EFFECT OF VARIOUS FARM RESIDUE BIOCHAR ON YIELD OF WATERMELON (*Citrullus lanatus* Thunb.), SOIL CARBON POOLS AND SOIL PROPERTIES IN ALFISOLS OF KONKAN

THESIS

Submitted in partial fulfilment of the requirements for the Degree of

MASTER OF SCIENCE
IN
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By
CHAVAN JYOTI SIDDHESHWAR
(ADPM/21/2828)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, DAPOLI

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NOVEMBER, 2023

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Under the Guidance of
Dr. R. V. DHOPAVKAR
Deputy Director of Research (Agril)
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NOVEMBER, 2023

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"EFFECT OF VARIOUS FARM RESIDUE BIOCHAR ON YIELD OF WATERMELON (*Citrullus lanatus* THUNB.), SOIL CARBON POOLS AND SOIL PROPERTIES IN ALFISOLS OF KONKAN"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.

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Place: Dapoli

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF VARIOUS FARM RESIDUE BIOCHAR ON YIELD OF WATERMELON (*Citrullus lanatus* THUNB.), SOIL CARBON POOLS AND SOIL PROPERTIES IN ALFISOLS OF KONKAN"** submitted for the degree of M.Sc. (Agri.) in Soil Science and Agril. Chemistry of the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by **Ms. Chavan Jyoti Siddheshwar (ADPM/21/2828)** under my supervision and that no part of this thesis has been submitted for any other degree. The student had completed all the Course and Research requirement as per the norms in regular.

The assistance and help received during the course of investigation have been fully acknowledged.

Place: Dapoli

Date: 30 / 01 / 2024

Chairman

Student Advisory Committee

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Head

Department of Soil Science and Agricultural Chemistry

THESIS APPROVAL BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER

This is to certify that the thesis entitled, **"Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* thunb.), soil carbon pools and soil properties in Alfisols of Konkan"** submitted by **Ms. Chavan Jyoti Siddheshwar (ADPM/21/2828)** to the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfillment of the requirements for the degree of M.Sc. (Soil Science and Agricultural Chemistry) in the subject having Agronomy, Horticulture and Biochemistry as Minor subject of Department Agronomy, Department of Horticulture and Department of Soil Science and Agricultural Chemistry has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One External Examiner after an open Viva-Voce examination in the presence of External Examiner on the same held on dated 25 / 01 / 2024.

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Place: Dapoli

Date: 30 / 01 / 2024

Chavan

(Chavan Jyoti Siddheshwar)

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ABBERIVATION

%	:	per cent
@	:	at the rate of
&	:	and
°C	:	Degree centigrade
°B	:	Degree Brix
Rs	:	Rupees
AHB	:	Areca nut Husk Biochar
BSS	:	Bright sunshine hour
CD (P=0.05)	:	Critical Difference at 5 per cent level
CEC	:	Cation Exchange Capacity
CFU	:	Colony Forming Unit
CHB	:	Coconut Husk Biochar
cm	:	Centimeter
DAT	:	Days after transplanting
day^{-1}	:	Per day
Dr.	:	Doctor
$dS\ m^{-1}$	:	Deci Siemen per meter
EC	:	Electrical conductivity
Epan	:	Pan evaporation
et al.	:	and others
etc	:	etcetera
Fig.	:	Figure
FYM	:	Farm Yard Manure
g	:	grams
ha^{-1}	:	Per hectare
i.e.	:	That is
IC	:	Inorganic Carbon
ICAR	:	Indian Council of Agricultural Research
J	:	Journal
K	:	Potassium
K_2O	:	Potassium oxide
Kcal	:	Kilocalorie
kg	:	Kilogram

kg ha^{-1}	:	kg per hectare
LC	:	Labile Carbon
M.S.	:	Maharashtra State
m^2	:	Metre square
m^{-2}	:	Per square metre
MBC	:	Microbial Biomass Carbon
mg	:	mili gram
mg kg^{-1}	:	miligram per kilogram
mm	:	milli metre
MOP	:	Muriate of potash
N	:	Nitrogen
No.	:	Number
OC	:	Organic Carbon
P	:	Phosphorous
P_2O_5	:	Phosphorous pentoxide
ppm	:	parts per million
RD	:	Rainy Day
RDF	:	Recommended Dose of Fertilizer
RHB	:	Rice Husk Biochar
RH-I humidity	:	Morning relative
RH-II humidity	:	Afternoon relative
S. E m.±	:	Standard error mean
t ha^{-1}	:	Tonnes per hectare
t ha^{-1}	:	ton per hectare
T max.	:	Maximum temperature
T mean	:	Mean temperature
T min.	:	Minimum temperature
TC	:	Total Carbon
Tr.	:	Treatment
Var.	:	Variety
viz.,	:	Namely
WSC	:	Water Soluble Carbon

Glossary

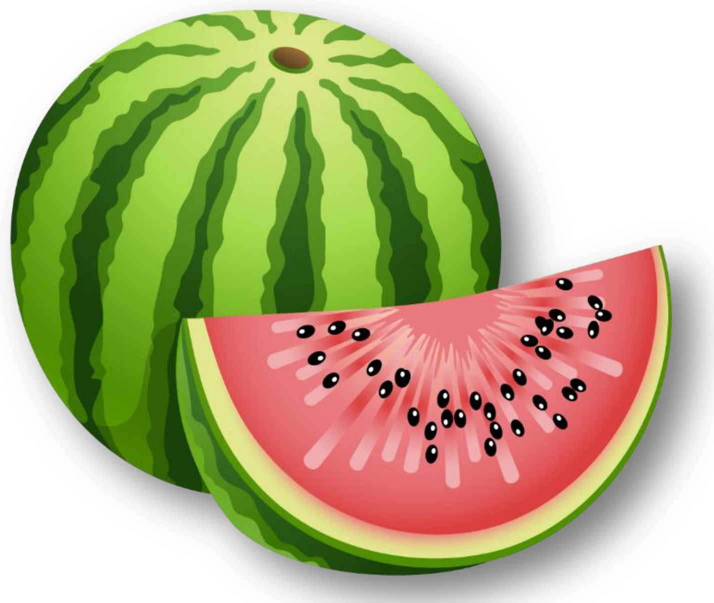
Biochar: Biochar is a fine-grained, carbon-rich, porous product remaining after plant biomass subjected to a thermo-chemical conversion process (pyrolysis) at temperature (at 300-600 ºC) in the absence of oxygen.

Lateritic soils: Soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidizing and leaching conditions.

Pyrolysis: Thermochemical decomposition of organic material at temperatures between 300 °C to 600 °C in the absence of oxygen

Cost of cultivation: Cost of cultivation refers to the total expenses incurred in cultivating one hectare of land.

Konkan: Konkan is the 720 km long rugged section of the western coastline of the Arabian Sea which extends from Damon in the North to the western side land of Maharashtra and Goa.



INTRODUCTION

CHAPTER I
INTRODUCTION

1.1 Background information

Among the cucurbits, watermelon is one of the key crops growing widely in India as well as other tropical and subtropical nations in Asia and Africa. It is thought that watermelon originated in Africa and then spread to other continents. Watermelons are plants that are grown in temperate to tropical areas and require temperatures above around 25 °C (77 °F) to flourish. Fruit of watermelon is known botanically as a pepo.

In 2020, global production of watermelon was 101.6 million tonnes, with China (mainland) accounting for 60% of the total (60.1 million tonnes). Turkey, India, Iran, Algeria, and Brazil were secondary producers with a combined annual output of 2.3 million to 2.5 million tonnes in 2020. As per the National Institute of Industrial Research, watermelon is cultivated in Uttar Pradesh, Himachal Pradesh, Rajasthan, Orissa, Gujarat, Punjab, Haryana, Assam, West Bengal, Andhra Pradesh, Maharashtra, and Tamil Nadu. According to the National Horticulture Board, Uttar Pradesh is the leading state in the production of watermelon in 2021-22 in India producing 706.65 tonnes followed by Andra Pradesh (628.57 tonnes), Tamil Nadu (315.19 tonnes), Karnataka (260.90 tonnes), Orissa (253.54 tonnes). Maharashtra ranks 9th in production of watermelon producing about 101.91 tonnes during 2021-2022, (Anonymous, 2021-22).

Watermelon is very nutritious and high in vitamin C, both of which are beneficial to health. Owing to high water content, low in sugar and calories. watermelon contains 92% water, 7.55 g of carbohydrates, 0.62 g protein, 30 kcal, and other vital elements. Carotenoids are prevalent in watermelon. Lycopene, phytotein, beta carotene, lutein, and neurosporene are a few of the carotenoids found in watermelon. Major carotenoids in watermelon include lycopene. The likelihood of cardiovascular illnesses is decreased by lycopene. Regular consumption of watermelon reduces the risk of developing chronic illnesses like cancer, diabetes, hypertension, and heart conditions by reducing the production of free radicals and reactive oxygen species. Watermelon contains phytochemicals with anti-inflammatory, anti-cancer, and antioxidant characteristics, such as beta-carotene, lycopene, vitamin C, and total polyphenolic content (Maoto *et al*.,2019)

According to the International Biochar Initiative (IBI), "Biochar is a solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment" (IBI, 2012). Biochar is a solid material rich in carbon that is created by pyrolyzing crop residue in an atmosphere with less or hardly any oxygen. When biomass is burnt to temperatures between 600 to 700°C. In a controlled process known as pyrolysis, organic waste from forestry and agricultural operations is burned to produce biochar, a material that resembles charcoal and thus crop burning in India might be resolved by biochar. During the pyrolysis process, volatile chemicals are released which are then condensed to produce bio-oil and a carbon-rich charcoal substance known as biochar. The processing temperature, heating rate, reactor pressure and the type of biomass material such as the presence of lignin, cellulose, hemicellulose, inorganic compounds and moisture, all have an impact on the production of biochar

Biochar is typically alkaline and is very porous (Glaser *et al.*, 2002; Downie *et al.*, 2009). Owing to its inherent chemical and physical characteristics, biochar has the potential to affect the soil pH, porosity, bulk density and water-holding capacity (Glaser *et al.*, 2002; Chan *et al.*, 2007). Moreover, the surfaces and pores of biochar absorb ions from soil solution using a mix of electrostatic, complexation, and capillary forces (Major *et al.*, 2010). These characteristics of biochar may reduce ion accessibility to soil microbes and nutrient loss from soil (Lehmann *et al.*, 2003). Hence, scientific and environmental researchers have conducted studies in various parts of the world.

1.2 Importance and Need of the Study

1.2.1 Importance

There are several pools of organic carbon exist, including active and passive pools. The substance that is labile or readily decomposable makes up the active pool of carbon. The active pool typically contributes 10–20% of the total soil organic matter and the passive pool contributes 50%–60% of the total. The active pool depends on the agroecosystem and management strategies comprising components such as soil microbial biomass carbon, water-soluble carbon, and carbohydrate carbon. The amount of organic matter that may easily be used as a food source by soil bacteria is provided by the LOC (Labile Organic Carbon). Compared to active pools, passive pools are more stable (Shrinivasrao *et al.*, 2013). Physical, chemical, and biological characteristics of soil are influenced by soil organic carbon (SOC). Cropland soil carbon needs to be preserved to increase agricultural output and reduce carbon emissions.

