)**			**Shoot length (cm)**			**root length**		
	0.5%PEG	**1%PEG**	**1.5%PEG**	**0.5% EG**	**1% EG**	**1.5%PEG**	**0.5% PEG**	**1% PEG**	**1.5% PEG**
RSV 1984	70.00	66.00	56.00	11.00	8.33	5.20	8.33	6.20	2.60
RSV1837	74.00	67.50	52.50	11.40	6.53	4.67	6.53	5.27	2.60
RSV1945	66.00	55.00	50.00	11.73	6.20	4.80	6.20	5.33	2.60
VJV111	62.50	52.50	48.00	11.67	7.27	5.27	7.27	5.93	1.87
VJV107	40.00	37.50	32.00	12.27	8.40	3.73	8.40	5.33	1.80
Lakamapur local	57.50	35.00	30.00	11.80	7.67	4.60	7.67	5.67	2.40
Kodmurki local	60.00	56.00	54.00	11.33	4.87	4.60	4.87	4.87	3.33
Bhagevadi local	56.00	45.00	39.00	11.33	7.40	5.33	7.40	5.93	2.80
SVD1365	78.00	62.00	42.00	12.13	7.53	4.27	7.53	5.47	2.80
CRS70	80.00	65.00	56.00	11.60	8.47	3.60	8.47	5.20	3.40
CRS73	60.00	54.00	48.00	12.33	7.53	3.80	7.53	5.13	3.60
Basavanapada	54.00	50.00	48.00	12.07	8.60	5.07	8.60	6.40	1.87
EP89	82.00	72.00	64.00	13.20	9.20	5.33	9.20	6.67	2.40
PVR947	78.00	68.00	72.00	11.40	7.00	4.20	7.00	5.20	2.67
PEC23	76.00	70.00	52.00	11.27	5.53	4.13	5.53	4.67	4.40
PEC15	60.00	48.00	44.00	12.73	7.53	4.40	7.53	5.47	2.93
PEC30	70.00	68.00	66.00	11.07	8.40	5.00	8.40	6.20	2.00
M 35-1(C)	82.00	80.00	76.00	14.40	11.27	8.93	11.27	9.60	4.73
CSV29R(C)	66.00	52.00	48.00	11.60	7.53	4.20	7.53	5.33	2.33
P. Suchitra(C)	52.50	47.50	40.00	9.20	6.13	3.40	6.13	4.33	1.93
Mean	**66.23**	**57.55**	**50.88**	**11.78**	**7.57**	**4.73**	**7.57**	**5.71**	**2.75**
	SEM		**CD**	**SEM**		**CD**	**SEM**		**CD**
TRT	0.935		3.440	0.137		0.504	0.282		1.041
CONC	0.417		1.539	0.061		0.226	0.126		0.466
T*C	1.866		6.881	0.274		1.009	0.565		2.083

Significantly higher mean vigour index I was exhibited under 0% PEG (2255.30) and 0.5% PEG (1277.15) followed by 1 % PEG (668.53). While, 1.5 % PEG showed significantly lower mean vigour index I (351.92). Among the genotypes, higher mean vigour index I was observed by the genotype RSV1837 (1734.74) followed by the genotype SVD1365 (1433.11).



Among the genotypes, higher mean vigour index II was observed by the genotype RSV1837 (13.73) followed by the genotype SVD1365 (13.28). Vigour index was recorded high in control than the 1.5 % PEG. These results indicate that sorghum is more tolerant to drought stress and confirms those reported by Santos *et al*.(2014) which found the sorghum by present the higher photosynthetic rates and photoassimilates partition showed the best ecophysiological performance under water restriction.

Conclusion

The genotype RSV 1837 showed maximum mean seedling length vigour index I and II followed by the genotype SVD 1365. On the basis of germination percentage, seedling length, vigour index I and II under 1.5 % PEG concentration, the sorghum genotypes RSV 1837, SVD 1365, Basavanapada and RSV 1984 may be utilized for future drought tolerance research work in sorghum.

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PP: 44 Comparative study of different farming practices on physical, chemical and biological properties of soil under cotton ecosystem

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Abstract: An experiment was conducted at IOF, UAS, Dharwad on a fixed site during *kharif* season for two years (2020-21 & 2021-22) to assess the effect of different practices on soil physical, chemical and biological properties in cotton. The mean of two years study revealed that, among soil physical properties, organic farming recorded significantly higher soil aggregate stability and maximum water holding capacity but, bulk density remained unaffected. Among soil chemical properties, the pH did not differ significantly while electrical conductivity was significantly higher in recommended package of practice (RPP) and higher organic carbon content in soil was recorded in organic farming practice compared to natural farming, integrated nutrient managemnt practice and RPP. RPP recorded significantly higher available N, P_2O_5 and K_2O, while sulphur, micronutrients and among biological properties, dehydrogenase activity were significantly higher in organic farming.

Keywords: Natural Farming, Organic Farming, INM, RPP and Cotton

Introduction

Over the years, relative contribution of organic manures as a source of plant nutrients vis-à-vis chemical fertilizers declined substantially. With increase in cost of production inputs, inorganic fertilizers became increasingly more expensive. Another issue of great concern was the sustainability of soil productivity as land began to be intensively tilled to produce higher yields under multiple and intensive cropping systems. The occurrence of multi-nutrient deficiencies and overall decline in the productive capacity of the soil due to non-judicious fertilizer use, have been widely reported. Such concerns and problems posed by modern-day agriculture gave birth to new concepts in farming, such as organic farming, natural farming, biodynamic agriculture, do-nothing agriculture, eco farming, *etc.* The essential feature of such farming practices imply, *i.e.*, back to nature. Nevertheless, before arriving at a conclusion regarding promoting any of these alternative technologies, it is important to undertake their scientific evaluation and likely impact on food security of the country (NAAS, 2019).

Material and Methods

The experiment was carried out at Institute of Organic Farming (AI-NPOF), University of Agricultural Sciences, Dharwad during 2020-21 and 2021-22 on medium black clay loam soil to study the effect of different farming practices on cotton (Variety: CO-14) during *kharif* under rainfed condition. The experiment was laid out in randomized complete block design with eleven treatments and three replications. Treatment details: T_1: Control, T_2: Natural Farming (NF): *Beejamrit* (B) + *Ghanjeevamrit* (G) + *Jeevamrit* (J) + Mulching (M) + Intercropping (I), T_3: Natural Farming (NF): Mulching (M) + Intercropping (I), T_4: Natural Farming (NF): *Ghanjeevamrit* (G) + *Jeevamrit* (J) + Mulching (M) + Intercropping (I), T_5: Natural Farming (NF): *Beejamrit* (B) + Mulching (M) + Intercropping (I), T_6: Natural Farming (NF): *Beejamrit* (B) + *Ghanjeevamrit* (G) + *Jeevamrit* (J) + Intercropping (I), T_7: Natural Farming (NF): *Beejamrit* (B) + *Ghanjeevamrit* (G) + *Jeevamrit* (J) + Mulching (M), T_8: Organic farming (OF), T_9: Integrated Nutrient Management-Natural Farming Plant Protection (INM-NFPP), T_{10}: Integrated Nutrient Management-Conventional Farming Plant Protection (INM-CFPP) and T_{11}: Recommended Package of Practices (RPP). These treatments were common for both the experiments. In cotton, green gram (Variety: DGGV-2) was intercropped in respective treatments. The observations were recorded at harvest.

Results and discussions

Soil physical parameters like maximum water holding capacity (59.94%) and aggregate stability (46.31%) were significantly higher in organic farming compared to RPP and it was on par with NF: B+G+J+M+I. INM practices (INM-NFPP and INM-CFPP) were also on par with organic farming with respect to aggregate stability. The improvements in soil physical parameters were due to the application of organic manures like FYM + vermicompost + neem cake. Whereas, in NF: B+G+J+M+I, the improved soil physical parameters was attributed to application of *jeevamrit* and mulching which helps to withhold the moisture content and similar results were quoted by Ravi *et al.* (2022). However, bulk density did not differ significantly.

Soil pH did not vary significantly by different farming practices but EC was higher in RPP over other farming practices. Significantly higher soil organic carbon (0.74 %) was observed under organic farming as compared to natural farming after the harvest of cotton. RPP recorded significantly higher soil available N (232.99 kg ha^{-1}), P_2O_5 (27.36 kg ha^{-1}) and K_2O (341.49 kg ha^{-1}) at harvest than organic and natural farming and it was on par with INM-NFPP and INM-CFPP. However, organic farming was on par with RPP with respect to available N and K_2O and was superior to natural farming practices. Organic farming recorded significantly higher available secondary nutrients *i.e.*, Sulphur (31.96 ppm) and micronutrients *viz.*, Fe (13.95 ppm), Zn (1.38 ppm), Mn (18.81 ppm) and Cu (2.82 ppm) at harvest, than RPP and natural farming. However, available S and Zn of INM and RPP were on par with organic farming and also Fe, Mn and Cu were on par with INM practices.

Significantly higher dehydrogenase (36.40 µg TPF formed g^{-1} soil day^{-1}) activities were recorded under organic farming as compared to RPP and natural farming. However, INM and natural farming practices were on par with organic farming at the harvest. Similar results were quoted by Channagouda (2019) in cotton.

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PP: 45 Rice Residue Management Alternatives: Influence on Soil Microbial Dynamics, Carbon and Wheat Performance in Northwestern India

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Abstract: Residue management in the rice-wheat cropping system (RWCS) of the Indo-Gangetic Plains is vital for sustainable agriculture. A study in Haryana, India, assessed Happy Seeder-based zero tillage (ZTW) with residue retention on soil health and productivity. ZTW with full or partial residue retention significantly enhanced microbial counts (47.3–73.1%), enzyme activity (up to 98.6 µg TPF g^{-1} soil $24h^{-1}$), organic carbon (0.36–0.42%), and soil moisture (13.4–23.6%), while reducing soil pH (7.49 to 7.27). Grain yield increased by 9.8–11.3%, compared to residue burning and removal practices. ZTW with residue retention offers a sustainable approach to improving soil health and crop productivity.

Keywords: Happy Seeder, Residue retention, Zero tillage, Organic carbon, Soil moisture

Introduction

The rice-wheat cropping system in the northwestern IGP of India encompasses 4.1 million hectares across Punjab, Haryana, Uttarakhand, and western Uttar Pradesh, generating approximately 34 million tonnes of rice crop residue annually. Southeast Asian countries collectively produce 150 MT of rice residues yearly (Singh et al., 2021).A critical challenge emerges from combine harvester operations, which leave behind residue in narrow strips or gluts, particularly when not equipped with spreaders. The constrained window between rice harvest and rabi crop sowing (October-November) leads to approximately 80% of rice residue being burnt, contributing to 42% of India's total greenhouse gas emissions (GHGs) (Agrarwal *et al.,* 2016).Residue burning releases aromatic hydrocarbons, volatile organic compounds, and fine inhalable particles, contributing to atmospheric brown cloud (ABC) formation and degraded air quality. The northwestern Indian states alone burn 23 million tonnes of rice residue annually, resulting in significant nutrient loss and reduced soil organic carbon pools. Crop residues contain 40-45% carbon, which, when returned to soil, enhances microbial activity and soil organic matter. Key soil quality indicators include total microbial count, diazotrophs, actinomycetes, and alkaline phosphatase. Diazotrophs, utilizing carbon from residue, fix nitrogen for crop growth, while actinomycetes facilitate cellulose and hemicellulose degradation (Korav *et al.,* 2022).

The Happy Seeder technology represents a significant advancement in in-situ residue management, enabling direct wheat seeding in rice stubbles without tillage. This approach reduces carbon and energy footprints by 14.1% and 12.9%, respectively, compared to conventional. The technology effectively manages residue by cutting heavy loads of loose and anchored rice residue into mulch, offering a sustainable alternative to burning. The system's sustainability faces multiple challenges, including yield stagnation, groundwater depletion, and declining soil health, necessitating immediate attention to residue management practices that are economically viable, environmentally sustainable, and logistically feasible.