Soil organic carbon is a significant component that impacts the quality of the soil and many of its physical and biological characteristics. The structural stability of soils decreases when SOC decreases. SOC is a critical requirement of soil quality because of its connection to crop productivity (Lal, 1997). Arable lands with restored SOC are a potential sink for atmospheric carbon dioxide. There are several distinct pools of soil organic carbon, each with a unique chemical makeup and breakdown stage. The percentage of each type of carbon that is present in soil can reveal crucial details about the condition of the soil. The amount of fresh organic matter that is incorporated into the soil each year has a significant impact on the percentage of total carbon. There will be more residue and particle organic carbon in systems that produce a lot of organic material, such as well-managed pastures or native plants. Low levels of these carbon pools are often seen in agricultural systems with continuous cropping, protracted fallow periods, and management techniques that hasten the decomposition of organic matter.

1.2.2 Need

Managing crop residues is one of the new issues facing the agricultural industry. Crop residue is a new issue for agriculture. Plant stems and other woody plant debris take longer to break down, making composting them challenging. In these situations, farmers burn crop residue because it offers a quicker way to clear the agricultural field for preparing the soil and sowing. However, burning biomass results in the release of gases, including greenhouse gases like carbon dioxide and other gases, in addition to the loss of important biomass and nutrients. Millions of tonnes of crop leftovers that are not utilized as fuel or fodder can be converted in India into biochar, which can then be used to supplement soil carbon. A common way to regulate the health and fertility of the soil is the effective use of biomass by transforming it into a beneficial source of soil amendment. There is a lot of potential for biochar manufacturing in India.

Similarly, For the cultivation of food crops in modern agriculture, the use of fertilizers, particularly inorganic fertilizers, has become essential. However, consistent lack of care in the use of inorganic fertilizers, little or no use of organic manures, and lack of recycling of crop residue have negatively impacted soil fertility as well as soil carbon pools, soil physical, chemical, and biological properties. The use of organic sources coupled with inorganic fertilizers is the greatest approach to maintaining soil fertility and good soil quality. Integral to sustainable agriculture, which demands resource management without degrading environmental quality that is integrated nutrient management. The use of organic materials, particularly biochar, to maintain the fertility and productivity of the soil is becoming more widely known. In this sense, biochar has become increasingly significant in managing soil fertility and productivity. In this situation, biochar is an ideal approach for maintaining both soil quality and crop productivity.

Biochar has a large surface area and contains a significant number of microspores, which aid in the retention of nutrients. It also serves as a habitat for beneficial microbes and encourages the storage of organic carbon in soil. To improve soil health and carbon sequestration, soil is to be supplemented with a type of charcoal known as biochar. To combat climate change and global warming, biochar is being studied as a potential method for carbon sequestration. Because of its unique capacity to promote soil development, water conservation, the production of renewable energy and carbon sequestration, biochar has the potential to be an excellent component for the agricultural sector. Researchers suggested using biochar to boost the health of degraded soils as a remedy to this rising crisis.

In the Konkan region as there is acidic soil pH, the application of biochar which is alkaline in nature found to be most beneficial. The application of organic along with inorganic fertilizers increases soil fertility by increasing the amount of readily available nutrients (Anup *et al.*, 2010), but there is only limited information on the impact of biochar along with inorganic fertilizers on soil fertility, soil carbon pool, and productivity of watermelon in Alfisols of Konkan.

1.3 Objectives

An experiment was carried out on the 'Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan' with the following objectives,

1. To assess the effect of biochar on soil carbon pools.

2. To assess the effect of biochar application on soil properties.

3. To study the effect of biochar application on the yield and quality of watermelon.

1.4 Hypothesis

Watermelon is becoming more well-liked in the Konkan area. Compared to other vegetable crops, it is a crop with a short growing season and quick returns. In the Konkan region, watermelon has gained popularity as a "vegetable cash crop." Its cultivation area in the Konkan region is expanding daily. Low input conditions, low perishability, and a lack of modern techniques are all factors that contribute to the low productivity issue facing watermelon farming. Watermelon's low productivity is largely due to conventional farming methods and insufficient fertiliser application. Therefore, using a sufficient proportion of biochar along with the appropriate proportions of fertiliser will boost quality and increase productivity.

Biochar is a resistant substance that is dark black in colour, partially combusted (pyrolyzed) and serves to improve the nutritional status and carbon stock of soil. It is a porous carbonaceous sorbent that is often made from biological materials (crop residues) and forms as a result of particular thermochemical transformations (pyrolysis) that take place under oxygen-scarce situations. Biochar is often made from biomass generated from plant and agricultural leftovers that contain functional and aromatic groups that contain oxygen. Its physicochemical characteristics enable it to be used for an extended period, safely store carbon in the environment and enhance soil health. By adding carbon to the soil directly, biochar has the potential to boost conventional agriculture's production (McHenry, 2009).

1.5 Scope and limitations

1.5.1 Scope

The concentration of atmospheric carbon dioxide may be greatly impacted by a small change in soil organic carbon, thus affecting the global carbon cycle. The carbon cycle is a natural method of recycling carbon atoms, which repeatedly go from the atmosphere into living things on Earth and back into it. It is therefore important to store soil organic carbon while addressing problems of climate change and food security. By encouraging soil microbes, biochars can improve the C pools in the soil. Enhancing soil carbon storage with biochar can help with the fight against global warming. When combined with biochar and FYM, chemical fertilizer applications to soils could simultaneously benefit the environment and sequester carbon.

One method for managing soil health and fertility is the effective utilization of biomass by transforming it into a beneficial source of amendments and nutrients. One method for effectively using biomass is to carbonize it into the very stable carbon compound known as biochar, which is then used as a soil amendment. One practical solution that can increase soil carbon sequestration rates naturally, cut down on farm waste, and improve soil quality is the use of biochar in agricultural settings. In addition, it has been demonstrated in several studies conducted throughout the world that using biochar improves productivity in traditional agriculture while reducing GHG emissions from agricultural soils. This restored the interest of agricultural experts in creating biochar and using it as a soil amendment, especially in India.

The use of biochar improves soil carbon sequestration and reduces greenhouse gas emissions. Several studies have demonstrated that adding biochar can quickly increase soil carbon stores. Biochar could sequestrate an average of 376.11 mega tonnes of carbon dioxide equivalent carbon in the soil and could help India reduce 41.41–63.26% of emissions from agriculture and its allied activities (IIT, Delhi). biochar has a very long shelf life in the soil and is a highly effective way of storing carbon. Biochar is one of the renewable ways to lower the emission of greenhouse gases. According to the Renewable and Sustainable Energy Review, biochar has also demonstrated great promise for the capture and storage of carbon dioxide. Adsorption of carbon dioxide depends significantly on the high surface area and low activation energy.

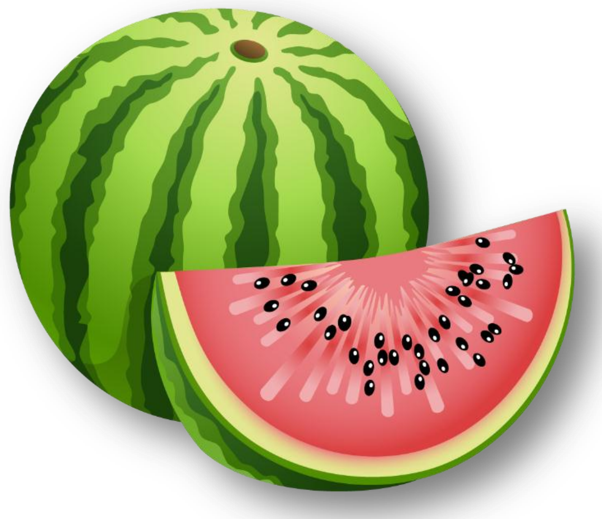
1.5.2 Limitations

Reuse of agricultural waste, such as the huge quantities of rice husk and coconut husk that are present in the area, would increase production while simultaneously enhancing soil fertility and carbon sequestration. However, so far, no comprehensive research has been carried out in the area supporting biochar use, its optimum dosage, effects on yield, watermelon quality, and soil nutrient status.

A limited amount of biochar is utilized in India for horticulture crop development and its effects on soil properties are being studied. There aren't many studies on the production and application of biochar as a soil amendment. Global horticulture, agriculture and society could all be significantly impacted by the widespread use of biochar to improve soil fertility or reduce carbon emissions. Agriculture benefits greatly from the application of biochar to soils. The biomass supply, pyrolysis temperature, application rate and viability from an economic perspective are crucial as well as variable factors.

Biochar is not a uniform substance. It is made up of a variety of fractions and pools that decompose in the soil at various rates. As biochar is a recalcitrant, it has the ability to store carbon, and it is efficient at doing so over an extremely long time frame. The same characteristics enable biochar in the gradual slow release of mineral nutrients.

In view of the importance of biochar in watermelon cultivation, the experiment entitled "Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thumb.), soil carbon pools and soil properties in Alfisols of Konkan" was planned during the *Rabi* season of 2022–2023.



REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Biochar is a solid substance that is rich in carbon, highly porous, and nutrient-rich. Utilizing biochar as a soil supplement can help to improve the physical, chemical, and biological properties of the soil. Thus, application of biochar plays important role in improving fertility status and crop productivity.

In the light of above, the literature related to the present study on the 'Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan' is reviewed as well as presented in the following heads:

2.1 Characterization of biochar

2.2 Effect of biochar on carbon pools of soil

2.3 Effect of biochar on soil properties

2.3.1 Effect of biochar on chemical properties of soil

2.3.2 Effect of biochar on biological properties of soil.

2.4 Effect of biochar on yield and quality parameters

2.1 Characterization of biochar

Downie *et al*. (2009) revealed that the physical and chemical properties of biochar are affected by different properties of feedstock and pyrolysis conditions such as the highest treatment temperature (HTT) as well as furnace residence time.

Rice husk biochar had an 8.70 pH, 18.72% carbon, 0.12% phosphorous, 17.57 Cmol (p+) kg-1 CEC, and 0.20% potassium content (Masulili and Utomo, 2010).

Shenbagavalli *et al*. (2012) reported that the pH of coconut coir biochar was 9.40, the EC was 3.25 dSm^{-1}, the CEC was 32 Cmol (p+) kg^{-1}, the total organic carbon was 276 g kg^{-1}, the total nitrogen was 8.5 g kg^{-1}, the total phosphorous was 1.5 g kg^{-1}, and the total potassium was 5.3 g kg^{-1}.

Carter *et al*. (2013) concluded that rice husk biochar prepared at temperature between 900-1000 degree Celsius had pH 7.79, total OC 28.7% (% dry weight) as well as CEC of 44.5 C mol kg^{-1}.

Brewer *et al*. (2014) revealed that the organic carbon content of biochar was 15.4%, pH 8.25 as well as specific surface area of 69.9 m^2g^{-1}.

Jindo *et al*. (2014) studied four organic waste biochars, namely rice husk, rice straw, apple tree wood, and oak tree wood biochars, and reported pH values of 6.84, 8.62, 7.02, and6.43 respectively and reported that low temperature pyrolysis produced high biochar yields, in contrast, high temperature pyrolysis led to biochars with high carbon content, large surface area and high adsorption characters.

Wan et. al. (2014) reported that pH, carbonate content, base cations as well as alkalinity of biochar increased with an increase in temperature.