Materials and Methods

A field experiment was conducted at CCS Haryana Agricultural University, Regional Research Station, Karnal, India (29°43'41"N, 76°58'50"E) on sandy loam soil to evaluate residue management practices in rice-wheat cropping systems (RWCS). Initial soil parameters included Ten treatments were tested: T1: conventional tillage wheat (CTW), T2: CTW drill sown (without burning), T3: zero tillage wheat (ZTW) with anchored stubbles, T4: ZTW after partial burning, T5: ZTW after full residue burning, T6: ZTW with Happy Seeder (HS) in full residue load, T7: ZTW with HS after using chopper and spreader (full residue load), T8: CTW broadcast sown with rotavator, T9: CTW drill sown after chopper, spreader & rotavator, and T10: CTW spatial drill sown with three replications in RCBD. Wheat variety HD-2967 was grown with fertilization (150 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}). Soil samples at 75 DAS and maturity were analyzed for microbial and enzymatic activities using ANOVA and DMRT(Gomez and Gomez, 1984).

Results and Discussion

Rice residue management under different tillage practices significantly influenced soil properties, microbial dynamics, and wheat productivity during 2018-2020. Zero tillage wheat (ZTW) with surface residue retention using Happy seeder demonstrated superior performance across all measured parameters compared to conventional tillage (CTW).

Soil microbial populations exhibited peak activity at 75 DAS (anthesis stage), corresponding to higher soil organic carbon levels. ZTW with Happy seeder after chopper and spreader operation showed maximum microbial populations (94.9-99.8 × 107 cfu/g soil), enhancing total microbial count by 47.9-60.4%, diazotrophic count by 59.0-73.1%, and actinomycetes count by 47.3-54.2% compared to residue burning treatments. This increase aligns with Lehmann and Kleber's (2015) findings on residue solubility and microbial accessibility. Conversely, conventional tillage with residue burning reduced microbial populations due to elevated soil temperatures (50-70°C), decreasing heterotrophic microorganisms from 77% to 9% (Kumar *et al.,* 2019).The enhanced microbial activity corresponded with increased enzymatic activity, with ZTW showing highest alkaline phosphatase (98.6 µg TPF g^{-1} soil $24h^{-1}$) activity.

Surface retention of rice residue under ZTW significantly improved soil properties, increasing soil organic carbon (0.36-0.42%) compared to CTW without residue (0.32-0.33%). The system enhanced soil moisture content by 16.94-23.60% at 75 DAS and 13.44-16.20% at harvest over CTW residue removal plots. These improvements align with findings by Jat *et al.* (2019) and Rajanna *et al.* (2022), who reported 31% higher soil organic carbon under residue retention practices. The improved soil conditions translated into enhanced crop productivity, with ZTW using Happy seeder showing 9.8-11.3% higher grain yield and 7.4-9.6% increased biomass yield compared to residue burning treatments (Figure 1). The enhanced productivity was attributed to improved nutrient availability through increased microbial activity and soil organic matter content (Nandan *et al.,* 2019).

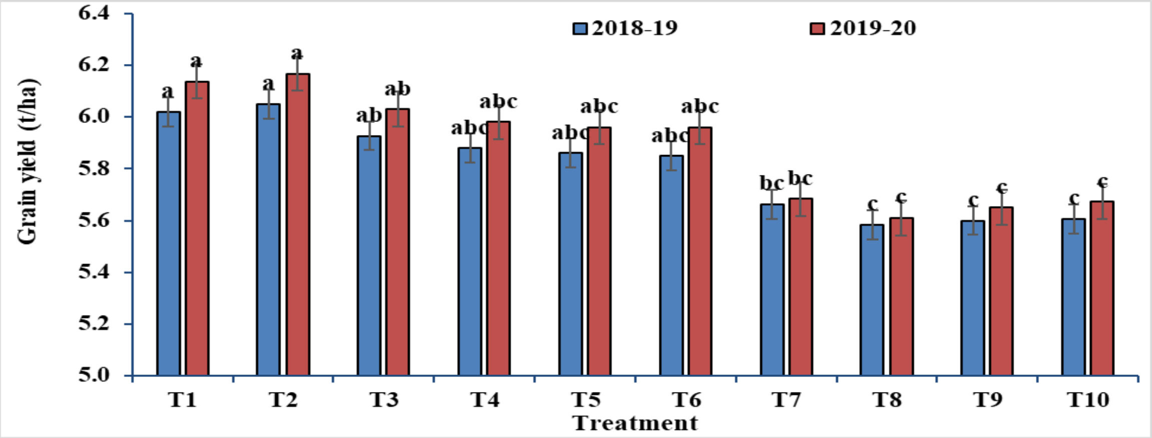

Figure 1.Effect of rice residue management and wheat crop establishment methods on grain yield of wheat under rice-wheat cropping system (2018–19 and 2019–20).

Conclusion

Zero-tillage wheat with Happy seeder and full residue retention significantly enhanced soil microbial populations, enzymatic activities, and soil organic carbon, while residue burning and conventional tillage with residue removal showed adverse effects. This integrated approach to rice residue management demonstrates the synergy between technological innovation and sustainable agriculture, offering a viable solution for maintaining productivity, soil health, and environmental quality in rice-wheat cropping systems globally.

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PP: 46 Assessment of Tissue Cultured Bamboo Species in Soppinabetta Lands in Central Western Ghats of Karnataka, India

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Abstract: Uttara Kannada district in Karnataka's Central Western Ghats is rich in forest resources, with Soppinabetta lands allocated to arecanut farmers for forest-derived organic matter. A field experiment in these lands assessed survival and growth of tissue-cultured bamboo species. *Bambusatulda* showed the highest height increment (67%), followed by *Guaduaangustifolia* (58.8%), while *D. asper* had the least. *D. asper* also recorded the highest collar diameter increment (1.47%), followed by *D. stocksii* (1.27%), with *B. balcooa* lowest (0.03%). Maximum culms per clump were in *D. brandisii* (8.33) and *D. asper* (7.67), influenced by high moisture and nutrient availability.

Key words: Soppinabetta, Tissue culture, Bamboo species and growth attributes

Introduction

Bamboo, often referred to as "Green Gold," is a versatile and fast-growing member of the grass family (*Poaceae*). Its remarkable growth rate, reaching up to 80 cm per day, and its extensive utility make it one of the most significant renewable resources globally. With approximately 110 genera and over 1,500 species worldwide, bamboo is distributed across tropical and subtropical regions, playing a vital ecological and economic role.

India, known for its rich bamboo biodiversity, is home to 18 genera and 128 species, with about 21 commercially important varieties. The Western Ghats, a biodiversity hotspot, provide an ideal environment for bamboo growth, particularly in regions like the Soppinabetta lands of Karnataka. Traditionally, these lands, located on hill slopes adjacent to areca orchards, have been managed sustainably for grazing, mulching, and collecting resources like fuelwood and green leaves.

Introducing tissue-cultured bamboo species in these lands offers a sustainable solution to enhance bamboo production while conserving biodiversity. Tissue culture ensures the propagation of high-quality, disease-free bamboo plants, promoting both ecological restoration and commercial benefits. This study explores the potential of tissue-cultured bamboo in Soppinabetta lands, highlighting its role in sustainable forestry and rural development.

Material and Methods

Location and Source

The study was conducted during 2021–22 in the Bettalands of Kanagodu village, Sirsi, located in Uttara Kannada district, Karnataka. Six-month-old tissue-cultured bamboo seedlings raised in a nursery were used for the experiment.

Experimental Details and Design

- Design: The experiment followed a Completely Randomized Block Design (CRBD).
- Treatments: Seven different treatments were applied to evaluate the growth and survival attributes of bamboo.
- Replications: Each treatment was replicated three times.

- Seedlings per Treatment: Ten seedlings were used for each treatment per replication.

This setup enabled systematic evaluation of tissue-cultured bamboo species under controlled conditions to assess their performance in the Bettalands ecosystem.

Table no 1: Details of treatment

Treatments	Species
T_1	*Dendrocalamusstocksii*
T_2	*Bambusatulda*
T_3	*Bambusavulgarius*
T_4	*Bambusabalcoova*
T_5	*Dendrocalamusbrandisii*
T_6	*Guaduaangustifolia*
T_7	*Dendrocalamus asper*

Growth Parameters Recorded

The following growth parameters were measured using standardized methods:

- **Plant Height**: Measured from the ground to the tip of the tallest shoot using a measuring scale (cm).
- **Collar Diameter**: Measured at the plant base using a digital calliper (mm).
- **Number of Culms per Clump**: Counted manually.

Observations were recorded at 60-day intervals throughout the study period.

Statistical Analysis

Data was analyzed using analysis of variance (ANOVA) to determine statistical significance. Mean values were compared using the critical difference (CD) method. Microsoft Excel and OPSTAT software were used for evaluation and interpretation.

Results and Discussion

The present study conducted in Kanagodu village, Sirsi taluk, Uttara Kannada district, during 2022-23, revealed notable differences in the growth performance of bamboo species under various treatments (Fig.01). *Bambusatulda* (T2) exhibited the highest height increment (67.00%), followed by *Guaduaangustifolia* (T6) with 58.80%, while *Dendrocalamus asper* (T7) showed the least height increment. Similar trends were observed in collar diameter, where *Dendrocalamus asper* (T7) recorded the highest increment (1.47%), followed by *Dendrocalamusstocksii* (T1) at 1.27%, with *Bambusabalcooa* (T4) and *Guaduaangustifolia* (T6) showing the lowest increments. For the number of culms per clump, *Dendrocalamusbrandisii* (T5) achieved the highest increment (8.33%), while *Bambusabalcooa* (T4) showed the least (2.33%). These results are consistent with studies across India. Kumar *et al.* (2015) found that *Bambusatulda* and *Dendrocalamusstocksii* tend to show better growth in terms of height and collar diameter, owing to their efficient nutrient uptake and adaptability to different soil types. Singh *et al.* (2013) also observed similar results, where *Dendrocalamus asper* excelled in collar diameter growth due to its robust root system and high nutrient demand. Furthermore, Jain *et al.* (2017) reported that *Dendrocalamusbrandisii* has an inherent capacity for higher culm production, which corresponds with the results of the current study. Other studies, such as those by Panda *et al.* (2016) and Rathore *et al.* (2019), have emphasized the importance of selecting appropriate potting media for bamboo seedlings, showing that media with balanced organic content, good aeration, and moisture retention can significantly enhance seedling growth. These collective findings underscore the importance of species selection and media composition in optimizing bamboo cultivation, providing insights into best practices for sustainable agroforestry in regions like the Western Ghats.

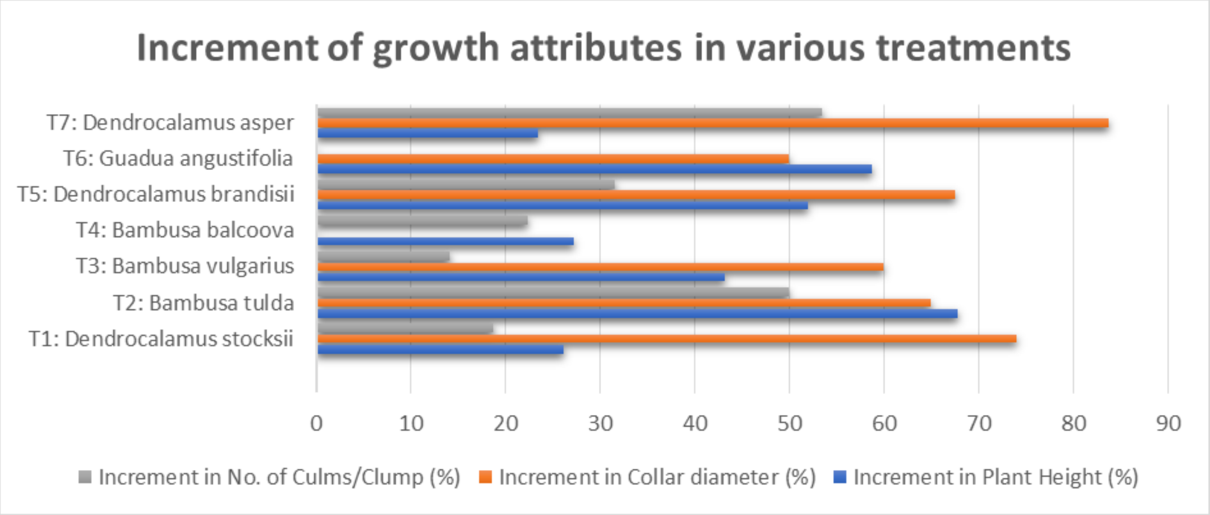

Fig. 01: Graphical representation of Increment of growth attributes of various bamboo species

Conclusion

The selection of appropriate bamboo species is crucial for achieving optimal growth and yield in the Bettalands of Kanagodu village. *Dendrocalamus asper* and *Bambusatulda* demonstrated the best growth performance, highlighting their potential for commercial cultivation. Proper management of planting conditions and potting media, as evidenced by the study, is essential for ensuring healthy seedling establishment and sustainable bamboo farming. These findings contribute valuable insights for enhancing bamboo cultivation practices in the region, promoting both ecological sustainability and economic benefits.

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PP: 47 Regenerative Agricultural practices for Carbon-neutral farming

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Abstract: Carbon-neutral farming refers to agricultural practices that aim to balance the amount of carbon dioxide emitted during farming operations with the amount of carbon captured and stored, particularly in soil, trees, and plants. The modern agricultural practices affect the environment namely nutrient cycle, soil erosion, carbon sequestration, and many other ecological patterns. There is clear evidence of a decline in the organic carbon (OC) contents in many soils as a consequence of intensification of agriculture in India. Carbon sequestration in Integrated Farming system (IFS), Organic farming and Natural farming is the process of storing carbon dioxide from the atmosphere in soil for a longer time through agricultural practices in the form of usage of organic manures, microbial concoctions, cover crop, companion crop, reduced tillage, mulching, diversified cropping systems and agro forestry can reduce the adverse effects on the environment. These farming practices may enhance the food quality apart from improving soil structure, increased soil bio diversity, better water holding capacity and increased nutrient availability. So Carbon-neutral farming is not just a trend but a necessity for the future of agriculture.

Key words: Carbon-neutral farming, Carbon sequestration, Natural Farming, Organic Farming,

Carbon-neutral farming aims to balance carbon emissions with carbon sequestration, turning farming practices into part of the climate solution. The agriculture sector plays a critical role in addressing climate change, as it accounts for significant greenhouse gas emissions — primarily through deforestation, livestock methane, and fertilizer-related nitrous oxide. Embracing carbon-neutral practices empowers farmers to fight climate change, improve soil health, enhance resilient farming systems, and secure food for the future.

Top Strategies for Achieving Carbon-neutral Farming are Sustainable Soil Management by adopting Key techniques like no-till farming, cover cropping, and crop rotation which enhance, soil health, sequester carbon, and reduce greenhouse gas emissions.

No-Till Farming: This practice avoids disturbing the soil, allowing it to retain organic matter that stores carbon over time. No-till farming can sequester up to 0.5 metric tons of carbon per hectare annually.

Cover Crops: Planting cover crops between growing seasons helps protect the soil, improve soil structure, and promote natural carbon sequestration.

Crop Rotation: Rotating crops helps maintain soil fertility and reduces the need for chemical fertilizers, which can release harmful emission. Soil carbon sequestration not only contributes to carbon neutrality but also improves water retention and enhances overall farm productivity.

Rattan Lal, Soil Scientist and World Food Prize Laureate says “Soil is the solution to climate change. By sequestering more carbon in soils, we can take a significant step toward mitigating the effects of global warming.”

Renewable Energy in Farming: The adoption of renewable energy sources is a major step towards reducing carbon emissions in farming operations. Solar panels, wind turbines, and bioenergy are increasingly being integrated into farming systems to replace fossil fuel use.

Solar and Wind Energy: Installing solar panels and wind turbines on farms helps generate clean energy, powering everything from irrigation systems to storage facilities.

Bio-energy: Some farms are converting organic waste into biogas, which can be used to power farm machinery and equipment (**Tim LaSalle, 2024**).

Agroforestry Practices: Agroforestry, the integration of trees and shrubs into farming systems, offers a powerful method for capturing and storing carbon. This practice not only sequesters carbon but also supports biodiversity, improves soil health, and protects crops from extreme weather.

Alley Cropping: Planting trees between rows of crops enhances carbon capture while providing shade, which can reduce water loss.

Silvi-pasture: Combining forestry and grazing allows for better livestock management while sequestering carbon in trees and soil. Agroforestry is particularly effective in regions prone to desertification, helping restore degraded lands while reducing carbon emissions.

Natural Farming (NF) is regenerative; it increases the carbon content in the soil allows us to retain more water in soil creating life in the soil with humus which increases the fertility of the soil. The concept of natural farming lies with the diversified farming system that integrates crops, trees and livestock, allowing the optimum use of functional biodiversity. Natural Farming if done effectively enhances farmer's income while delivering many other benefits, such as restoration of soil fertility and environmental health, and mitigating and/or reducing greenhouse gas emissions. The soil is always supposed to be covered with organic mulch, which creates humus and encourages the growth of friendly microorganisms. Farm made bio-cultures named 'Jeevamrit, Beejamrit etc.' are added to the soil instead of any fertilizers to improve micro flora of soil. It holds the promise of enhancing farmers' income while delivering many other benefits, such as restoration of soil fertility and environmental health, and mitigating and/or reducing greenhouse gas emissions. In natural farming no tilting of soil and no fertilizers, is done just the way it would be in natural ecosystems. Natural farm-made herbal pesticides like Agniastra, Bramhaastra, Dashparni ark and Neem Astra are used to control pests and Shunti astra and sour butter milk to control diseases. Weeds are considered essential and used as living or dead mulch layer. Multi-cropping is encouraged over single crop method. Concoctions are necessary to enhance the fertility of soil. Hence Natural farming plays an important role in carbon neutral farming by carbon sequestration and low external input usage.

Organic farming (OF) refers to "a system which avoids and largely excludes the use of artificial inputs" (e.g., fertilizers, pesticides, hormones, feed additives, etc.). Organic farming depends upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral-grade rock additives, and biological systems of nutrient mobilization, ensuring plant protection optimally. "Organic agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and good quality of life for all involved. A combination of organic farming and improved sludge, biochar with organic fertilizer, biofertilizers, organo-minerals and digital technology is of utmost importance to reduce the limitations and challenges of organic farming. The innovative and sustainable approach of organic farming enhances the agricultural productivity and quality of life of many farmers in an environmentally friendly way (Gamage et al., 2023). Bharat Prakash Meena et. al., (2023) highlights the major techniques in regenerative agriculture are Minimum Soil disturbance-conservation Tillage, Keep the soil covered, crop rotation with maximum crop diversity, Agroforestry with perennial Crops, integration of livestock with cropping System and use of Biochar in Agriculture. All these principles and practices are used in organic and Natural farming. Villat and Nicolas (2024) examined *N*=345 soil carbon sequestration measures across seven regenerative practices – agroforestry, cover cropping, legume cover cropping, animal integration, non-chemical fertilizer, non-chemical pest management, and no tillage. They reported that all seven practices effectively increased the carbon sequestration rate. There were no statistically significant differences among the practices. Combining these practices may further enhance soil carbon sequestration.

Waste Management and Organic Farming: Efficient waste management is crucial for carbon-neutral farming. Circular farming turns waste into resources, reducing emissions and enhancing sustainability. **Composting:** Organic farm waste, like crop residues and manure, is composted into nutrient-rich fertilizer, cutting the need for synthetic alternatives and lowering greenhouse gas emissions. **Biochar:** Produced through pyrolysis, biochar locks carbon in the soil for centuries while boosting soil health and water retention. **Circular Systems**: Livestock waste becomes fertilizer, and crop residues become animal feed, creating a closed-loop that minimizes waste and cuts carbon emissions. This integrated approach helps farms reduce methane and achieve sustainability.

Integrated Farming System (IFS) model developed for marginal farmers (0.70 ha) of sugarcane-ratoon-wheat + dairy dominated farming system in western plain zone of Uttar Pradesh resulted in 139.2 t sugarcane equivalent yield (SEY) with share from cropping system (28%), agri-horti (16%), multilayer farming (18%), dairy (29%) and boundary plantation (9%) modules. Model recorded net return of Rs 2.37 lakhs with B:C ratio of 2.10 and 396 man days of employment generation. Through the recycling of waste/residue ensured internal generation of 96.2kg N, 28.3 kg P and 98.3 kg K thus significant saving in mineral fertilizers. Net GHG emission of this IFS model was 2429.3 kg CO2 -e thus making the model as climate smart (Anon, 2022).

Success Story: Sikkim's Organic and Carbon-Neutral Journey: Sikkim, a small Indian state, became the world's first fully organic state in 2016. By eliminating chemical fertilizers and pesticides, the state also took significant steps toward carbon-neutral farming. Organic farming practices, like using compost and natural pest control, have reduced carbon emissions and improved soil health. The state's efforts have also boosted local biodiversity and attracted eco-tourism, providing additional income for farmers. Sikkim's success showcases how shifting to sustainable agricultural practices can simultaneously benefit the environment and the economy.

The Government of Karnataka sponsored a project on evaluation and performance of natural farming in comparison with established organic and conventional farming practices in different crops and cropping systems of Northern transitional zone of Karnataka. The results of the trails since 2018 shows that the organic farming with Groundnut + Finger Millet recorded significantly higher organic carbon content in soil compared to other different farming practices in millet based cropping systems. The organic carbon content was also increased under natural farming as compared to its initial levels due to use of microbial consortia in the form of Bheejamrit, Jeevamrit and Ghanajeevamrit and mulching of millet harvested straw and other crop residues. Improvement in soil organic carbon, nutrient availability, soil microbial activities and reduction in cost of cultivation were noticed under natural farming practices in all the zones. In natural farming practices, soil physical, chemical and biological properties were improved over the years in all the crops and cropping systems. The soil physical properties viz., Maximum Water Holding Capacity (MWHC) increased, Bulk density decreased and porosity increased in organic farming to the maximum extent followed by natural farming and least in Chemical farming and RPP. The soil general and beneficial micro floras as well as enzymatic activities were higher in natural farming and organic farming practices than RPP and Chemical Farming in all the crops and cropping system (Chandrashekara et al., 2023). Carbon-neutral farming is not just a trend but a necessity for the future of agriculture. So we can conclude that the natural farming and organic farming will act as an alternative agricultural practices for rejuvenating soil and resilient agricultural practices.

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PP: 48 Enhancing the soil carbon stock of degraded lands through silvipasture systems in India

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Desertification and land degradation atlas of India indicated that degraded land area was increased from 94.53 m ha to 97.85 m ha in recent 15 years. Increasing the soil carbon stock of degraded land is one of the most viable options for improving land productivity. Adopting fodder-based silvipasture system is one of such a potential eco-friendly system having huge scope to restore degraded land through increased soil carbon stock, microbial diversity and soil properties. The review from various studies indicated that *Leucaena leucocephala* based silvipasture systems increased the soil organic carbon stock by 12.5 to 204 per cent, 79 to 200 per cent and 24 to 231 per cent in 0 to 15 cm, 15 to 30 cm and 30 to 45 cm of soil depth respectively. Hence, silvipasture acts as a promising way to restore the soil carbon stock of degraded lands along with the increased fodder and timber production.

Keywords: Carbon stock, degraded lands, fodder, silvipasture and tree crops

Introduction

Land resources are the basis for human livelihood and societal development. India with 2.4 per cent of global land area is homeland to around 18 per cent of global human population, 20 per cent livestock population and 8 per cent of world's agriculture. Nearly 30 per cent (97.85 m ha) of the total geographic area of India is degraded. Silvipasture is a highly promising and eco-friendly system with significant potential for increasing soil carbon stock which restores the degraded lands. In silvipature system, tree canopy and grasses capture carbon via photosynthesis, storing it in their biomass and roots, while their fallen leaves and roots contribute organic matter to the soil, increasing soil organic carbon (SOC). Pastures also capture CO_2 through photosynthesis, and their roots, along with manure from livestock, further enhance soil carbon. Rotational grazing practices improve vegetation growth, increasing root mass and carbon storage. The integration of trees and pastures improves soil structure, promoting carbon retention and reducing soil erosion. The system's reduced disturbance compared to conventional farming prevents carbon loss, while the modified microclimate from tree canopy reduces evaporation and supports pasture growth, leading to more carbon sequestration. Over time, silvipasture systems build up significant carbon stocks in both soil and biomass, making them an effective strategy for mitigating climate change.