Nguyen Van Lanh *et al*. (2009) reported that an increase in combustion temperature in the gasifier resulted in a decrease in the yield of rice hull biochar but increased the water retention capacity. In a 35-day biotest, the length of the maize stem and of the roots, and the weight of the roots, were linearly increased due to an increase in the water retention capacity of the rice hull biochar and the concentration of biochar added to the soil.

Rumi *et al*. (2015) revealed that biochar is a carbon rich material that contains 50 percent of its original carbon which is highly recalcitrant nature, which is produced during the pyrolysis process. Not only biochar but also bio-oil and gases are produced.

Hossain *et al*. (2020) studied different biochar prepared from rice straw, rice husk and sawdust and concluded that rice straw biochar had the highest pH (8.80) and electrical conductivity, EC (3.45 dS/m). The organic carbon was highest in rice straw biochar (46.50%) followed by with rice husk (39.3%) and saw dust (25.3%). The total nitrogen contents of the rice straw, rice husk and saw dust were 1.78%, 1.59% and 1.11%, respectively

Nagula (2021) studied the biochar prepared from tender coconut husk and reported that the produced biochar had an alkaline pH (8.35), high total organic carbon (70.10 %) and CEC (15.26 cmol kg^{-1}). The nutrient composition of the biochar produced by the refined technology is N (1.52 %), P (0.40 %), K (2.26 %), Ca (0.54 %), Mg (0.20 %), S (0.46 %), Fe (89.9 mg kg^{-1}), Mn (2.84 mg kg^{-1}) and B (6.78 mg kg^{-1}). The heavy metal contents (Pb, Cd, Ni, Cr, Zn and Cu) were very low when compared to the maximum allowed threshold levels.

Swapna *et al*. (2021) reported that biochar prepared from pigeon pea stalk and bamboo had C (%) 41 and 46 and N (%) 0.71 and 0.16 respectively.

2.3 Effect of biochar on carbon pools of soil

X. Ye (2015) reported that the application of peanut shell biochar on tobacco growing soil could increase soil total carbon, readily oxidizable active organic carbon, dissolved organic carbon, organic carbon mineralization rate, soil carbon activity, soil carbon activity index and soil carbon pool management index.

Hartely *et al*. (2016) observed in his trial that the addition of several biochar derived from different feed stocks increased the total organic carbon in micro aggregate fraction and also raised in the concentration of dissolved organic carbon in the pore water from the biochar treated soil.

Zhang *et al*. (2017) observed that the application of straw and straw derived biochar (8 t/ha and 16 t/ha) with inorganic fertilizers significantly increased the soil organic carbon by 33.7 to 79.6 percent and microbial biomass carbon by 18.9 to 46.5 percent

Naggar *et al*. (2018) observed that organic carbon was increased with the addition of biochar under different soil particles size fractions due to the interaction of soil particles with biochar and the increase in organic carbon content was about 37 percent 42 percent and 76 percent in soil particle size fractions of 53 to 205, <53, 250 to 2000µm respectively.

Arif *et al*. (2018) conducted a field trial and observed that the application of biochar with FYM and nitrogen fertilizer increased soil properties like carbon content, nitrogen, and phosphorous status in biochar treatment over no biochar treatment soil.

Shilpa *et al*. (2019) conducted an experiment using Cob rind biochar and estimated that application of biochar @ 4 t ha^{-1} 100 percent FYM (T_7) recorded higher labile carbon pools such as microbial biomass carbon, potassium dichromate oxidizable carbon, potassium permanganate oxidizable carbon and total organic carbon status such as total carbon, total organic carbon except cold water extractable carbon and total inorganic carbon compared to other treatment.

Arunkumar *et al*. (2019) reported that application of 8 t ha^{-1} biochar, 10 t ha^{-1} FYM with RDF (100:50:50 kg ha^{-1}) to soil significantly increased the soil carbon pools *viz*. potassium dichromate oxidizable carbon (PDOC), potassium permanganate oxidizable carbon (PPOC), and soil microbial biomass carbon (SMBC) contents in soil at harvest of aerobic rice due to combined application of biochar (8 t ha^{-1}) and FYM (10 t ha^{-1}) applied with RDF compared to biochar, FYM, and RDF alone. Cold water extractable carbon (CWEC), total organic carbon (TOC), and total carbon (TC) contents in soil increased with increase in biochar rate but statistically no much significant.

The different carbon fractions of soil such as total carbon, total organic carbon and total inorganic carbon increased with increasing biochar levels with FYM at harvest of field bean. Lowest values of the carbon fractions were recorded in control T_1 treatment suggested by Madhupriya (2019).

Murthy (2020) concluded that soil treated with 500 °C biochar @ 10 t ha^{-1} recorded higher PPOC, total carbon, inorganic carbon and organic carbon than 300 and 400 °C @ 5,7.5,10 t ha^{-1} and also conclude that high temperature produces more stable biochar.

Panda (2020) suggested different doses of fertilizer in combination with three sources of biochar significantly increased the carbon fraction such as water soluble carbon, $KMnO_4$ oxidizable carbon, soil microbial biomass carbon, soil organic carbon during both the years of rice-wheat cropping system.

Tianbao *et al*. (2021) revealed that peanut shell biochar application increased the organic carbon content of the treated soil by up to 46.85% compared with conventional fertilisation. Biochar with particle size < 20 μm improved the mean weight diameter of soil water-stable aggregates by 2.5–12.5%and the easily oxidisable carbon content of the biochar-treated soil showed up to 2.22 g kg^{-1}, increasing by 80.31–89.58% compared with that achieved through conventional fertilisation. The average soil dissolved organic carbon content was 356.64 mg kg^{-1}, which is 78.86% higher than that of conventional fertilisation. Additionally, biochar with a particle size < 20 μm also enhanced the soil carbon pool management index by 186.17%.

Karekar *et al*. (2021) conducted research on Effect of incorporation of various crop residue on carbon pool, soil properties and yield of mustard in Alfisols and concluded that labile carbon increased to 324.29 mg kg^{-1} at harvest by application of crop residue as compared to control 150.24 mg kg^{-1}. soil microbial biomass carbon found 235.55 μg kg^{-1} increased at harvest by application of crop residue than control 153.72 μg kg^{-1} at harvest. Application of crop residue improve carbon pool including soil organic carbon, inorganic carbon, labile carbon, microbial biomass carbon effectively than control.

Mavi *et al*. (2021) reported C mineralization was found to be lower in sole biochar amended soil indicating recalcitrant nature of biochar-C. This was also confirmed by almost similar MBC in the control and the biochar amended soil. Input of C in BC+RS, BC+FYM and BC+GM treatment was more than sole biochar treated soil, however net C loss from BC+RS, BC+FYM and BC+GM was only more than sole biochar treatment.

Nandini *et al*. (2022) concluded Application of biochar in combination with FYM significantly increased water soluble carbon (WSC), potassium permanganate oxidizable carbon (POXC) and microbial biomass carbon (MBC).

2.3 Effect of biochar on soil properties

2.3.2 Effect of biochar on chemical properties of soil

Masulili *et al*. (2010) found that applying rice husk biochar at a rate of 10 t ha^{-1} to acid sulphate soils increased soil pH from 3.36 (control) to 4.40.

Jienetal (2013) conducted incubation study and reported that application of 5% waste wood biochar to acidic Ultisol resulted significant increase in pH from 3.9 to 5.1.

In another pot experiment conducted by Danish *et al*. (2014) revealed that the addition of 3% rice straw biochar significantly increased soil pH from 8.26 to 8.41.

Chintala *et al*. (2018) studied the effect of biochars in ameliorating soil acidity which helped to increase the soil pH, EC, and CEC and also tends to decreased the exchangeable acidity. Corn stover biochar was found to have significantly better liming potential than switchgrass biochar.

Mukherjee *et al*. (2013) observed that the presence of micropores and large surface area of biochar contribute to potentially to potentially alter soils surface area, pore size distribution, water holding capacity, penetration and bulk density.

Vaccari *et al*. (2015) studied that due to the application of biochar at the rate of 14 ton ha^{-1} in field experiments shows a significantly increase in carbon content, availability of P and K, soil cation exchange capacity as well as the availability of NH_4^+ as compared to control in soil of pH 8.1.

Liu *et al* (2016) also observed that the application of rice straw biochar which is prepared at 550 °C @ 10.5 ton ha^{-1} had significantly increased the soil pH, organic carbon content, available P, and available K after harvest of rice as compared to control.

Deepak Kumar (2017) concluded that in both topsoil and subsoil, an increase in pH, available K and cation exchange capacity was observed in the biochar amended soil compared to the baseline values and the FYM only control treatment.

Pawar *et al*. (2019) stated as biochar is a source of nutrients and it also alters the soil nutrient pools and availability. Biochar applied up to 10 cm depth of soil may decrease the denitrification potential and lower NO_2 emission, greatly controlling the leaching of mobile nutrients such as potassium, thus improving water use efficiency, nutrient availability and plant growth.

Wangmo *et al*. (2022) stated that soil pH, % nitrogen, available P (mg kg^{-1}), available K (mg kg^{-1}), CEC, % BS, and % organic matter increased with increasing quantities of rice husk biochar. The different doses of biochar improved soil chemical properties such as soil pH, P, K, CEC, Organic matter, and C.

Banapatti *et al*. (2023) conducted research on Effect of biochar on yield of watermelon (*Citrullus lanatus* Thunb.) and physico-chemical and biological properties of soil in Alfisols of Konkan during *Rabi* season in Konkan region and concluded that application of rice husk biochar along with RDF improve soil physical, chemical and biological properties followed by coconut husk biochar along with RDF as compared to control and RDF.

Xingfan *et al*. (2023) conducted research on study of biochar on physiochemical properties of sugar beet under fomesafen residues and concluded that biochar enhanced soil physicochemical properties as well as improved soil enzyme activities, with 1% biochar pH is raised by (3.49%) and soil water content (SWC) by 13.85%, available nitrogen raised by 9.68%, available potassium by 17.71%, and soil organic matter increased by 11.85%.

2.3.4 Effect of biochar on biological properties of soil

Courty *et al*. (2015) reported that Application of biochar @ 3% leads to straw berry rhizosphere enhanced Rhizobium count from 0.04% to 0.15% and Schlesneria count from 0.30% to 0.65%.

Pandian *et al*. (2016) studied the effect of different biochars on microbial populations of soils and concluded that the highest population of bacteria was observed in the red gram stalk biochar(RSB) 5 t ha^{-1}(42×10^{-6}CFU) followed by Maize stalk biochar (MSB) 2.5 t ha^{-1}(41 $\times 10^{6}$CFU), while the maximum fungal population of 33×10^{-3} colonies was found in composted coir pith (CCP) 10 t ha^{-1} followed by RSB 2.5 t ha^{-1}(33×10^{-3}CFU). Among the treatments, the highest population of actinomycetes was observed in CSB 5 t ha^{-1} (30×10^{-4} CFU).

Azimzadeh (2017) showed in his study that the application of biochar has advantageous biological effects such as increasing microorganism colonies and their protection against predators, raising soil fertility, enhancing crop yield and carbon sequestration, climate change mitigation, and biofuel production.