Material and methods

This review included the studies on the restoration of degraded lands through silvipasture systems. The literature search was done in Google Scholar with the search terms which include silvipasture, agroforestry, grasses, fodder, degraded lands, tree crops, soil carbon stock, agrisilvipasture. Each search was further refined to include only studies related to enhancing the soil carbon stock through silvipasture systems which were published from India.

Results and Discussion

The results from the collected studies indicated that silvipasture systems had a significant effect on soil organic stock of degraded lands. The silvipastoral system sequestered 36.3 to 60.0 per cent higher total soil organic carbon stock as compared to the tree system and 27.1 to 70.8 per cent higher over the pasture system (Mangalassery *et al*., 2014). *Acacia nilotica* based silvipasture system recorded maximum above ground biomass (71.27 t ha^{-1}), below ground biomass (14.25t ha^{-1}), litter biomass (4.39 t ha^{-1}), total biomass (89.91t ha^{-1}), total carbon stock (49.45t ha^{-1}) and total CO_2 sequestration (250.92 t ha^{-1}) among the various silvipasture systems (Kala *et al*., 2022). This was attributed to uniform stand structure combined with high carbon density of trees. Total biomass production of different land use systems followed the order: *Acacia nilotica* > *Aegle marmelos* > *Pongamia pinnata* and *Emblica officinalis* respectively. The higher biomass and carbon stocks observed in silvipastoral systems, it might be due to more stand density and uniform age structure. It was evident previous studies that higher C stock from leaf litter fall and twig biomass from *Acacia nilotica* increased the biomass and carbon stock production. Similarly, *Acacia nilotica* + *Cenchrus ciliaris* silvipasture system recorded significantly higher soil carbon stock (20.5 t ha^{-1}) in degraded saline calcareous soil of North-West India (Kumari *et al*., 2018). Plants contribute to the formation of stable soil aggregates soil through fine roots and mycorrhizal associations. Horti-pasture system recorded higher soil carbon stock as compared to sole pasture, sole tree and barren land (Ramakrishnan *et al*., 2021). Though guava + pasture system recorded higher soil carbon stock and was on par with bael + pasture system. The buildup of higher in guava + pasture system could be due to slower decomposition of residues, higher quantity of biomass production, release of organic acids / allelochemicals by biomass and roots and release of higher nutrients (N, P and K) to soil. The higher soil organic carbon could be due to the high moisture content, improved soil physical properties, grass root growth, and enhanced microbial and enzyme activities in silvipasture system. Soil organic carbon stock was higher under guinea grass (7.20 t ha^{-1}) among the range grasses in the degraded lands of semi-arid region (Halli *et al*., 2022). It might be due to the secretion of bioactive molecules such as sugars, amino acids, carboxylic acids and secondary metabolites from rhizosphere microbiota and helped in the buildup of soil organic carbon. Likewise, *Leucaena leucocephala* system recorded higher organic carbon of 1.46, 1.44, 1.36 g kg^{-1} in shallow (0-15cm), medium (15-30cm) and deeper (30-45cm) layer, respectively (Baradwal *et al*., 2023). Under the 0-15 cm soil depth, *Leucaena leucocephala*, *Hardwickia binata*, and *Acacia nilotica* based silvipasture system had 204, 195 and 129 per cent greater total organic carbon, respectively, than fallow land. These land-use systems showed total organic carbon values that were 199, 83 and 110 per cent greater than fallow land, respectively, in the 15–30 cm soil layer. Similarly, in the deeper soil layer, these systems had 232, 24 and 105 per cent higher total organic carbon, respectively, than fallow land. Higher litter fall from the silvipasture system has increased the soil organic carbon content.

Table 1. Effect of silvipasture systems on soil carbon stock of degraded lands

Sl. No	Silvipasture system	Effect	Reference
1	*Acacia nilotica* + *Cenchrus ciliaris* system	The highest above (5.08 kg ha^{-1}) and below ground (1.75 kg ha^{-1}) and soil carbon stock (6.80 kg ha^{-1}).	Mangalassery *et al*. (2014)
2	*Acacia nilotica* + *Cenchrus ciliaris* system	Higher soil organic carbon content (0.74%, 0.58% and 0.44% in 0-7.5 cm, 7.5-15 cm and 15-30 cm depth respectively) over grassland vegetation (0.17%, 0.16% and 0.12% respectively) of calcareous soil.	Kumari *et al.* (2018)
3	*Acacia nilotica* + *Cenchrus ciliaris* system	The highest total soil carbon stock (20.5 t ha^{-1}).	Kumari *et al.* (2018)
4	Guava + pasture system	The maximum soil carbon (0.86%) and was on par with bael + pasture system.	Ramakrishnan *et al*. (2021)
5	*Leucaena leucocephala* based system	Higher organic carbon of 1.46, 1.44, 1.36 g kg^{-1} as compared to fallow land (0.48, 0.48 and 0.41 g kg^{-1}) in shallow (0-15cm), medium (15-30cm) and deeper (30-45cm) soil layers respectively.	Baradwal *et al*. (2023)
6	*Acacia nilotica* based silvipasture system	The highest total carbon stock (47.17 t ha^{-1}) and total CO_2 sequestration (66.09 t ha^{-1}) in soil.	Kala *et al.* (2022)

Conclusion

The combination of trees and pasture effectively sequesters carbon, with systems like *Acacia nilotica*-based silvipasture which perceived the highest biomass and CO_2 sequestration. These systems contribute to the restoration of degraded lands by enhancing the soil organic carbon stock and properties of degraded lands. This improves the soil fertility and productivity of degraded lands.

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PP: 49 Enhancing rice defense: Biochar soil amendment and its role in induced resistance against yellow stem borer, *Scirpophaga incertulas* Walker

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Abstract: The impact of biochar on rice variety TN-1 and its induced resistance against yellow stem borer (YSB) was studied at the Agricultural Research Station, Gangavathi, in 2021. Results showed that 8% biochar significantly enhanced plant growth parameters, including height, tillers, and chlorophyll levels, while reducing YSB infestation. Biochar-treated plants exhibited prolonged larval development, higher larval mortality, and increased resistance due to elevated phenol and tannin content. The study also observed increased enzyme activity (peroxidase, catalase, and SOD) and nutrient levels, highlighting biochar's potential for improved plant growth and pest resistance.

Introduction

Over 1,400 insect species attack rice, with 20 being major pests in India. The yellow stem borer (YSB) is the most destructive, causing up to 87.66% yield loss if left uncontrolled. Its resistance to insecticides highlights the need for alternative methods like biochar, a carbon-rich material derived from organic matter, which improves soil health and may reduce pest damage. Biochar's role in enhancing plant defenses against pests, particularly YSB, is promising, but limited research exists on its effects on chewing insect pests. This study explores biochar's potential in boosting rice resistance biochemically.

Materials and Methods

The investigation was conducted at the Agricultural Research Station, Gangavathi, Karnataka, India, during 2021-22. Commercial biochar was added to soil at concentrations of 0%, 2%, 4%, 6%, 8%, and 10%, with the TN-1 rice variety planted in pots. Yellow stem borer (YSB) larvae were released on the plants to assess the effects of biochar on plant growth, pest damage, and biochemical changes. Plant height, tiller number, stem diameter, and trichome density were measured, along with larval development time, mortality, and fecundity. Soil nutrients and biochemical parameters like phenols, tannins, proteins, and enzymes were analysed to understand biochar's role in enhancing resistance against YSB.

Results and Discussion

The study revealed that biochar significantly improved rice plant growth parameters, with 8% biochar (T4) yielding the best results. Plant height increased to 67.02 cm by 60 days after transplanting (DAT), and tiller count reached 11.03 per hill. Stem diameter peaked at 0.98 cm, trichome density at 90.17 trichomes/cm², and SPAD chlorophyll values at 61.83. Biochar also reduced yellow stem borer damage, with the lowest dead heart percentage (1.10% at 20 DAT) and minimal stem tunnelling (6.03 cm). Additionally, larval development was delayed, mortality increased, and biochemical defenses like phenol, tannin, and lignin content were enhanced.

This study explored the effects of biochar on rice growth and resistance to the yellow stem borer (YSB). Biochar enhanced plant height, tiller number, stem diameter, and leaf chlorophyll content, linked to increased nutrient availability. The high silicon content in biochar boosted trichome density, reduced stem borer damage, and prolonged larval development time, while increasing larval mortality (Ashrith *et al*., 2020 and Ahmad *et al*., 2019). Biochemical changes, including elevated phenol, tannin, and protein levels, were observed, further strengthening plant defenses (Abbas *et al.,* 2017; Yang *et al*., 2017 and Li *et al*., 2007). However, excessive biochar raised soil alkalinity, potentially limiting nutrient absorption. Overall, biochar improved plant resilience and nutrient uptake but requires careful management for optimal results.

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PP: 50 Nano Biochar in Agriculture: Enhancing Crop Productivity and Sustainability

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Abstract: The advent of nano biochar, a form of biochar engineered at the nanoscale, has the potential to revolutionize agricultural practices by improving soil health, enhancing nutrient availability, and increasing crop productivity. Nano biochar offers advantages over traditional biochar due to its increased surface area, higher reactivity, and improved capacity to retain nutrients and water. This review explores the impact of nano biochar on crop productivity, focusing on its effects on soil fertility, nutrient cycling, water management, and microbial activity. We also discuss the challenges related to its production, cost, and environmental risks. While nano biochar has demonstrated significant promise in laboratory and field studies, further research and standardization are required to fully realize its potential in agriculture.

Introduction

As global agricultural demands grow, the need for sustainable practices that enhance soil fertility, optimize resource use, and increase crop yields becomes increasingly important. Traditional farming methods often lead to soil degradation, water scarcity, and excessive reliance on synthetic fertilizers, which pose environmental risks. In this context, biochar, a carbon-rich material produced through the pyrolysis of organic biomass, has gained attention for its potential to improve soil quality and reduce environmental impacts (Lehmann *et al*., 2011).However, traditional biochar has limitations, such as relatively low surface area and slow reactivity. Nano biochar, a refined version of biochar engineered at the nanoscale (typically <100 nm), has emerged as a more effective alternative due to its enhanced chemical and physical properties (Zhang *et al*., 2018). Nano biochar offers an improved surface area, greater nutrient retention, and higher water-holding capacity, which can directly enhance crop productivity and sustainability in agricultural systems. This review focuses on the impact of nano biochar on crop productivity, including its effects on soil fertility, nutrient management, water retention, and soil health.

What is Nano Biochar?

Nano biochar is a form of biochar that has been processed into nanoparticles through methods such as ball milling, chemical activation, or plasma treatment (Pires *et al*., 2020). The nanoscale size significantly increases the material's surface area and reactivity, allowing it to interact more effectively with plant roots, soil particles, and microorganisms. These enhanced properties make nano biochar a more efficient soil amendment compared to traditional biochar, offering superior potential for improving crop yields and promoting sustainable farming practices (Zhang *et al*., 2020).

Properties of Nano Biochar and Its Impact on Crop Productivity

1. **Increased Surface Area and Nutrient Adsorption** One of the most significant benefits of nano biochar is its greatly increased surface area, which enhances its ability to adsorb and retain essential nutrients such as nitrogen, phosphorus, and potassium. Nano biochar's increased nutrient retention capability can help reduce nutrient leaching, particularly in sandy or well-drained soils (Chen *et al*., 2020). This results in better nutrient availability for crops, improving their growth and productivity, and reducing the need for chemical fertilizers. Recent studies have demonstrated that nano biochar significantly increases soil cation exchange capacity (CEC) and enhances nutrient cycling, which in turn promotes better plant growth.