Application of biochar @ 65 mg ha^{-1}plus compost @50 mg ha^{-1} significantly increased phosphatase activity in clay textured soils from 250 nanomoles g^{-1} (control) to 1000 nanomoles g^{-1} (Trupiano *et al*., 2017).

Siva Devika *et al*. (2018) conducted an experiment and concluded that the addition of biochar @5 t ha^{-1} to sweet corn cropping clay loam soil have shown increase in population of bacteria from 26.31×10^{-6} CFU g^{-1}soil to 31.66×10^{-6} CFU g^{-1} soil and actinomycetes from 3.90×10^{-6} CFU g^{-1} soil to 7.32×10^{-6} CFU g^{-1} soil when compared to control plot.

Gowthami B., (2019) recorded that the application of biochar in red sandy loams of North coastal Andra Pradesh improved fungi, bacterial and actinomycetes populations significantly and also improved dehydrogenase activity within soil under groundnut crop.

Manasi *et al*. (2021) showed that the application of different sources of biochar found a positive response toward microbial activity in soil. Application of maize cob biochar had a stimulating effect on soil bacterial and actinomycetes populations. It also stimulated the dehydrogenase enzyme activity in the soil.

Banpatti *et al*. (2023) concluded that the application of rice husk biochar and coconut husk biochar significantly improved soil dehydrogenase activity and phosphatase activity within the soil.

2.4 Effect of biochar on yield and yield quality parameters

The application of biochar @ 10 t ha^{-1} along with NPK increased the rice plant height significantly from 46.75 cm (control) to 78.23cm at 90 DAP and grain yield from 4.32 t ha^{-1} to 6.79 t ha^{-1} (Zaitun *et al*. 2021).

The impact of fly ash, biochar, coal, and vermicompost on palak (*Beta vulgaris* L.) Cv. all green on growth, yield, and quality. According to the findings, treatments T_2 (RDF + Biochar) and T_4 (RDF + Vermicompost) had the highest yield of leaves per ha (208.33 q ha^{-1}) when compared to other treatments (Devi *et al*., 2012).

Venkatesh *et al*. (2012) observed the application of biochar at different rates and reported that no appreciable negative effect on crop yield. The grain yield in biochar treated plots was significantly higher than in control plots. However, no significant differences were observed between biochar application rates at 3.0 and 6.0 t ha^{-1}+ RDF.

Gyanranjan *et al*. (2013) observed that the application of biochar (1:2) to supply 50% recommended N and 50% N through fertilizer and 100% P and K through fertilizer (T_4) resulted in better plant growth and nutrient uptake by the crop and also the vegetable yield of French bean.

Carnaje *et al*. (2015) concluded that application of bamboo biochar @ 2% on acidic soil increased the mung bean production by 27% in height, 8.5% - 15.7%for root nodules and up to 102% of pods.

Dainy (2015) studied the effectiveness of biochar from tender coconut husk for improved crop production and concluded that application of biochar @ 20 t ha^{-1} together with 2% Plant Growth Promoting Rhizobacteria (PGPR) and NPK as per package of practices, resulting in a yield of 1358 g plant^{-1} (20.12 t ha^{-1}) can be deemed the most economically viable and best treatment.

Zhai *et al*. (2016) showed the influence of biochar and ameliorants on the production and quality of watermelon (*Citrullus lanatus*) and reported that applying biochar (BC) and biochar-based ameliorant (BCA) to agricultural soil increased the yield of watermelon (*Citrullus lanatus*).

Glodowska *et al*. (2017) reported that the application of biochar @ 5 t ha^{-1} significantly increased plant height from 49.87 cm to 57.07 cm and plant dry weight from 0.48 g to 1.24 g and pod dry weight from 0.069 g to 0.133g, respectively.

Gokila *et al*. (2017) stated that the application of biochar (5t ha^{-1}) with a recommended dose of inorganic fertilizers and biofertilizers increased the yield components of maize and crude protein content.

Agbna *et al*. (2017) observed the effects of deficit irrigation and the addition of biochar on the growth, yield and quality of tomatoes and found that biochar amendment treatments (T_2 and T_3) enhanced the growth of tomatoes compared with the control (T_1).

Syed *et al*. (2020) conducted an experiment and reported that biochar along with inorganic fertilizers significantly increased jute yield and quality.

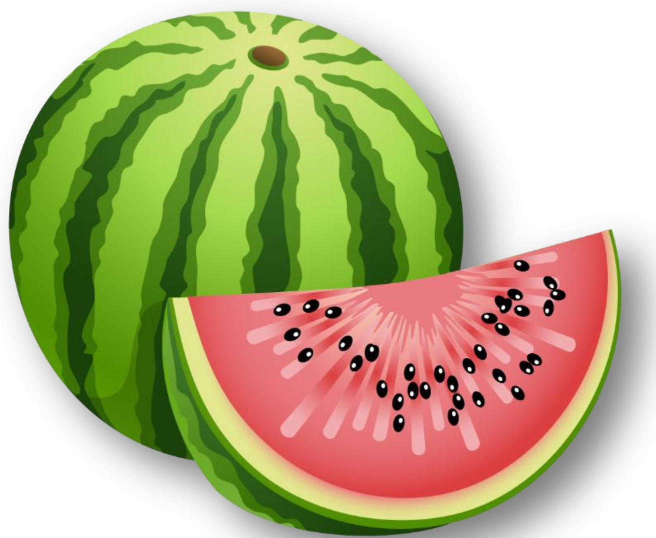
Yakubu *et al*. (2020) studied the impact of rice straw biochar and irrigation on okra yield and water productivity and found that under deficit irrigation, the 10t ha^{-1} and 30 t ha^{-1} (P) biochar treatments significantly increased okra fresh fruit yield (YFF) by 67 and 82%, respectively, but had no effect on total above-ground biomass yield (YTBM).

Surve *et al*. (2021) conducted a trial on the effect of the application of biochar on the growth, yield and quality of watermelon (*Citrullus lanatus* thumb.) during *Rabi* season in the Konkan region and concluded that 75% RDF plus 4 ton ha^{-1} Rice husk biochar found better growth rate than RDF. The yield of treatment 75% RDF plus 4 ton ha^{-1} Rice husk biochar was found (43.52 t ha^{-1}) better than RDF only (27.97 t ha^{-1}).

Ofori *et al*. (2021) reported that 5 t ha^{-1} poultry litter biochar (PLB) + 50% NPK increased the cabbage yield by 73% compared with the control and also concluded that PLB and NPK fertilizers can be applied to improve the soil chemical properties, growth and yield of cabbage.

Usman *et al*. (2023) reported that the application of tomato grown in biochar-amended soil showed a significant increase in the studied attributes. Plant height, root length, fresh and dry weight of root, the number of fruits per plant, fruit fresh and dry weight, ash%, crude fat, crude fiber, crude protein, and lycopene contents were increased in tomato plants grown in biochar-amended soil under control and drought stress.

Kanchan *et al*. (2023) conducted a trial on the response of watermelon (*Citrullus lanatus* Thunb.) variety Ayesha to crop residue biochars and concluded that Rice husk biochar (6 ton ha^{-1}) plus 100% RDF gives better yield (51.15 t ha^{-1}) followed by Coconut husk biochar (6 ton ha^{-1}) plus 100% RDF (49.12 t ha^{-1}). Application of biochars improves yield significantly than control.



MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

A field and laboratory study entitled "Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan" was conducted during *Rabi* season of 2022-23 at the College of Horticulture, Dapoli Dist- Ratnagiri (M.S.) in Konkan region.

The materials used and methods adopted for the investigation are discussed in this chapter

3.1 Details of experimental material

3.1.1 Location of experimental site

The trial was conducted at the College of Horticulture, Dapoli during the *Rabi* season of 2022–2023. (M. S.). The present research effort was concentrated in the Ratnagiri district, which is in Zone 1 of Maharashtra's "Very High Rainfall Lateritic" (VRL) region. The Konkan area of Maharashtra covers 30,728 square kilometres. Dapoli, on the west coast of Maharashtra, is 240 metres above mean sea level. It has warm, humid environment that is constant throughout the year. It is situated at 17° 45" latitude and 73° 12" longitude on a global map.

3.1.2 Agroclimatic conditions

The region receives between 3500 and 4000 mm of rainfall annually, primarily from the Southwest monsoon that occurs from June to October. The weather data collected at the Meteorological Observatory in Dapoli during the crop-growing period are shown in Table 3.1.

Table 3.1: Meteorological observations during the crop growth period (2022-23)

MW	Period	Average temperature (°C)		Average relative humidity (%)		Wind speed	Rain	RD	BSS	Epan
		Max	Min	Mor	Eve	(Kmhr^{-1})	(mm)	day	(hrs.)	(mm)
44	**29.10 –04.11**	31.9	15.2	88	62	5.5	0	0	10.2	3.6
45	**05.11 –11.11**	33.0	15.4	86	55	2.2	0	0	10.0	3.6
46	**12.11 –18.11**	32.8	15.0	91	50	2.2	0	0	9.9	3.9
47	**19.11 –25.11**	32.0	13.9	92	56	2.4	0	0	9.6	3.8
48	**26.11 –02.12**	32.9	16.6	93	52	2.4	0	0	8.5	4.0

MW	Period	Average temperature (^oC)		Average relative humidity (%)		Wind speed	Rain	RD	BSS	Epan
		Max	Min	Mor	Eve	($Kmhr^{-1}$)	(mm)	day	(hrs.)	(mm)
49	**03.12 –09.12**	33.2	16.6	93	50	2.3	0	0	6.8	4.1
50	**10.12 –16.12**	32.1	17.7	92	53	2.5	0	0	5.5	3.8
51	**17.12 –23.12**	34.1	16.8	94	51	2.7	0	0	8.6	4.2
52	**24.12 –31.12**	32.2	14.4	92	55	2.7	0	0	8.4	4.0
1	**01.01 - 07.01**	31.7	14.7	95	52	2.6	0	0	7.6	3.8
2	**08.01 - 14.01**	30.8	11.6	93	49	2.8	0	0	7.8	3.4
3	**15.01 - 21.01**	29.9	11.0	92	51	2.4	0	0	8.6	3.4
4	**22.01 - 28.01**	28.9	12.9	93	53	3.3	0	0	7.5	3.6
5	**29.01 - 04.02**	32.0	15.3	89	50	3.3	0	0	6.0	3.8
6	**05.02 - 11.02**	33.6	12.7	88	42	2.7	0	0	9.2	4.2
7	**12.02 - 18.02**	35.6	11.8	84	31	3.5	0	0	10.0	4.5
8	**19.02 - 25.02**	35.3	12.9	89	44	3.2	0	0	10.0	4.4
9	**26.02 - 04.03**	35.4	15.0	85	39	3.2	0	0	10.6	4.6
10	**05.03 - 11.03**	35.8	17.7	75	34	4.1	0	0	9.9	5.3
11	**12.03 - 18.03**	34.6	18.5	90	51	3.9	0	0	9.2	4.7
12	**19.03 - 25.03**	30.6	16.6	88	61	4.8	2.8	1	9.2	4.0
13	**26.03 - 01.04**	30.2	15.0	89	60	4.8	0	0	10.8	4.7
14	**02.04 - 08.04**	31.8	18.3	86	56	5.0	0	0	10.4	5.2
15	**09.04 –15.04**	35.6	21.5	81	55	4.3	0	0	7.7	5.6