2. **Improved Water Retention and Irrigation Efficiency** Nano biochar's increased porosity and high surface area allow it to retain more water than traditional biochar. This makes it particularly useful for improving soil water-holding capacity, especially in arid or drought-prone regions (Tan *et al*., 2015). By improving water retention, nano biochar reduces the frequency of irrigation and helps crops maintain consistent moisture levels during dry periods, which is crucial for improving crop yield and minimizing water use.In a recent field trial by

3. **Promotion of Soil Microbial Activity and Soil Health** Soil health is closely linked to the abundance and diversity of soil microorganisms, which play key roles in nutrient cycling, organic matter decomposition, and plant disease suppression. Nano biochar's high surface area provides an ideal substrate for the colonization of beneficial microorganisms, including nitrogen-fixing bacteria, phosphorus-solubilizing fungi, and mycorrhizal fungi (Sohi *et al*., 2010). These microbes help improve soil fertility and promote plant growth by enhancing nutrient availability and improving soil structure. A recent study by Liu *et al*. (2023) reported that the application of nano biochar to rice fields increased microbial biomass and the abundance of beneficial soil bacteria, such as *Bacillus* spp. and *Pseudomonas* spp. This led to enhanced nutrient cycling and improved rice productivity, further demonstrating the positive effects of nano biochar on soil microbial communities and crop performance.

4. **Enhanced Soil Fertility and Plant Growth** The enhanced nutrient retention, water-holding capacity, and microbial health promoted by nano biochar contribute to improved soil fertility. Studies have shown that nano biochar can improve soil pH, increase the availability of micronutrients, and reduce soil acidity, making the soil environment more conducive to plant growth (Bhardwaj *et al*., 2021). Additionally, the slow-release properties of nano biochar mean that nutrients are available to crops over an extended period, further enhancing plant growth and yield. In a study by Pires *et al*. (2020), the application of nano biochar to tomato plants resulted in improved root development, larger fruit size, and a 15% increase in yield compared to conventional biochar and control treatments. This demonstrates the potential of nano biochar to enhance crop growth and productivity by improving soil fertility and nutrient availability.

Nano Biochar in Fertilizer and Irrigation Management

1. **Reduction in Fertilizer Requirements** By enhancing nutrient retention and reducing nutrient leaching, nano biochar can reduce the need for synthetic fertilizers. This is particularly important in regions with nutrient-poor soils or where fertilizer use is unsustainable. Nano biochar can help optimize nutrient availability, reduce the environmental impact of fertilizers, and lower input costs for farmers.A study by Wang *et al*. (2023) found that nano biochar application reduced the amount of nitrogen fertilizer needed for optimal corn growth while maintaining high yields. This reduction in fertilizer use not only improves farm profitability but also reduces the environmental risks associated with fertilizer runoff, which can lead to water pollution and soil degradation.

2. **Improved Water Use Efficiency** The ability of nano biochar to retain water in soil improves water use efficiency in crops. This is particularly important in water-scarce regions or areas where irrigation infrastructure is limited. Nano biochar's water retention properties help ensure that crops receive a steady supply of moisture, even in regions with erratic rainfall or periods of drought. Recent research by Zhang *et al*. (2022) demonstrated that nano biochar increased the water-use efficiency of rice fields by 18%, resulting in higher yields with less water input. This highlights the potential of nano biochar as a water-conserving tool in agricultural systems, which is increasingly critical under the pressures of climate change.

Pollution Mitigation and Environmental Benefits

In addition to enhancing crop productivity, nano biochar has demonstrated potential for mitigating environmental pollution. Nano biochar can adsorb heavy metals, organic pollutants, and other toxic substances from the soil, reducing their bioavailability and minimizing their environmental impact (Yang *et al*., 2021). This pollutant-remediating effect makes nano biochar particularly useful in contaminated soils or agricultural systems located near industrial areas.

Moreover, like traditional biochar, nano biochar contributes to carbon sequestration, potentially mitigating climate change by storing carbon in soils. The stability of nano biochar in soil means that it can persist for years, sequestering carbon and reducing atmospheric CO2 concentrations (Lehmann *et al*., 2011).

Challenges and Limitations

1. **Cost of Production**: The production of nano biochar is more expensive than conventional biochar, primarily due to the specialized processes required to create nano scale particles. This can limit its affordability for small-scale farmers (Tian *et al*., 2019).

2. **Environmental and Health Concerns**: The introduction of engineered nanoparticles into soils raises concerns about their long-term effects on soil ecosystems and potential toxicity to soil organisms, including earthworms and beneficial microbes (Kah *et al*., 2019). The safety of nano biochar for both plants and soil health requires further investigation.

3. **Lack of Standardization**: There is no standardized approach for producing, characterizing, and applying nano biochar in agriculture. Variations in production methods, feed stocks, and particle size can result in inconsistent outcomes (Bhardwaj *et al*., 2021).

Conclusion

Nano biochar holds significant promise as an innovative tool for enhancing crop productivity and promoting sustainable agricultural practices. Its enhanced properties—such as increased surface area, improved nutrient retention, and better water-holding capacity—can improve soil fertility, optimize nutrient and water management, and support healthier soil ecosystems. However, challenges related to production costs, environmental impact, and standardization must be addressed to fully realize its potential. Continued research and development in nano biochar production, application methods, and long-term effects are critical to ensuring its safe and effective use in agriculture.

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PP: 51 Biochar and Its Impact on Soil Health: A Review

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Abstract: Biochar, a carbon-rich material derived from biomass through pyrolysis, has gained attention as a soil amendment for enhancing soil health. Its properties, including high porosity, large surface area, and chemical stability, enable it to improve soil physical, chemical, and biological properties. This review explores biochar's production, characteristics, and its multifaceted impact on soil health, including nutrient retention, soil structure improvement, and microbial activity. Additionally, challenges and research gaps in biochar application are discussed, supported by recent studies.

1. Introduction

Soil health is critical for sustainable agriculture and environmental resilience. However, modern agricultural practices have led to soil degradation, loss of organic matter, and decreased fertility. Biochar has emerged as a potential solution to these challenges, with its ability to enhance soil properties while sequestering carbon. Biochar is produced through pyrolysis, a thermochemical process where biomass is heated in a low-oxygen environment. The resulting material exhibits unique characteristics that can enhance soil health, reduce greenhouse gas emissions, and improve water and nutrient use efficiency.

2. Properties and Characteristics of Biochar

Biochar's efficacy as a soil amendment depends on its physicochemical properties, which are influenced by feedstock type and pyrolysis conditions. Some of the key characters are it has high porosity and surface area which enhances water retention and adsorption of nutrients. The chemical stability provides long-term carbon sequestration in soil. The cation exchange capacity (CEC) improves nutrient retention and availability. It **c**an reduce soil acidity and enhance nutrient availability in acidic soils. For instance, biochar produced from agricultural residues, such as rice husks or corn stover, tends to exhibit high nutrient retention capacity, while woody biochar offers better structural benefits.

3. Impact of Biochar on Soil Health

3.1. Physical Properties

Biochar improves soil structure, porosity, and bulk density, which are critical for water infiltration and aeration. Studies show that sandy soils treated with biochar exhibit increased water-holding capacity, while clay soils benefit from reduced compaction and improved drainage (Lehmann *et al.,* 2011).

3.2. Chemical Properties

Biochar enhances soil nutrient availability by adsorbing nutrients like ammonium, nitrate, and phosphate, reducing leaching losses (Joseph *et al.,* 2020). It also interacts with organic and inorganic fertilizers to improve their efficiency. Biochar application can ameliorate acidic soils, creating favorable conditions for crop growth.

3.3. Biological Properties

Biochar creates habitats for beneficial soil microorganisms by providing a stable carbon source and increasing habitat complexity. Enhanced microbial activity leads to better organic matter decomposition and nutrient cycling (Thies and Rillig, 2009). Moreover, biochar's role in reducing soil-borne pathogens has also been reported.

4. Challenges and Limitations

Despite its numerous benefits, the application of biochar in agriculture faces several challenges. One major issue is the variability in biochar properties, which arises from differences in feedstock type and pyrolysis conditions. These variations can lead to inconsistent results in improving soil health, making it difficult to predict the effectiveness of biochar under different circumstances. Additionally, the cost and accessibility of biochar remain significant barriers. Large-scale production and application can be prohibitively expensive, particularly for small-scale farmers, limiting its widespread adoption. Moreover, improper application of biochar poses potential risks. Over application can result in nutrient imbalances or even toxicity in certain soil types, which could harm plant growth rather than benefit it. To fully harness the potential of biochar, further research is needed to standardize its properties, understand its long-term effects on different soil types, and optimize application rates to suit specific agricultural systems.

5. Conclusion

Biochar is a promising soil amendment with the potential to address critical issues in soil health and agricultural sustainability. Its ability to improve soil structure, enhance nutrient retention, and foster beneficial microbial communities makes it a valuable tool for farmers. However, addressing production challenges and understanding site-specific responses are crucial for maximizing its benefits. Future research should focus on integrated approaches combining biochar with other sustainable agricultural practices to improve soil health and productivity.

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PP: 52 Enhancing Soil Fertility with Residue-Based Composts and Biofertilizers in Pigeonpea Systems

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Abstract: A study at MARS, University of Agricultural Sciences, Dharwad, assessed soil nutrient dynamics in pigeonpea systems influenced by residue composts and biofertilizers. FYM combined with biofertilizers significantly enhanced soil organic carbon (0.55%), nitrogen (236.11 kg ha^{-1}), phosphorus (24.59 kg ha^{-1}), and potassium (394.33 kg ha^{-1}) compared to other treatments. This treatment was on par with cotton, wheat, pigeonpea, sesame, and maize residue composts with biofertilizers for nitrogen, phosphorus, and potassium. Available nitrogen at 30-60 cm depth was also higher in FYM with biofertilizers (181.67 kg ha^{-1}). RDF treatments alone showed significantly lower nutrient status.

Introduction

Crop residues are a vital source of nutrients for subsequent crops, with India generating about 679 million tonnes annually. Among these, cereals produce the most residues, followed by fibers, oilseeds, pulses, and sugarcane. Approximately 201 million tonnes of these residues, with a nutrient potential of 4.86 million tonnes of NPK, are available for recycling. Additionally, animal excreta can potentially supply 17.77 million tonnes of NPK, though only 33.3% of it is currently utilized. Pigeonpea (*Cajanus cajan*), an important pulse crop in India, plays a crucial role in the diet but faces yield limitations due to inadequate nutrient application, particularly nitrogen and phosphorus.

To address these challenges, the use of residue-based composts and biofertilizers offers an alternative to inorganic fertilizers. Compost cultures, which include ligno cellulolytic microbes such as *Trichoderma viridae*, *Phanerochaete chrysosporium*, and *Aspergillus sidowia*, accelerate the decomposition of crop residues into high-quality compost. Combining these composts with biofertilizers like *Rhizobium*, phosphorus-solubilizing bacteria (PSB), and mycorrhiza can enhance nutrient availability and improve soil fertility. This study aimed to assess the effect of integrated nutrient management using different residue-based composts on pigeonpea productivity.

Materials and methods

A field experiment was carried out during *kharif* 2016 at Main Agricultural Research Station, University of Agricultural Sciences Dharwad, which is situated at 15º26’ N latitude and 75º01’ E longitude and at an altitude of 678 m above mean sea level. The experimental site was low in nitrogen at 0-30 and 30-60 cm depth (250.6 and 217.00 kg ha^{-1}, respectively), medium in phosphorus at 30 cm depth (24.32 kg ha^{-1}) low at phosphorus in 30-60 cm depth (18.32 kg ha^{-1}) and high in potassium at both 0-30 and 30-60 cm depth (398 and 370 kg ha^{-1}, respectively).

Table 1: Available organic carbon, nitrogen, phosphorus and potassium in soil after the harvest of pigeonpea as influenced by different crop residue based composts, FYM and biofertilizers

Treatments	Organic carbon (%)	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})	
		0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm
T_1: Sesame residue compost @ 6 t ha^{-1} + Biofertilizers + RDF	0.54	234.33	179.32	23.37	18.00	392.85	350.83

T_2: Wheat residue compost @ 5.4 t ha^{-1} + Biofertilizers + RDF	0.54	234.67	179.68	23.67	18.22	393.96	352.00
T_3: Pigeonpea residue compost @ 4 t ha^{-1} + Biofertilizers + RDF	0.54	234.50	179.52	23.56	18.11	393.58	352.77
T_4: Cotton residue compost @ 7.1 t ha^{-1} + Biofertilizers + RDF	0.55	235.24	180.62	24.33	18.67	394.18	355.23
T_5: Maize residue compost @ 6.4 t ha^{-1} + Biofertilizers + RDF	0.53	233.33	179.18	22.67	17.56	392.33	350.45
T_6: FYM @ 6 t ha^{-1} + Biofertilizers + RDF	0.55	236.11	181.67	24.59	18.89	394.33	357.51
T_7: FYM @ 6 t ha^{-1} + Without Biofertilizers + RDF	0.54	235.22	180.49	24.00	18.33	394.00	354.33
T_8: Biofertilizers + RDF	0.51	212.33	165.67	21.71	17.15	378.33	320.00
T_9: RDF alone	0.50	192.48	156.33	20.67	16.67	369.85	299.85
S.Em. ±	0.008	1.40	1.31	0.92	0.56	3.51	3.77
C.D. at 5 %	0.023	4.20	3.93	2.77	1.68	10.53	11.31

Result and discussion

The study aimed to evaluate the effect of various residue-based composts and biofertilizers on soil nutrient availability after the harvest of pigeonpea (*Cajanus cajan*). Soil organic carbon (SOC), nitrogen (N), phosphorus (P), and potassium (K) levels were analyzed across treatments, which included different residue-based composts, farmyard manure (FYM), and RDF (recommended dose of fertilizers) with and without biofertilizers. The initial soil organic carbon content was 0.52%. After harvest, significant variations in SOC content were observed across treatments. FYM (0.55%) and cotton residue compost combined with biofertilizers (0.55%), followed by FYM without biofertilizers and residue composts of wheat, pigeonpea, sesame, and maize along with biofertilizers, all yielding 0.54% recorded significantly higher soil organic carbon. However, significantly lower SOC content was observed in treatments with RDF alone (0.50%) and RDF with biofertilizers (0.51%). The higher organic carbon in residue-based compost treatments can be attributed to the efficient decomposition facilitated by the compost culture, which supports a higher microbial activity and organic matter content in the soil. These findings align with previous studies by Tejada and Gonzalez (2003) and Thenmozhi and Paulraj (2012), who noted that composts with a narrow C:N ratio and the presence of microbial cultures lead to better organic carbon retention. Similarly, soil nitrogen status at different depths was significantly influenced by the residue based composts. At the 0-30 cm depth, the initial available nitrogen was 250.66 kg ha^{-1}. Significantly higher available nitrogen after harvest was found in the treatment combining FYM with biofertilizers (236.11 kg ha^{-1}), followed by other residue-based composts with biofertilizers, such as cotton, wheat, pigeonpea, sesame, and maize, all showing values around 234-235 kg ha^{-1}. In contrast, the RDF-alone treatment showed a significantly lower nitrogen content (192.48 kg ha^{-1}), which was also lower than RDF with biofertilizers (212.33 kg ha^{-1}). At 30-60 cm depth, the initial nitrogen was 217 kg ha^{-1}, and FYM with biofertilizers again recorded the higher available nitrogen (181.67 kg ha^{-1}), followed by other residue-based compost treatments with biofertilizers (179.18–180.62 kg ha^{-1}). RDF alone resulted in significantly lower nitrogen (156.33 kg ha^{-1}), and RDF with biofertilizers (165.67 kg ha^{-1}) showed slightly higher levels. The higher nitrogen availability in organic treatments may be attributed to the nutrient release from organic materials, which supply essential nitrogen to crops, as supported by Aher *et al.* (2015), who reported a similar increase in nitrogen content with organic manure application. Significantly higher available phosphorous was with residue based composts. At the 0-30 cm depth, the initial available phosphorus was 24.32 kg ha^{-1}. After harvest, the significantly higher phosphorus levels were observed in FYM with biofertilizers (24.59 kg ha^{-1}), followed by cotton, wheat, pigeonpea, sesame, and maize residue composts with biofertilizers (23.37–24.33 kg ha^{-1}). The RDF treatments, both with and without biofertilizers, recorded significantly lower phosphorus levels (20.67 and 21.71 kg ha^{-1}, respectively). At 30-60 cm depth, the initial phosphorus level was 18.32 kg ha^{-1}. The significantly higher available phosphorus was recorded in FYM with biofertilizers (18.89 kg ha^{-1}), followed by other organic treatments (18.00–18.67 kg ha^{-1}). RDF alone resulted in the lower phosphorus (16.67 kg ha^{-1}), with RDF with biofertilizers also showing lower values (17.15 kg ha^{-1}). This increase in phosphorus availability could be due to organic acids released during the microbial decomposition of organic matter, which enhances the solubility of native phosphates, as indicated by Johnston and Poulton (1997) and Bharadwaj and Oman war (1994). This was strengthened by the results on potassium status. At the 0-30 cm depth, the initial available potassium was 398 kg ha^{-1}. Significantly higher potassium content after harvest was observed in FYM with biofertilizers (394.33 kg ha^{-1}), followed by cotton, wheat, pigeonpea, sesame, and maize residue composts with biofertilizers (392.33–394.18 kg ha^{-1}). The RDF treatments alone recorded lower available potassium (369.85 kg ha^{-1}), and RDF with biofertilizers had slightly higher levels (378.33 kg ha^{-1}). At 30-60 cm depth, the initial available potassium was 370 kg ha^{-1}. FYM with biofertilizers again recorded the higher available potassium (357.51 kg ha^{-1}), followed by other residue-based composts with biofertilizers (350.45 – 355.23 kg ha^{-1}). Lower available potassium was found in RDF alone (299.85 kg ha^{-1}) and RDF with biofertilizers (320.00 kg ha^{-1}). The higher potassium levels in the integrated organic treatments could be due to the release of potassium from organic manures, which also improve soil cation exchange capacity and facilitate the availability of potassium from non-exchangeable pools, as observed by Reganold (1988) and Bulluck *et al.* (2002).

Conclusion

The findings of this study highlight the significant impact of residue-based composts and biofertilizers on soil nutrient dynamics in pigeonpea cultivation. Organic treatments, particularly those combining FYM and residue composts with biofertilizers, resulted in higher soil organic carbon and better availability of nitrogen, phosphorus, and potassium compared to conventional RDF treatments. The improved nutrient availability is likely due to enhanced microbial activity and the nutrient-releasing properties of organic amendments, which support better soil fertility and crop productivity. These results reinforce the importance of integrated nutrient management strategies in sustainable agriculture, especially for crops like pigeonpea, which benefit from both organic and mineral fertilizers.

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PP: 53 Effect of varied levels of fertilizer and PGPR on soil health in green gram

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Abstract: Effective nutrient management is essential for sustainable agriculture, particularly in leguminous crops like green gram (*Vigna radiata*), which play a vital role in soil fertility enhancement and food security. A field study was conducted with varied levels of fertilizer and a combination of solid and liquid formulation of PGPR. Among treatments tried, application of 75 % RDF + 75 % FYM has recorded significantly higher availability of nitrogen, phosphorous and potassium (236.98, 80.54 and 132.9kgha^{-1}) followed by 100% RDF + 100% FYM(232.72, 79.24 and 130.35 kgha^{-1}).

Introduction

Sustainable agriculture necessitates the judicious management of soil nutrients to ensure long-term productivity and environmental health. The application of fertilizers and bio-inoculants, such as plant growth-promoting rhizomicrobial consortia (PGPR), has emerged as a promising strategy to enhance soil fertility and crop performance. Green gram (*Vigna radiata*), a significant pulse crop in tropical and subtropical regions, is valued for its nutritional profile and its ability to fix atmospheric nitrogen through symbiosis. However, optimizing nutrient management practices for this crop remains a critical challenge, particularly in the context of declining soil health and nutrient imbalances. This study aims to evaluate the impact of different fertilizer levels and rhizomicrobial consortia on the available nutrient status of soil at harvest in green gram cultivation. The findings will provide insights into sustainable strategies for enhancing soil fertility and productivity while minimizing environmental impacts.

Material and methods

A field study was conducted during 2021 at College of Agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga. The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatments and three replications. Treatment consisting of varied levels of fertilizer and combination with solid and liquid formulation of PGPR viz.: T_1: 75 % RDF + 75 % FYM, T_2: 100 % RDF + 100 % FYM, T_3:125 % RDF + 125% FYM, T_4: 75 % RDF + Solid formulation of PGPR, T_5: 100% RDF + Solid formulation of PGPR, T_6: 125% RDF + Solid formulation of PGPR, T_7: 75 % RDF + Liquid formulation of PGPR, T_8: 100 % RDF + Liquid formulation of PGPR and T_9: 125 % RDF + Liquid formulation of PGPR.

Results and discussion

Available nutrient status of the experimental soil showed significant difference among the treatments after harvest of the crop (Table 1). Treatment received with75 % RDF + 75 % FYM recorded significantly higher availability of nitrogen, phosphorous and potassium (236.98, 80.54 and 132.97kgha^{-1}) followed by 100% RDF + 100% FYM (232.72, 79.24 and 130.35 kgha^{-1}) and significantly lower availability of nitrogen, phosphorous and potassium (213.91, 73.26 and 110.52 kgha^{-1}) was noticed in 125% RDF + liquid formulation of PGPR. The perusal of the data indicate that organic carbon status of the soil after harvest did not indicate significant variations for varied levels of fertilizer and PGPR. However highest organic carbon (4.62 g kg^{-1}) was recorded in the treatment applied with 125% RDF + liquid formulation of PGPR and lowest in 75% RDF + 75% FYM (4.5 gkg^{-1}).

Soil nutrient status of the soil is inversely related to the crop nutrient uptake as there is a greater nutrient uptake by the crop which means greater will be the depletion of nutrient sin the soil. Lower available nitrogen, phosphorous and potassium after harvest was noticed in 125 % RDF + liquid formulation of PGPR (T9). Greater depletion of N, P and K from soil in T9 treatment when compared to package of practice might be due to application liquid plant growth promoting rhizomicrobial consortia increased the nutrient availability in the soil root ecosystem makes easy for uptake. Basal application of fertilizers also enhances the plant nutrient uptake from the soil to meet the crop demand for producing the maximum dry matter production and seed yield this results in maximum depletion of nutrients in T9 (Singh *et al.*, 2016).

Table. 1: Available soil nutrient status at harvest of green gram as influenced by varied levels of fertilizer and PGPR.

Treatment details		Available N	Available P_2O_5	Available K_2O	OC (g kg^{-1})
		Kg ha^{-1}			
T_1	75 % RDF + 75 % FYM	236.98	80.54	132.97	4.50
T_2	100 % RDF + 100 % FYM	232.72	79.24	130.35	4.58
T_3	125 % RDF + 125 % FYM	229.03	78.32	127.95	4.57
T_4	75 % RDF + Solid formulation of PGPR	230.56	78.96	129.42	4.56
T_5	100 % RDF + Solid formulation of PGPR	224.68	77.87	126.23	4.59
T_6	125 % RDF + Solid formulation of PGPR	221.46	76.28	120.46	4.59
T_7	75 % RDF + Liquid formulation of PGPR	223.08	77.24	125.75	4.58
T_8	100 % RDF + Liquid formulation of PGPR	215.30	74.36	116.80	4.61
T_9	125 % RDF + Liquid formulation of PGPR	213.91	73.26	110.52	4.62
S. Em±		3.45	0.79	3.16	0.09
CD (P=0.05)		10.37	2.38	9.48	NS

Note:
PGPR: Plant Growth Promoting Rhizomicrobial Consortia
Solid formulation = 12.5 kg ha^{-1}, Liquid formulation = 625 ml ha^{-1},
Recommended dose of fertilizer (RDF) = 13:25:25 kg N, P_2O_5, K_2O ha^{-1} + 7.5 t FYM ha^{-1} + 10 kg $ZnSO_4$ha^{-}
Farm yard manure (FYM): From treatment $T_4$to T_9 FYM is applied as per recommended dose
Initial N: P_2O_5:K_2O and OC is 230.22: 75.89: 135.23 (kgha^{-1}) and 4.57 (gkg^{-1})

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PP: 54 Sunflower (*Helianthus annuus* L.) residue decomposition rate and dehydrogenase activity in soil under rainfed condition and urd bean crop

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Abstract: A study was conducted at MARS, University of Agricultural Sciences, Dharwad during *kharif* 2014 and evaluated sunflower residue treatments on soil decomposition and dehydrogenase activity under urd bean. Sunflower residue at 4 t/ha used as mulch recorded higher CO_2 evolution (56.08 mg/100 g soil in 2 days), while pre-decomposed residue (75 days with compost culture) showed lower values (36.44 mg) by 27th day. Dehydrogenase activity was higher with pre-decomposed residue (47.52 µg TPF g^{-1} day^{-1}) and FYM at 5 t/ha (47.48 µg TPF g^{-1} day^{-1}), while mulch application recorded lower activity (38.79 µg TPF g^{-1} day^{-1}). Pre-decomposed residues and FYM enhanced soil microbial activity and nutrient availability.