3.1.3 Soil

Initial soil sampling was done at random from the experimental field at a depth of 0 to 15 centimetres before the start of the experiment. The composite sample was then examined for its carbon pools, physicochemical and biological properties, and nutrient status. The properties of the initial soil sample are presented in Table. 3.2

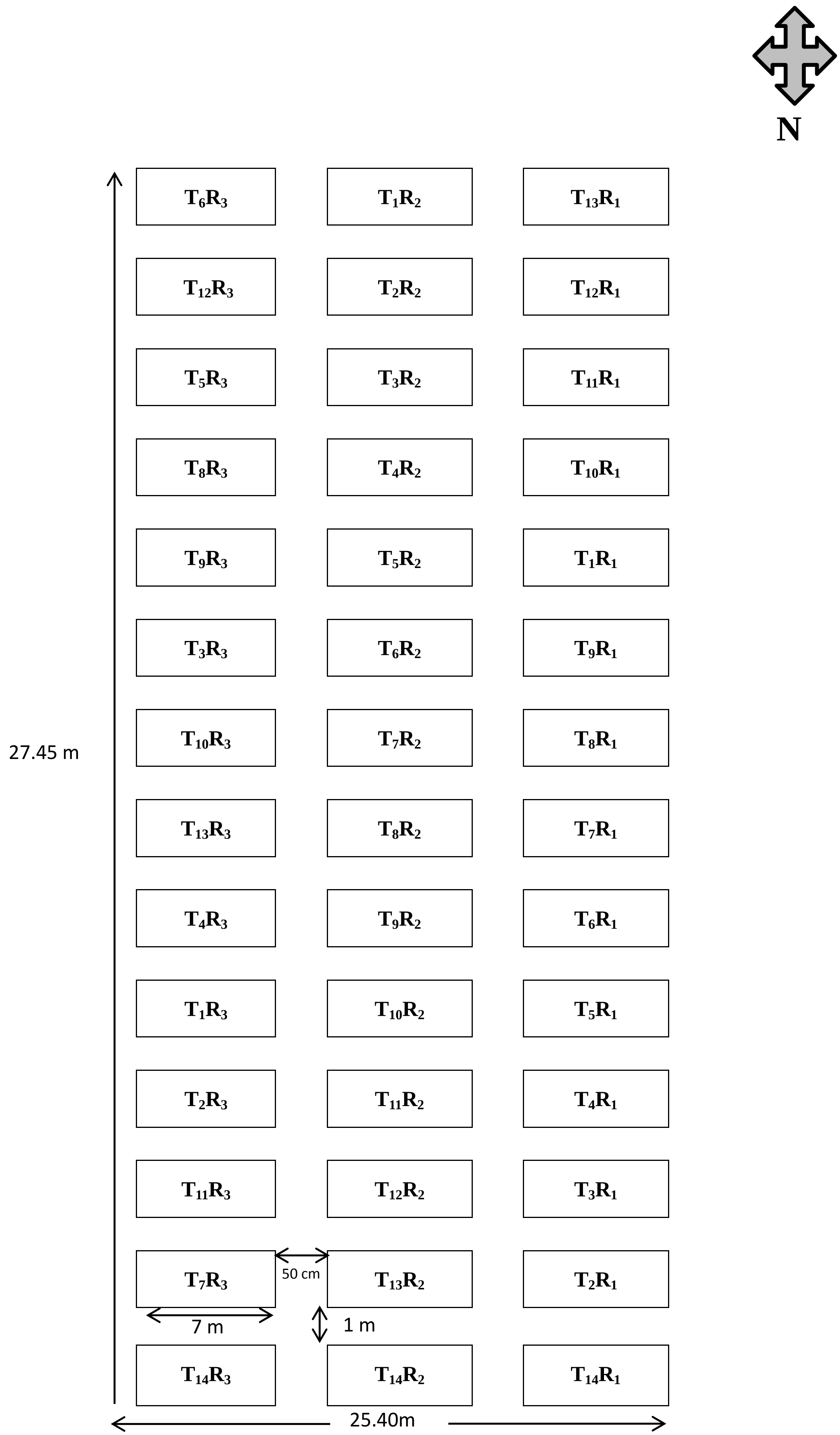


Fig. 3.1 : Layout of the experimental field

Table 3.2: Initial chemical and biological properties of the experimental soil

1	Soil properties	Composition
A.	**Soil carbon pool**	
i.	Soil organic carbon (g kg^{-1})	14.00
ii.	Water soluble carbon (mg kg^{-1})	52.11
iii.	Soil inorganic carbon (g kg^{-1})	1.15
iv.	Labile carbon (mg kg^{-1})	270.01
v.	Soil total carbon (g kg^{-1})	15.15
vi.	Microbial biomass carbon (mg kg^{-1})	184.12
B.	**Chemical properties**	
i.	pH (1:2.5)	5.38
ii.	Electrical conductivity (dS m^{-1})	0.098
iii.	Available N (kg ha^{-1})	293.52
iv.	Available P_2O_5 (kg ha^{-1})	11.51
v.	Available K_2O (kg ha^{-1})	282.94
C.	**Biological properties**	
i.	Dehydrogenase (µg TPF g^{-1} 24 hr^{-1})	7.79
ii.	Microbial count	
a)	Bacterial population (CFU g^{-1} soil)	35.65
b)	Fungal population (CFU g^{-1} soil)	4.00
c)	Actinomycetes population (CFU g^{-1} soil)	7.30

3.1.4 Preparation and characterization of biochar

Biochars were prepared from different farm residues, such as rice husk, coconut husk, and areca nut husk which are available in the Konkan region. Biochar was prepared by the pyrolysis process in the absence or limited supply of oxygen at a temperature of 350-500 degrees Celsius by drum method at College of Agricultural Engineering, Dapoli. These pyrolyzed materials were kept for cool down for 4-5 hours and then these half-burned biochar materials were ground into fine powder. These biochars were analysed in a laboratory for various parameters. The results are discussed in Table 3.3

3.1.4 Nutrient Composition of Biochar

Analysis of biochar was done by following methods

Sr no.	Parameter	Method	Reference
1.	pH (1:10)	Potentiometric method	Jackson (1973)
2.	EC (dS m^{-1})	Conductometric method	Jackson (1973)
3.	Nitrogen %	Kjeldahl digestion and distillation method	Jackson (1973)
4.	Phosphorus %	Vanado-molybdate method	Chopra and Kanwar (1978)
5.	Potassium %	Di acid digestion and flame photometric method	Jackson (1973)
6.	Total Carbon %	Dry combustion method	Tiessen and Moir (1993)

Table 3.3: Nutrient composition of Biochar

Biochar	pH (1:2.5)	EC (dSm^{-1})	N (%)	P (%)	K (%)	Total Carbon (%)	C : N ratio
Coconut Husk Biochar (CHB)	9.05	0.143	0.156	0.077	0.13	74.50	477.56
Rice Husk Biochar (RHB)	9.34	0.321	0.184	0.153	0.15	83.54	454.02
Areca nut Husk Biochar (AHB)	9.21	0.289	0.166	0.103	0.14	80.20	483.13

3.1.5 Experimental crop

In the current study, watermelon (*Citrullus lanatus* Thumb.) variety Ayesha was used as experimental crop during the month of *Rabi* 2022-23. In November, watermelon seeds were planted, and they were harvested 90 to 120 days later.

3.1.6 Experimental details

The field study was conducted in *Rabi* 2022 at the College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli in a randomised block design with fourteen treatments and three replications. Details of trial are as follows

Plate: 1 Biochar prepared from various crop residue

Rice Husk Biochar

Coconut Husk Biochar

Areca nut Husk Biochar

Table no. 3.4 Experimental Details

Location	-	College of Horticulture, Dapoli
Soil type	-	Lateritic
Soil order	-	Alfisols
Crop	-	Watermelon
variety	-	Ayesha
Season	-	Rabi 2022-23
Plot size	-	7 m × 2 m
Spacing	-	2 m × 0.5 m
Design	-	Randomized Block Design (RBD)
Treatment	-	14
Replication	-	3

3.1.7 Treatment details

The experiment was laid out with 14 treatments consisting of different combinations of inorganic fertilizers and biochars. The treatments are as mentioned below in the Table 3.5.

Table 3.5 Treatment details

Treatment	**Treatment details**
T_1	GRDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1}
T_2	100% RDF + CHB (2 ton ha^{-1})
T_3	75% RDF + CHB (2 ton ha^{-1})
T_4	100% RDF + CHB (4 ton ha^{-1})
T_5	75% RDF + CHB (4 ton ha^{-1})
T_6	100% RDF + RHB (2 ton ha^{-1})
T_7	75% RDF + RHB (2 ton ha^{-1})
T_8	100% RDF + RHB (4 ton ha^{-1})
T_9	75% RDF + RHB (4 ton ha^{-1})
T_{10}	100% RDF + AHB (2 ton ha^{-1})
T_{11}	75% RDF + AHB (2 ton ha^{-1})
T_{12}	100% RDF + AHB (4 ton ha^{-1})
T_{13}	75% RDF + AHB (4 ton ha^{-1})
T_{14}	Absolute control

RHB- Rice husk biochar, CHB- Coconut husk biochar, AHB- Areca nut husk biochar
Note: FYM @ 15 ton ha^{-1} applied to all treatments except treatment T_{14} (Absolute control)

3.1.8 Cultivation details

3.1.8.1 The detail information about cultural practices adopted during the cropping period in *Rabi* 2022 has been noted in Table 3.6.

Table 3.6: Schedule of cultural operation performed during *Rabi* 2022

Sr. No	Field operations	Frequency	Date
1.	Preparatory tillage		
i.	Ploughing	1	05/11/2022
ii.	Harrowing	1	07/11/2022
2.	Field operations		
i.	Initial soil sample collection	1	08/11/2022
ii.	Layout of experimental plot	1	10/11/2022
iii.	Application of FYM.	1	11/11/2022
iv.	Sowing	1	19/11/2022
v.	Application of fertilizers 1st dose of N and full dose of P_2O_5 and K_2O along with Biochar	1	12/11/2022
vi.	Gap filling	2	01/12/2022 14/12/2022
vii.	Application of 2nd dose of Nitrogen	1	22/12/2022
viii.	Application of 3rd dose of Nitrogen	1	25/01/2023
ix.	Hand weeding	4	11/12/2022 13/12/2022 22/12/2022 28/12/2022
3.	Plant protection measures, spraying of insecticides and fungicides		
i.	Drenching with 19:19:19 (10 gm/10 lit)	7	11/12/2022 18/12/2022 23/12/2022 28/12/2022 24/01/2023 01/02/2023 08/02/2023
ii.	Drenching with humic acid granular (10 gm/10 lit)	1	16/12/2022
iii.	Drenching with Fungicide Carbendazim (2gm/1 lit)	1	10/1/2022 20/1/2022
iv.	Spraying of Chloropyriphos (2ml/lit)	2	21/12/2022 5/1/2023

Plate: 2 Application of fertilizers and biochar

Sr. No	Field operations	Frequency	Date
v.	Combined spraying of Imida (0.5 gm/lit) and Carbendazim (2gm/lit)	1	15/1/2023
vi.	Spraying of Bavistin (1 gm/lit)	1	01/02/2023
vii.	Spraying of Cypermethrin (1 ml/lit)	2	01/02/2023 9/2/2023
viii.	Collection and destruction of infected fruits and leaf	1	27/12/22
ix.	Rakshak trap fitted for fruit fly	1	31/1/2022
4.	Collection of soil and plant samples		
a)	Soil sampling		
	i) Soil sampling at 30 DAS	1	20/12/2022
	ii) Soil sampling at 60 DAS	1	23/1/2023
	iii) Soil sampling at harvesting	1	03/03/2023
b)	Plant sampling		
	i) Plant sampling at 30 DAS	1	21/12/2022
	ii) Plant sampling at 60 DAS	1	24/01/2023
	iii) Plant sampling at harvesting	1	26/03/2023
5.	Harvesting	4	23/02/2023 To 02/03/2023
6.	Recording yield data		
I ii	Weight of fruits Number of fruits	4	23/2/2023 To 2/3/2023

3.1.8.2 Land preparation

After the previous crop was harvested, the area underwent one ploughing and two harrowing. The plots were set up in accordance with the plan of the experiment at the time of sowing. Black polythene mulching sheets were applied to the raised beds that had been built. In order to maintain the required spacing of 20.5 metres, pits were dug on raised beds at intervals of 50 cm, with a second row of the same plot separated at intervals of 2 metres.