Material and methods

The experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences Dharwad. Carbon dioxide evolution during decomposition of sunflower in soil (Narwal *et al.*, 1999). Dehydrogenase activity in the soil samples was determined by following the procedure as described by Casida *et al*. (1964).

Result and discussion

The decomposition rate of sunflower residue in soil, as indicated by CO_2 evolution, showed a marked decrease in CO_2 between the 2nd, 5th, and 7th days of incubation, stabilizing by the 27th day. On day 27, sunflower residue at 4 t/ha decomposed for 75 days with compost culture recorded a significantly lower CO_2 evolution (36.44 mg) compared to other treatments. Sunflower residue at 4 t/ha used as mulch at sowing recorded higher CO_2 evolution (56.08 mg) in the first 2 days, followed by chopped sunflower residue incorporated 15 days before sowing (47.70 mg). FYM at 5 t/ha applied 15 days before sowing had a lower CO_2 evolution (38.15 mg), similar to sunflower residue with compost culture.

Dehydrogenase activity at 45 DAS was higher in the treatment with sunflower residue at 4 t/ha decomposed for 75 days with compost culture (47.52 µg TPF g^{-1} day^{-1}), comparable to FYM at 5 t/ha applied 15 days before sowing (47.48 µg TPF g^{-1} day^{-1}). The lowest dehydrogenase activity was observed in sunflower residue at 4 t/ha used as mulch at sowing (38.79 µg TPF g^{-1} day^{-1}). This variation may be attributed to the allelopathic effects of sunflower residue as indicated by Narwal *et al.* (1999)

PP: 55 Transforming Soil Resilience: Biochar Applications for Enhanced Erosion Control in high rainfall areas

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Biochar, a carbon-rich material produced through pyrolysis of organic matter, has gained attention as a potential soil amendment due to its benefits in improving soil fertility, enhancing water retention, and mitigating soil erosion. This review explores the effects of biochar on loessial soils, focusing on its role in reducing soil erosion and nitrogen loss under simulated rainfall conditions. Biochar was applied at different particle sizes (<0.25, 0.25–1, and 1–2 mm) and four application rates (1%, 3%, 5%, and 7%) to soils held at a 27% slope. Simulated rainfall events (90 mm h^{-1}) were used to mimic erosive conditions. The results showed that lower biochar application rates (1% and 3%) reduced soil erosion, while higher rates (7%) increased soil loss. Finer biochar particles (<0.25 mm) were more prone to erosion and led to higher nitrogen and biochar losses in sediments. In contrast, coarser particles (1–2 mm) demonstrated better soil retention and lower nutrient leaching. The findings highlight the importance of considering both biochar particle size and application rate when recommending biochar as a soil amendment, especially for erosion-prone areas. This study contributes to the growing body of knowledge on biochar's environmental benefits, offering insights for its effective use in sustainable land management practices.

Keywords: Biochar, nitrogen, rainfall, sediments and soil erosion

PP: 56 Effects of organic supplements and inorganic nutrients levels on productivity of maize in the northeastern region

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Abstract: The field study entitled effects of organic supplements and inorganic nutrients levels on productivity of maize in the northeastern region was conducted during the *kharif* season of 2023 at the Experimental Farm of ICAR–Indian Agricultural Research Institute (IARI), Assam. The experiment was laid out in split plot design and consists 3 organic supplements (Control, FYM @ 10 t/ha and Vermicompost @ 2.5 t/ha) in main plots and four inorganic nutrients levels(control, 50% RDF, 75% RDF and 100% RDF along with 300 kg lime/ha with all levels) in subplot and replicated thrice. The experimental findings showed that among organic supplements, FYM @10 t/ha shows higher growth parameters, grain yield (4.37 t/ha), net returns (₹71040) and improvement in soil health. Among inorganic nutrients management levels,100% RDF was superior in terms of crop growth, grain yield (4.43t/ha) and moreprofi table (netB:C1.7) compared to other levels.

Introduction

Maize (*Zea mays* L.) is an important cereal crop belongs to the grass family *Poaceae* and the world's most important cereal crop after wheat and rice. It is known as the 'Queen of Cereals'. In the 2022-23 period, India achieved a production of 33.6 million metric tons from 10 million hectares, resulting in a yield of 3,349 kg per hectare (GOI, 2023). In Assam, maize cultivation covers a relatively small area and has lower production and yield levels than in other Indian states. Currently, around 41,154 hectares are used for maize farming, producing approximately 147,902 metric tons, with an average yield of 3.59 tons per hectare (Directorate of Economics and Statistics, Government of Assam, 2021). Higher crop yields are often linked to genetic advancements and extensive use of chemical fertilizers, has led to significant environmental harm, degraded soil quality and reduced maize yields over time (Hepperly *et al*., 2009). The use of organic manures (OM) in agriculture enhances soil's physical and chemical properties, boosts crop productivity and is an eco-friendly, affordable, and accessible nutrient source. Inorganic fertilizers and O Meach have their limitations and when used alone, cannot guarantee sustainable crop productivity (Arif *et al*., 2016). However, an integrated nutrient management approach, which combines both inorganic and organic fertilizers, presents an effective alternative for sustaining or restoring soil fertility and crop productivity over the long term.

Material and methods

A field experiment was carried out in the *kharif* season of 2023 at the Experimental Farm of ICAR–Indian Agricultural Research Institute (IARI) in Assam, India, to evaluate how maize responds to various nutrients sources in the acidic soils of Assam. The soil at the experimental site was sandy loam, consisting of 70.5% sand, 11% silt, and 18.4% clay, with an electrical conductivity of 0.12 dS/m. It was acidic (pH 4.84), with a bulk density of 1.31 g/cm^3. The soil showed high organic carbon content (1.18%), low available nitrogen (197.6 kg/ha) and phosphorus (9.26 kg/ha), and moderate potassium levels (121.8 kg/ha). The experiment was laid out in split plot design and consists 3 organic supplements (Control, FYM @ 10 t/ha and Vermicompost @ 2.5 t/ha) in main plots and four inorganic nutrients levels (control, 50% RDF, 75% RDF and 100% RDF along with 300 kg lime/ha with all levels) in subplot and replicated thrice. Maize hybrid LQMH-1 was sown on 3rd August 2023 in rows keeping distance of 60 cm and plant to plant distance of 20 cm with seed rate of 20 kg/ha. The recommended dose of 60:40:40 kg/ha N, P_2O_5, K_2O was applied through urea, di-ammonium phosphate (DAP) and muriate of potash (MOP). The other agronomic practices, including weed control, irrigation, and insect-pest management, were standardized across all treatments. The data collected were statistically evaluated using analysis of variance (ANOVA) with the OPSTAT software.

Results and discussion

The results indicated that the use of organic supplements and varying levels of inorganic nutrients significantly impacted maize yields, including grain, stover, and overall biological yield. Among the organic supplements, applying 10 t FYM/ha achieved the highest grain yield (4.37 t/ha), stover yield (8.18 t/ha), and biological yield (12.54 t/ha), outperforming other treatments and showing similar results to vermicompost applied at 2.5 t/ha. These outcomes align with findings by Syed *et al*. (2009), possibly due to improved soil moisture, increased nutrient availability, efficient nutrient absorption, consistent nutrient release, and better erosion resistance compared to the control (Ali *et al*., 2020).

For inorganic nutrients levels, the treatment with 100% RDF recorded the highest grain yield (4.43 t/ha), stover yield (8.17 t/ha), and biological yield (12.60 t/ha) compared to other treatments. This can be attributed to the established role of primary nutrients up to 100% RDF per hectare in enhancing three key yield factors: creating a robust vegetative structure for nutrient uptake, optimizing photosynthesis, and supporting the development of a strong reproductive sink. This balanced source-sink relationship likely boosted both vegetative and reproductive growth, leading to higher yields. Among mineral nutrients, primary nutrients are critical for maximizing crop genetic potential by fostering growth and development. There was significant interaction between organic supplements and inorganic nutrients levels on grain yield of maize (Fig 1).

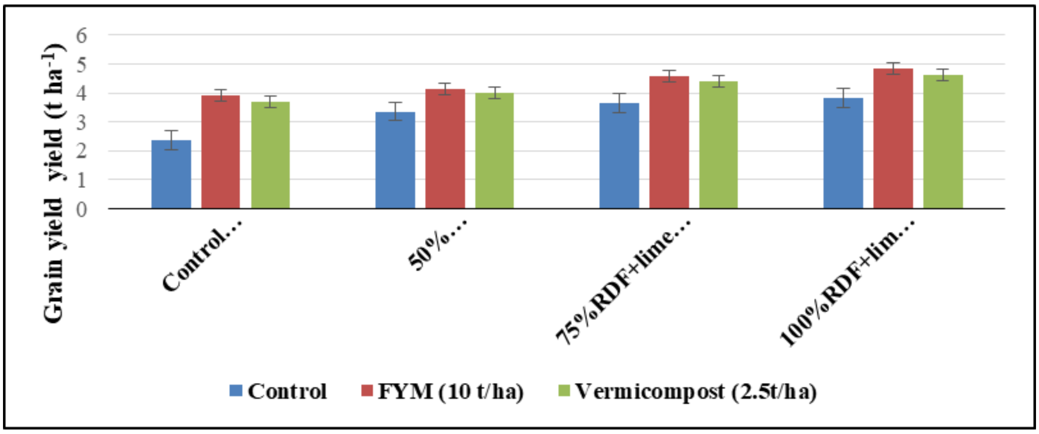

Fig.1 Interaction effect of organic supplements and inorganic nutrients management levels on grain yield of maize

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PP: 57 Exploring Biochar Use in Agriculture: Experiences of farmer from Mudhol

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Biochar is charcoal, sometimes modified, that is intended for organic use, as in soil. It is the lightweight black remnants, consisting of carbon and ashes, remaining after the pyrolysis of biomass, and is a form of charcoal (Khedulkar, *et al.*,2024). It is a stable, carbon-rich substance that has gained attention in agriculture due to its potential to enhance soil health, improve crop yields, and mitigate climate change by sequestering carbon. These facts have been experimented by a farmer in Bagalkote district. During field visits of Krishi Vigyan Kendra Bagalkote, these experiences were documented and published in daily newspaper. Shri Shrikant Kumbar, recipient of Krishi Pandit, by Govt of Karnataka for maintaining sustainable farming, Director of Golden spice Farmer Producer Organisation, is an inquisitive farmer from Mugalkhod village of Mudhol taluka. He tried to prepare biochar for application in different crops. He used around 50 kgs of sesbania and any available wood which was by product of live fencing of his farm. After drying it , he made them into pieces and filled in one metal bin of 200 *l* capacity. Perforations were made at the base and a chimney was attached on the top of this bin. Then he allowed the wood to burn. The oxygen was supplied from the bottom of the bin and smoke escaped through chimney. Thus , he burnt the wood and after making sure all the wood is burnt, either water was poured in the bin or the coal was taken out and was made cool by pouring water. About 15-20 kg of biochar was obtained and was broken into small pieces, so that it can be easily applied to plants. He applied this biochar to apple ber @ 1 kg for three years, from which he realized 100-150kg yield vs 90 kg in control plots. Secondly he has useds biochar to enrich the organic manure for applying turmeric crop , and for the application of green leafy vegetables. Through the application of biochar in agriculture Mr. shrikant has realized improvement in soil fertility, as biochar helps retain nutrients in the soil, preventing leaching and enhancing the availability of essential minerals for plants. He has also experienced the porous nature of biochar allowed it to hold water, which is especially beneficial in regions with dry climates or during periods of drought. However, the systematic study is essential to test the favorable changes in soil pH, which has favoured the plant growth, to test the soil micro flora, fertilizer efficiency, and also the amount of locked in carbon into the soil and economic returns. There is also need to workout the cost of production and optimization of quantity.

PP: 58 Carbon Emission and Carbon Sequestration Dynamics in Rural Areas of Dharwad District, Karnataka.

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Abstract: A study was conducted in Timmapur and Mummigatti villages of Dharwad district, Karnataka, India, to measure carbon emissions and sequestration over one year. Using an Air Quality Monitor and CO meter, researchers found that Mummigatti village had higher annual mean concentrations of CO_2 (1301.2 ppm) and CO (65.6 ppm) than Timmapur (CO_2 at 1020.4 ppm, CO at 34.7 ppm). PM2.5 and PM10 levels were also higher in Mummigatti. Emissions peaked in summer and were lowest during the rainy season. *Tamarindus indica* and *Azadirachta indica* showed the highest carbon sequestration, indicating older, larger trees contribute significantly to carbon mitigation in these areas.

Keywords: Carbon emission, Carbon sequestration, Carbon dioxide (CO_2), Carbon monoxide (CO), Particulate Matter ($PM_{2.5}$ and PM_{10}), DBH.

Introduction

Carbon emissions, driven by industrialization, deforestation, and transportation, significantly contribute to climate change, global warming, and health risks. India, the third-largest emitter globally, faces challenges from pollutants like particulate matter, CO_2, and CO. Mitigating emissions through carbon sequestration, a process where trees capture and store atmospheric carbon, is vital. This study examines outdoor carbon emissions and evaluates carbon sequestration under microclimatic influences.

Materials and methods

Study Area

The study was conducted in Timmapur and Mummigatti villages, Dharwad district, Karnataka.

Carbon Emission Measurement

Parameters (temperature, relative humidity, CO_2, $PM_{2.5}$, PM_{10}) were measured using an Air Quality Monitor, and CO using a CO meter from October 2021 to September 2022. Measurements were taken at the village center, distances of 100-500 m, and 200 m beyond the last house in all directions.

Carbon Sequestration Estimation

Biomass was assessed using a non-destructive method through quadrates (10 x 10 m) at the village center, 300 m, and 600 m distances. Tree height, Girth at Breast Height (GBH), and biomass parameters were used to estimate carbon storage and sequestration.

Statistical Analysis

Two-way ANOVA assessed variations in emission parameters. Regression and Pearson's correlation analyzed relationships between tree age, DBH, biomass, and carbon sequestration.

Results and Discussion

Carbon Emission Levels

Annual mean carbon emission levels were higher in Mummigatti compared to Timmapur. CO_2 levels were 1301.2 ppm in Mummigatti vs. 1020.4 ppm in Timmapur. CO levels were 65.6 ppm and 34.7 ppm, respectively. $PM_{2.5}$ and PM_{10} concentrations were also elevated in Mummigatti (118.8 μm^3 and 168.2 μm^3) compared to Timmapur (73.9 μm^3 and 121 μm^3).Emission levels exceeded safe limits due to biomass reliance, fossil fuel usage, open burning, and deforestation.

Seasonal Variation

Emissions peaked in summer due to increased agricultural activities, biomass burning, and forest fires, while the lowest levels occurred in the rainy season due to rainwater absorption, reduced human activity, and vegetation growth. CO_2 levels ranged from 944.3 ppm (rainy season, Timmapur) to 1376.8 ppm (summer, Mummigatti). $PM_{2.5}$ and PM_{10} levels were lowest during the rainy season and highest in summer.

Carbon Sequestration

Timmapur Village: 16 species and 50 trees assessed. Total biomass: 0.846 kg, carbon storage: 423.01 g, and carbon sequestration: 1547.88 g. Mummigatti Village: 13 species and 34 trees assessed. Total biomass: 0.715 kg, carbon storage: 357.41 g, and carbon sequestration: 1308.05 g.The major species contributing to carbon sequestration were *Azadirachta indica* (443.78 g/tree) and *Tamarindus indica* (439.44 g/tree) in Timmapur, and *Tamarindus indica* (489.31 g/tree) and *Azadirachta indica* (352.66 g/tree) in Mummigatti.Trees with higher age and DBH sequester more carbon due to greater biomass and efficient growth characteristics.

Conclusion

Carbon emissions, higher in Mummigatti due to local activities and industries, peaked in summer and dropped in the rainy season. Older trees with larger DBH, especially *Tamarindus indica* and *Azadirachta indica*, showed superior carbon sequestration. Promoting these species' plantations can reduce emissions, enhance carbon storage, improve rural health, and support sustainable development, mitigating climate change.

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PP: 59 Application of biochar in sustainable agriculture and carbon sequestration: A review

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Abstract: Current agriculture faces multiple challenges due to rapid increasing food demand and environmental concerns. This review summarizes the impact of biochar on crop productivity, soil fertility and mitigating the climate change. Biochar, a low cost solid carbon-rich product produced from agricultural crop residues, wastes and wood, through pyrolysis in an oxygen-deficient condition. Application of biochar contributed to higher productivity, carbon sequestration, waste recycling, nutrient retention and a reduction in greenhouse gas emissions. This review explored the various ways biochar was applied to sustainably enhance crop yield, soil fertility and ensure safe agricultural practices.

Keywords: Agriculture, Biochar, Carbon sequestration, Environment, Soil health.

PP: 60 A Review of Biochar's Impact on Sugarcane Growth and Yield

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Abstract: Biochar, a stable carbon-rich substance produced through the thermo-chemical decomposition of organic materials, has gained attention for its potential to improve agricultural productivity and mitigates climate change. It is derived from agricultural biomass and waste, biochar enhances soil health, nutrient cycles, and microbial activity, making it a promising tool for sustainable agriculture. This review explores the effects of biochar application on sugarcane production, focusing on its influence on growth, yield, and underlying mechanisms. Studies indicate that biochar improves sugarcane growth parameters, such as leaf area and photosynthetic activity, especially under saline stress condition. It also boosts sugarcane yield, with increases in biomass, millable cane number and sugar content observed in various trials. These improvements are attributed to biochar's ability to enhance soil structure, water retention, nutrient availability, and microbial activity, as well as its role in mitigating environmental stress. The positive impact of biochar on sugarcane productivity is influenced by application rate, biochar type, and local soil and climate conditions. Overall, biochar shows significant promise in enhancing sugarcane growth and yield, supporting sustainable farming practices and offering agronomic and environmental benefits.

Introduction

Biochar, a stable carbon-rich substance produced through the thermochemical decomposition of organic materials, has gained significant attention in recent years for its beneficial effects on agricultural productivity. Derived from agricultural biomass and waste, biochar improves soil health, enhances nutrient cycles and supports plant growth through various mechanisms, including improved nutrient availability and microbial activity (Zhao *et al*., 2014; Rafique *et al*., 2019). Moreover, biochar plays a vital role in mitigating climate change by sequestering carbon in the soil and reducing greenhouse gas emissions compared to traditional methods of waste disposal, such as open-air burning (Woolf *et al*., 2010). As a result, biochar has emerged as a promising tool for sustainable agriculture, offering both agronomic and environmental benefits.

Sugarcane, one of the world's most important cash crops, is a particularly demanding plant in terms of nutrient requirements. It is extensively grown in tropical and sub-tropical regions of the world, where continuous cultivation and improper fertilizer use have led to soil degradation, limiting crop productivity. Biochar, with its capacity to improve soil structure, nutrient retention and microbial health, has the potential to mitigate these challenges and boost sugarcane growth and yield. This review explores the various effects of biochar application on sugarcane production, focusing on growth parameters, yield and the mechanisms underlying these improvements.

Effect of Biochar Application on Growth Parameters of Sugarcane: Several studies have demonstrated the positive influence of biochar on sugarcane growth. For example, a study conducted by Liao F *et al.* (2019) in Guangxi, China, assessed the effects of biochar derived from cassava straw on sugarcane at various growth stages. The study included treatments with biochar application rates of 0 t ha^{-1} (control), 10 t ha^{-1} and 20 t ha^{-1}. Results indicated that biochar significantly increased the green leaf area at all growth stages. The 20 t ha^{-1} treatment (C20) led to the largest leaf area, with measurements of 3215.72 cm², 1460.76 cm², and 335.61 cm² at the seedling, elongation and maturity stages, respectively. While biochar reduced the net photosynthetic rate at the seedling stage, it had a stimulating effect during the elongation and maturity phases, increasing photosynthesis by 21.77 per cent and 18.49 per cent compared to the control. Furthermore, biochar application helped mitigate the adverse effects of saline stress on sugarcane growth, with the 10 t ha^{-1} treatment showing the smallest impact of salinity on plant height and stem diameter (Ngoc-Thang Vu *et al*., 2023). The enhanced photosynthetic activity and leaf area expansion observed with biochar application are likely attributed to its role in improving soil structure, moisture retention, and nutrient cycling, all of which contribute to better plant health. The interaction of biochar with soil microorganisms and the release of nutrients over time also support optimal plant growth, especially in nutrient-depleted soils.

Effect of Biochar Application on Yield and Yield Parameters of Sugarcane: Biochar's influence on sugarcane yield has been widely studied, with numerous studies reporting significant improvements. For instance, Fen Liao *et al*. (2015) observed that biochar treatments resulted in changes to sugarcane biomass at different growth stages. The 20 t ha^{-1} treatment (C20) exhibited a positive effect on biomass during the elongation phase (11.98 % increase), although a decline was recorded at the maturity stage. This suggests that while biochar may boost early growth, its long-term effects on biomass yield could be influenced by other factors, such as soil nutrient content and environmental conditions. In field trials conducted by R.G. Quirk *et al*. (2008) in New South Wales, Australia, the application of greenwaste biochar at 5 t ha^{-1} resulted in significantly higher cane yield (110 t ha^{-1}) compared to treatments with lime (86 t ha^{-1}). The addition of 10 t ha^{-1} of sugarcane trash biochar led to a substantial increase in the number of millable canes (11.33 per pot), which was comparable to other treatments combining compost and biochar. Hariyono *et al*. (2014) reported similar results, with a significant increase in millable cane number in treatments containing biochar, further reinforcing its positive impact on yield. In a more recent study by Jiming Xiao *et al*. (2023), the combination of deep tillage and biochar application (500 kg/ha) significantly enhanced both planting cane (173.67 t ha^{-1}) and ratoon cane (123.42 t ha^{-1}) yields, compared to conventional tillage without biochar. This highlights the importance of integrating biochar with other soil management practices for maximizing yield benefits. Furthermore, Lima and White (2017) reported that biochar derived from bagasse residues increased sugar yield by 32% when applied at 4%, especially in combination with fertilizers. This suggests that biochar not only enhances cane yield but also improves sugar content, making it a valuable amendment for improving both quantity and quality of sugarcane production.

Conclusion

Biochar application has been shown to significantly enhance sugarcane growth and yield, primarily through improvements in soil structure, nutrient availability, and water retention. Its ability to mitigate environmental stresses, such as salinity, and promote better nutrient cycling and microbial activity further supports its role in sustainable sugarcane production. The optimal benefits of biochar depend on factors such as the application rate, type of biochar, and the specific soil and climate conditions of the growing region. Thus, careful consideration of these factors is crucial for maximizing the potential of biochar in sugarcane farming.

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