3.1.8.3 Biochar and fertilizer applications

One week prior to sowing, all three of the biochar (rice husk, coconut husk and areca nut husk) and inorganic fertilisers were applied to the field in accordance with the treatments of the experiment. $1/3^{rd}$ dose of nitrogen applied at the time of sowing. The remaining two-thirds dose of nitrogen was applied in two equal split doses. Urea was applied at various levels in accordance with the treatments in 3 splits (as a basal dosage, at 30 DAS and at 60 DAS). All of the plots were applied with a full dose of P (SSP) and K (MOP) as a basal dose in accordance with the treatments.

Table 3.7: Chemical composition of manure and fertilizers

Nutrient content (%)	Urea	Single super phosphate	Muriate of potash	Farmyard manure
N	46.00	-	-	0.56 %N
P_2O_5	-	16.00	-	0.27 %P
K_2O	-	-	60.00	0.64 % K

3.1.8.4 Sowing of seeds

Two seeds were planted on each hill for each treatment as part of the experiment. At a depth of 2 to 2.5 cm and a spacing of 2 m by 0.5 m, seeds were sowed. Similar to this, 100 seeds were placed in the tray in order to grow seedlings that could be used to fill in any gaps as needed.

3.1.8.5 Gap filling

Gap filling was done to ensure optimum plant population in the field and to maintain optimum plant stand. Gap filling was done the 10^{th} and 15^{th} days after sowing seed in the field with the seedlings sown in the tray for transplanting.

3.1.8.6 Thinning

Only one healthy, disease-free seedling is retained per hill. Thinning was done 20 days after sowing.

3.1.8.7 Irrigation and Intercultural practises

To encourage early and consistent seed germination, irrigation was started as soon as seeds were planted. A drip irrigation system was set up, and irrigation was given according to the season, the water holding capacity, and the growth stage. Two irrigations were spaced out regularly to make sure the plants had a steady supply of moisture.

Weed free condition of the plot is essential for the healthy growth of plants to achieve this, weeding was done 25 DAS, 35 DAS and 50 DAS. Weeding was done manually. To defend against pests and diseases, plant protection techniques were adopted. five Rakshak traps were placed across the plot to keep fruit flies away from the fruit.

Plate :3 General view experimental plot view

3.1.8.8 Harvesting of watermelon

When fruit makes a dull sound when tapped or when its surface on the ground turns a light yellow tint. The spot where the fruit touches the ground becomes more prominent and changes colour to typically yellow. The tendril closest to the fruit becomes brown and dries up so that the fruit is ready for harvest. The fruit was harvested by applying these maturity indices. Watermelons were harvested after 90-95 DAS. After harvesting fruit were kept for 3-4 days to develop proper ripening, colour as well as ensure sugar translocation within fruits.

3.1.9 Estimation of yield parameters

1) Fruit yield kg/plot

Weight of each fruit was taken and fruit yield per kg was calculated.

2) Fruit yield ton/ ha

Yield was calculated during harvesting.

3.1.10 Soil sample collection

The initial soil sample was taken before applying biochar and inorganic fertilizers. At 30 DAS, 60DAS and harvest, soil samples (0–15 m) were taken from every plot and from each plot according to its treatment. For each treatment plot, a composite sample of soil was collected using the quartering method. After properly drying under shade, the materials were crushed to a fine consistency before being sieved through a 2 mm mesh sieve and also remove any more undesired plant debris or coarse sand particles. After processing, the samples were properly labelled. For biological analysis, moist soil was taken from near to root zone of the crop after 30, 60 DAS and at harvest.

3.2 Methods

The 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.

3.2.1 Soil analysis

3.2.1.1 Soil Carbon Pool

i. Organic carbon (OC)

It was estimated by Walkley and Black’s Wet oxidation method (1934) as suggested by Piper (1966).

0.5 gm soil sieved by 0.5 mm was taken in 500 ml conical flask. Added 10 ml 1N $K_2Cr_2O_7$ and 20 ml concentrated H_2SO_4. Kept the conical flask on the asbestos sheet for 30 min. then added 200 ml distilled water and added 4-5 drops of ferroin indicator. Titrated against 0.5 N ferrous sulphate. Run blank as same but without soil.

ii. Water soluble carbon

It was estimated by 0.1 N $K_2Cr_2O_7$ and H_2SO_4 method. Given by Chio *et al*. (1986). 10 gm air-dried soil taken in a centrifuge tube. Added 10ml distilled water to it. Shook this content on a horizontal shaker for 1 hr. After that centrifuged the content for 5-10 min. at 6000 RPM to cleared the supernatants. 10 ml supernatant or filtrate taken in a conical flask. Added 2 ml 0.1N $K_2Cr_2O_7$. Then subsequently added 10 ml concentrated sulphuric acid and 5 ml orthophosphoric acid. Kept the conical flask on a hot water bath at 100° Celsius for 30 min. After cooling added 1 ml of ferroin indicator and titrate against 0.01 N Ferrous Ammonium Sulphate (FAS). Run blank without soil.

iii. Labile carbon

Labile carbon was estimated by 0.02 M $KMnO_4$ method as given by Weil and Islam (2003).

5g air-dried soil in a centrifuge tube was taken. Added 20 ml 0.02 M $KMnO_4$ solution to it. Shook the content for 2 min on a horizontal shaker at 120 RPM. Centrifuged the content at 4000-5000 RPM for 20 min then 2 ml of clear supernatant taken and made the volume 50 ml and recorded the absorbance at 550 nm. Pipette 1, 1.5, 2, 2.5 and 5 ml of 0.02 M $KMnO_4$ solution and made volume 50 ml and prepared standard curve and read absorbance at 550nm. Plotted the curve and recorded the slope. Also, recorded the absorbance of 0.02 M $KMnO_4$ solution and considered it as blank.

iv. Microbial Biomass Carbon

Microbial biomass carbon was estimated by the chloroform fumigation method given by Vance (1987).

Three samples for each sample, one for fumigated soil, one for non-fumigated soil and one for determination of moisture percentage were maintained. 20 gm of fresh soil was taken. Fumigated the sample with ethanol-free chloroform for 24 hours in a vacuum desiccator. Kept another set in the refrigerator as non-fumigated sample. Removed the sample from the desiccator after fumigation. Both fumigated and non-fumigated samples were transferred in a 250 ml conical flask then added 25 ml 0.5 M K_2So_4 and shook the content on a horizontal shaker for 30

Plate: 4 Harvesting of watermelon

minutes, filtered through Whatman No. 42 filter paper. Pipetted out 10 ml in a 500 ml conical flask. Added 2 ml 0.1 N $K_2Cr_2O_7$, 10 ml H_2SO_4, 5 ml orthophosphoric acid and kept on the hot plate at 100 °C for 30 min. After that added 250 ml distilled water immediately and added 2 ml ferroin indicator. Titrated against 0.005 N Ferrous Ammonium Sulphate.

v. Soil total carbon

Soil total carbon was determined by the Dry combustion method in a muffle furnace at 600°C by Tiessen and Moir (1993). carbon content was determined from the brick red coloured combusted soil sample in pre-weight silica crucible.

3.2.1.2 Soil chemical properties

i) Soil pH

Using a pH meter with a glass and calomel electrode and a 1:2.5 soil-water suspension ratio, the pH of soil samples was determined (Jackson, 1973).

ii) Electrical conductivity

The electrical conductivity of the soil sample was measured in the supernatant solution of 1:2.5 ratio of soil: water extract using a conductivity meter and expressed as dS m^{-1} (Jackson,1973).

iii) Available Nitrogen

Available nitrogen in the soil was given by the Alkaline permanganate method given by Subbiah and Asija (1956) and expressed in kg ha^{-1}.

iv) Available Phosphorus

The available phosphorous of the soil was determined by the Bray No. 1 method of extracting the acid soil phosphorous in dilute 0.03 N NH_4F as given by Bray and Kurtz (1945). Phosphorus in the extractant was determined calorimetrically using a Spectrophotometer at a wavelength of 660 nm, as outlined by Black (1965) and expressed in kg ha^{-1}.

v) Available Potassium

It was estimated by extraction with neutral normal ammonium acetate (NH_4OAc, pH 7.0). Potassium in soil was determined with the help of a flame photometer as described by Jackson (1973). Expressed in kg ha^{-1}.

3.2.1.3 Soil Biological Properties

i) Total microbial count

For microbial count, the serial dilution technique was used given by Dhingra and Sinclair (1993)

a) Bacterial count

Beef extract media was made by combining 3 g of Beef extract, 5 g of peptone, 1 g of NaCl, 15 g of Agar-agar, and 1000 ml of distilled water, with the pH adjusted to 7.0. 1 gm soil sample was taken and 9 ml of sterile water was added to an attest tube, which was then vigorously shaken to attain a concentration of 10^{-1}. A 1ml suspension was transferred to a test tube and 9ml of water was added and shaken to achieve a concentration of 10^{-2}. This process was repeated to prepare a concentration of 10^{-8} of the soil solution in a test tube for bacterial population. Subsequently, 1 ml of the soil solution of the desired concentration (10^{-8}) was transferred to a sterile petri plate and Knight medium was poured. The petri plate was incubated at 30°C and the observation of bacteria g^{-1} of soil was recorded.

b) Fungal count

Prepared rose bengal media containing 10 g dextrose, 5 g peptone, 1 g potassium dihydrogen phosphate, 1 g $MgSo_4$, 0.03 ml rose bengal, 0.03 ml streptomyces solution, 15 g agar-agar, 1000 ml distilled water and adjusted pH 7.0. 1 gm soil in a test tube containing 9 ml sterile water i.e., 10^{-1} concentration was taken. Similar to the above prepared concentration of 10^{-5} for the fungal population. Similarly, transferred 1ml soil solution to petri plate containing media. Incubated at 30°C and recorded the observation.

c) Actinomycetes count

Prepared media 1 gm D-glucose, 0.1 g KH_2PO_4,0.1 g $NaNo_3$, $MgSo_4$, 15 g Agar-agar, 1000 ml sterile water and adjusted pH 7.0. Similarly, prepared soil solution of concentration 10^{-5} and 10^{-6}. Mixed soil solution with media in a petri plate and incubated. Recorded the observation.

ii) Dehydrogenase activity

Dehydrogenase activity in the soil sample was determined by following the procedure as described by Klein *et al*. (1971). One gram of air-dried soil was taken in an air-tight screw capped test tube (15 ml capacity). To that 0.2 ml of 3 per cent 2, 3, 5- triphenyl tetrazolium chloride (TTC) solution was added in each of the tubes to saturate the soil. In each tube, 0.5 ml of 1% glucose solution was added. The bottom of the tube was gently tapped to drive out all trapped oxygen and thus a water seal is formed above the soil. Ensure that no air bubbles are formed. Tubes were incubated at 28 ± 0.5 ^{0}C for 24 hours. After incubation 10 ml methanol was added and shaken vigorously. The contents were allowed to stand for 6 hr. The clear pink coloured supernatant solution was withdrawn and readings were taken with a spectrophotometer at a wavelength of 485 nm (blue filter). The amount of triphenyl formazan (TPF) formed was extrapolated from the standard curve drawn in the range of 10 µg to 90 µg TPF ml^{-1}. The results were expressed as µg TPF 24 hr^{-1} g^{-1} soil.

3.2.2 Plant Analysis

3.2.2.1 Plant tissue analysis for nutrient content

Plant tissue analysis was carried out to estimate the amount of nutrients in the plant. It was carried on 30, 60 DAS and at crop harvest. Prior to nutrient analysis, the samples were first cleaned with water and diluted HCl to remove dirt and impurities. After that samples were sun-dried and then oven-dried at 40°C for 48 hours. Morter pastel was used to powder the samples. These samples were examined for the concentration of various nutrient percentages found in the watermelon leaves during the study.

i) Total Nitrogen

The oven-dried plant samples (0.5 g each) were digested by using concentrated H_2SO_4 (15 mL) and H_2O_2 (5 mL). The volume was made by distilled water to 50 mL after digestion of the sample. A suitable aliquot was taken for distillation and nitrogen was determined by Kjelplus apparatus as described by Tandon (1993). The digested materials were distilled in an alkaline medium (40 % NaOH) and the liberated ammonia was trapped in a 2 per cent boric acid solution containing mixed indicator. The trapped ammonia was titrated against standard sulphuric acid (0.02 N). (Jackson, 1973).

ii) Total phosphorus

The oven dried plant and tuber samples (0.5 g each) were digested in a diacid mixture (9:4) *viz*., nitric acid and perchloric acid. The volume was made to 50 ml with distilled water after digestion, filtered and was used for the determination of nutrients.

Phosphorus content in the digested plant sample was estimated by Vanado-molybdo phosphoric yellow colour method in nitric acid medium and the colour intensity was measured by using a spectrophotometer at 420 nm wavelength as outlined by Chopra and Kanwar (1978).

iii) Total potassium

followed the same procedure for the digestion of plant samples as that of total phosphorus. The di-acid digest was diluted to 25 ml with distilled water and fed to a calibrated systronic flame photometer. By comparing the flame photometer readings of the sample with the calibration curve of potassium and per cent potassium in the plant sample was calculated (Jackson, 1973).

3.2.3 Quality parameters

1. Total soluble solids

Total soluble solids were recorded with the help of a hand refractometer and values were worked out and expressed in °B. Pulp of fruit was taken on hand refractometer and reading noted.

2. Reducing sugar

The reducing sugars were determined by the method of Lane and Eynon (1923) as described by Rangana (1995). A known weight of the sample was taken in a 250 ml volumetric flask. To this, 100 ml of distilled water was added and the contents were neutralized by 1N sodium hydroxide. Then, 2 ml of 45 per cent lead acetate was added to it. The content was mixed well and kept for 10 minutes. Then, 2.5 ml of 22 per cent potassium oxalate was added to it to nullify lead acetate. The volume was made 250 ml with distilled water and the solution was filtered through No. 4 filter paper. This filtrate was used for determination of reducing sugars by titrating it against the boiling mixture of Fehling 'A' and Fehling 'B' solutions (5 ml each) using methylene blue as an indicator to a brick red colour endpoint. The results were expressed on a per cent basis.

3) Lycopene content

Lycopene content was determined by the Acetone method of Ranganna, s. (1976). A sample was taken and pulped it well to a smooth consistency. 5 gm of this sample taken and extracted it with acetone using mortar and pestle until the residue is colourless. Transferred an acetone extract in a separating funnel containing about 20 ml petroleum ether and mixed gently. Added about 20 ml of 5% sodium sulphate solution and shook the separating funnel for clear separation of two layers. Separated the two phases and re-extract the lower aqueous phase with an additional 20ml petroleum ether until the aquation phase was colourless. Washed petroleum ether extract with a little distilled water. Poured the washed petroleum ether extract containing carotenoids containing 10 g of anhydrous sodium sulphate. Kept it aside for 30 min. Washed slurry with petroleum ether until it was colourless and transferred the washing to the volumetric flask. Made the volume and measured the absorbance on a spectrometer at 503 nm using petroleum ether as blank.

iv) Sensory Evaluation

Organoleptic evaluation of fruits of different treatments of watermelon under study was done with the help of a panel of 10 judges for assessing colour, flavour and texture by using a nine-point Hedonic scale.

Name of fruit:

Name of the evaluator:

Date of evaluation:

Sr. No.	**Sample No.**	**Sensory Score for**			**Average**
		Colour	**Flavour**	**Texture**	
1	T_1				
2	T_2				

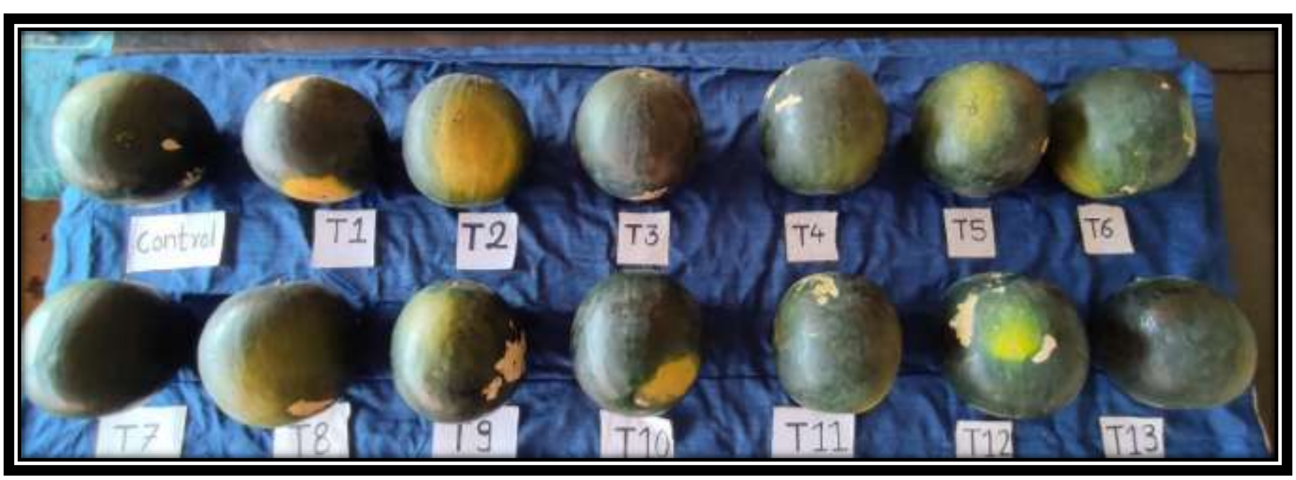
Sensory score	**Rating**
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like not dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

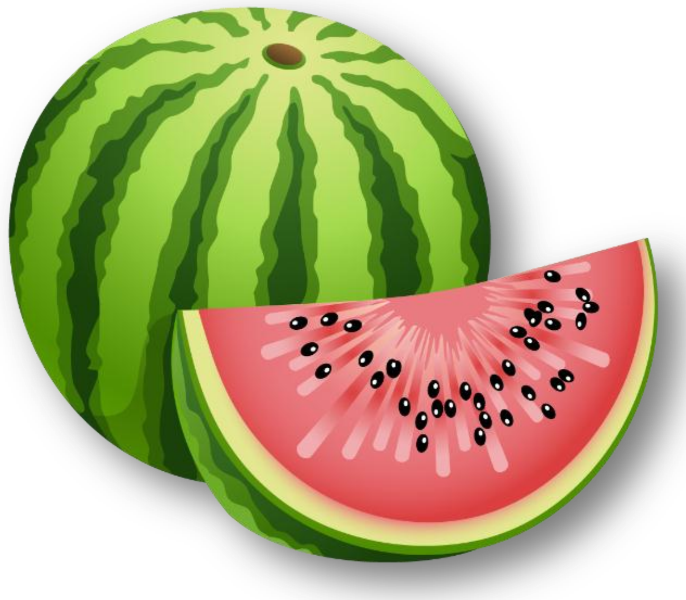
Note: The score of 5.5 above indicates acceptability within the score of 1 to 9

3.3 Statistical analysis

The experimental data was analysed statistically by the technique of analysis of variance as applicable to randomized block design. The significance of treatment difference was tested by 'F' (Variance ratio) test. The critical difference (CD) at 5 per cent level of probability was worked out for comparison and statistical interpretation of the treatment means (Panse and Sukhatme, (1969).

Plate: 5 Sensory Evaluation of watermelon





RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

An experiment was conducted during the *Rabi* season of 2023 at the College of Horticulture Dapoli to study the "Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan". The results of the investigation were presented under the following headings in this chapter;

4.1 Effect of various crop residue biochar on soil carbon pools

4.2 Effect of various crop residue biochar on properties of soil

4.3 Influence of various crop residue biochar on nutrient content in leaves of watermelon

4.4 Effect of various crop residue biochar on the yield of watermelon

4.5 Influence of various crop residue biochar on quality attributes of watermelon fruits

4.6 Chemical characterisation of biochars prepared from rice husk, coconut husk and areca nut husk

4.1 Effect of various crop residue biochar on soil carbon pools

The results of the effect 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), inorganic carbon (IC) and total carbon (TC) at 30 DAS, 60 DAS and harvest under watermelon crop as discussed under,

4.1.1 Effect of various crop residue biochar on soil organic carbon

The changes in soil organic carbon of soil were due to the influence of different levels of recommended dose of fertilizers with various crop residue biochar presented in Table 4.1 and Fig. 4.1. The results revealed that an increasing rate of biochar application influenced soil organic carbon considerably. Soil organic carbon ranged from 14.06 to 16.71 g kg^{-1} at 30 DAS, 14.08 to 16.88 g kg^{-1} at 60 DAS and 14.11 to 17.16 g kg^{-1} at harvest.

- **At 30 DAS**

The highest soil organic carbon value was 16.71 g kg^{-1} in treatment T_8, which included 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB) at 30 DAS. It was statistically at par to the soil organic carbon content in treatments T_4 with 100% RDF with 4 t ha^{-1} of coconut husk biochar (16.34 g kg^{-1}), T_5 containing 75% RDF with 4 t ha^{-1} of coconut husk biochar (15.52 g kg^{-1}), T_9 consisting of 75% RDF along with 4 t ha^{-1} of rice husk biochar (16.00 g kg^{-1}), T_{12} containing 100% RDF + 4 t ha^{-1} of areca nut husk biochar at 16.45 g kg^{-1}, and T_{13} comprising of 75% RDF with 4 t ha^{-1} of areca nut husk biochar at 15.94 g kg^{-1}, while significantly exceeding remaining treatments. The lowest soil organic carbon was found to be 14.06 g kg^{-1} in treatment T_{14}, which served as the absolute control.

- **At 60 DAS**

The maximum value of soil organic carbon was 16.88 g kg^{-1}, recorded in treatment T_8, which had contained 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB). This value was significantly superior to all other treatments, except for treatments T_4 containing 100% RDF + 4 t ha^{-1} of CHB at 16.55 g kg^{-1}, T_5 consisting 75% RDF + 4 t ha^{-1} of CHB (15.70 g kg^{-1}), T_9 comprising 75% RDF + 4 t ha^{-1} of RHB (16.25 g kg^{-1}) T_{12} (100% RDF + 4 t ha^{-1} of AHB) at 16.70 g kg^{-1} and T_{13} (75% RDF + 4 t ha^{-1} of AHB) at 16.11 g kg^{-1}, which were at par with the highest treatment. The minimum soil organic carbon was found in the absolute control treatment T_{14} at 14.08 g kg^{-1}.

- **At harvest**

During the harvest stage, the maximum organic carbon value was 17.16 g kg^{-1} in treatment T_8, which comprised 100% RDF with 4 t ha^{-1} of RHB. This value was on par with treatments T_4 100% RDF + 4 t ha^{-1} of CHB) at 16.80 g kg^{-1}, T_5 containing 75% RDF + 4 t ha^{-1} of CHB at 15.93 g kg^{-1}, T_9 consisting 75% RDF + 4 t ha^{-1} of (RHB) at 16.49 g kg^{-1}, T_{12} containing 100% RDF + 4 t ha^{-1} of AHB at 16.97 g kg^{-1}, and T_{13} consisting 75% RDF with 4 t ha^{-1} of areca nut husk biochar (AHB) at 16.34 g kg^{-1}. The lowest organic carbon value at harvest was 14.11 g kg^{-1}, found in treatment T_{14}, which served as the absolute control.

Application of biochar and FYM along with inorganic 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). Biochar had two types of carbon fractions i.e., labile and recalcitrant fractions (Nandini *et al.*, 2022). Dissolved organic matter and dissolved organic carbon content in biochar helped to improve SOC and biochar also improved the dissolved organic matter in soil. Wardle *et al.*, (2008) and Jerry *et al.*, (2009) also recorded that biochar acts as a carbon store of its own, it enhances soil organic carbon storage capacity of soil by turnover of native organic matter. It was found that biochar incorporation into soils could improve the protection of soil organic carbon in both macro and micro-aggregate size fractions (Liu *et al.*, 2016). Thereby helped the enhancement of SOC in the soil through physical protection (Hartley and Waterson 2016). The

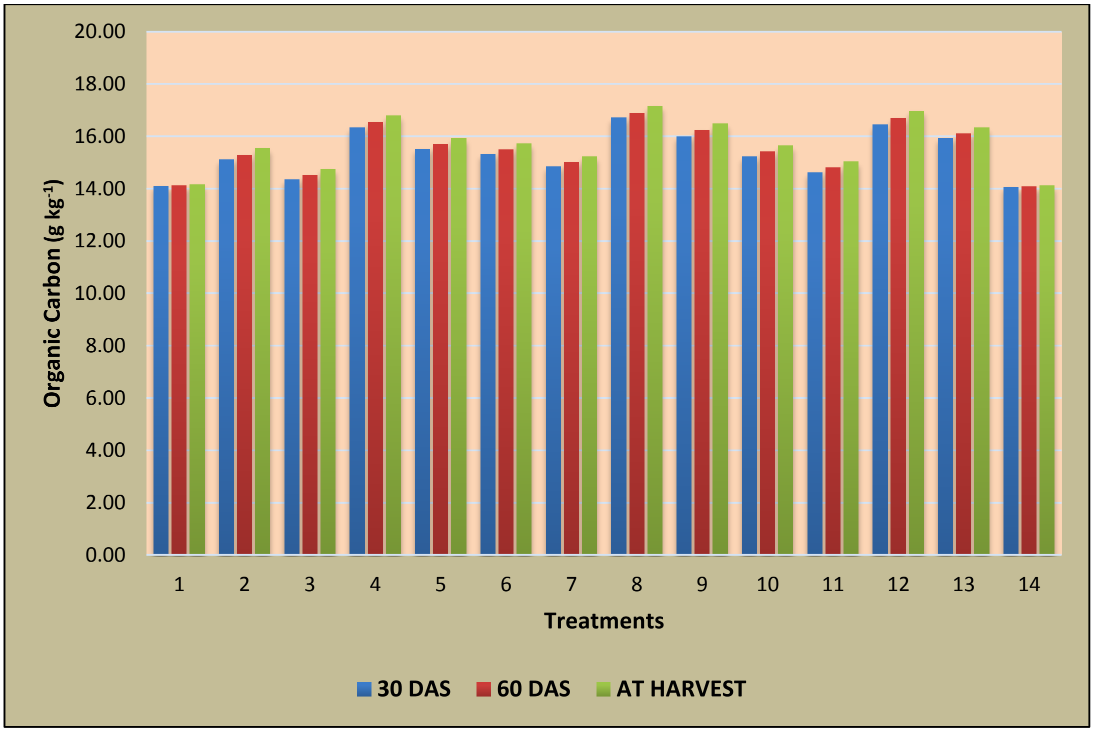


Fig 4.1 Effect of application of biochar on organic carbon of soil at different growth stages of watermelon

addition of biochar allowed the SOC sequestrated in the soil to be several magnitudes higher than naturally possible. Biochar is a matrix of organic complexes, and its application to soil systems enhances soil organic carbon (Elangovan and Chandrasekharan 2014).

Table 4.1: Effect of application of biochar on organic carbon of soil at different growth stages of watermelon

Tr no.	Treatment details	Organic carbon (g kg^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	14.11	14.13	14.16
T_2	100% RDF + CHB (2 t ha^{-1})	15.11	15.29	15.54
T_3	75% RDF + CHB (2t ha^{-1})	14.35	14.52	14.75
T_4	100% RDF + CHB (4t ha^{-1})	16.34	16.55	16.80
T_5	75% RDF + CHB (4 t ha^{-1})	15.52	15.70	15.93
T_6	100% RDF + RHB (2 t ha^{-1})	15.32	15.50	15.73
T_7	75% RDF + RHB (2 t ha^{-1})	14.84	15.02	15.23
T_8	100% RDF + RHB (4 t ha^{-1})	16.71	16.88	17.16
T_9	75% RDF + RHB (4 t ha^{-1})	16.00	16.25	16.49
T_{10}	100% RDF + AHB (2 t ha^{-1})	15.23	15.41	15.64
T_{11}	75% RDF + AHB (2 t ha^{-1})	14.62	14.80	15.03
T_{12}	100% RDF + AHB (4 t ha^{-1})	16.45	16.70	16.97
T_{13}	75% RDF + AHB (4 t ha^{-1})	15.94	16.11	16.34
T_{14}	Absolute control	14.06	14.08	14.11
	S.E. (±)	0.42	0.43	0.43
	CD (P=0.05)	1.22	1.24	1.25

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 influenced. Due to the continuous application of water through drip irrigation systems, soluble compounds present in biochar get dissolved may lead to temporary increase in soil organic carbon. The same results were found by Yang *et al.*, (2020) in which he was found that significant improvement in soil organic carbon in paddy soil under water saving irrigation after the addition of biochar as compared to flood irrigation. During winter season, decomposition rate may be slow which lead to steady increase in organic carbon. Then might be decline after 120 days after sowing. Result also supported by Rajakumar (2015) in which he carried out incubation study of 30, 60, 90, 120 and 150 days found decline in carbon fractions after 90 days. The addition of biochar helped in the improvement of microbial activity as there was significant improvement in microbial population which led to an increase in organic carbon in the soil, results supported by Gowthami

(2019). Murthy (2020) concluded there was a significant increase in organic carbon by the application of biochar under maize cultivation. (Nguyen *et al.*,2008; Liang *et al.*, 2009) recorded that the stable structure present inside the biochar inhibits the surface oxidation of organic carbon hence improving the stability of SOC against microbial degradation and also decreasing the mineralization rate of SOC which finally led to improving the soil organic content.

Results are supported by Masulili *et al.*, (2010), Sukartono *et al.*, (2011), Islami *et al.*, (2011), Nigussie *et al.*, (2012), Walelign *et al.*, (2014), Li *et al.*, (2015), Sara *et al.*, (2018), Daniel *et al.*, (2018), Xinliang *et al.*, (2019), Panda (2020), Mavi *et al.*, (2021), Madhupriya (2019)

4.1.2 Effect of various crop residue biochar on water soluble carbon

The influence of biochar on water soluble carbon at 30 DAS, 60 DAS and at harvest were presented in Table 4.2 and it revealed that WSC ranged from 54.85 mg kg^{-1} to 80.85 mg kg^{-1}, 54.08 mg kg^{-1} to 81.56 mg kg^{-1}, 53.76 mg kg^{-1} to 82.24 mg kg^{-1} at 30 DAS, 60 DAS and at harvest respectively.

- **At 30 DAS**

Application of 100% RDF along with 4 t ha^{-1} of rice husk biochar (T_8) resulted in a higher water-soluble carbon (WSC) content of 80.85 mg kg^{-1} at 30 days after sowing. Treatment T_8 was at par to treatments T_4 consisting of 100% RDF + 4 t ha^{-1} of coconut husk biochar (80.48 mg kg^{-1}), T_5 containing 75% RDF + 4 t ha^{-1} of coconut husk biochar (79.27 mg kg^{-1}), T_9 consisting 75% RDF + 4 t ha^{-1} of rice husk biochar (80.31 mg kg^{-1}), T_{12} receiving 100% RDF + 4 t ha^{-1} of areca nut husk biochar (80.58 mg kg^{-1}), and T_{13} receiving 75% RDF + 4 t ha^{-1} of areca nut husk biochar (79.35 mg kg^{-1}). The lowest value of water-soluble carbon was found to be 54.85 mg kg^{-1} in treatment T_{14}, which served as the absolute control.

- **At 60 DAS**

At 60 DAS, the maximum water-soluble carbon value was found in treatment T_8, which received 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB) (81.56 mg kg^{-1}). It was at par to treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (81.22 mg kg^{-1}), T_5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (79.90 mg kg^{-1}), T_9 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (80.94 mg kg^{-1}), T12 with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (81.31 mg kg^{-1}), and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (80.00 mg kg^{-1}). The lowest value (54.08 mg kg^{-1}) was observed in treatment T_{14}, representing the absolute control, at 60 DAS.

❖ **At harvest**

The treatment with 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB) exhibited the highest value of water-soluble carbon (WSC) at 82.24 mg kg^{-1}, which was at par to treatments T_4 (100% RDF + 4 t ha^{-1} of coconut husk biochar) at 81.82 mg kg^{-1}, T_5 receiving 75% RDF + 4 t ha^{-1} of coconut husk biochar (CHB) at 80.62 mg kg^{-1}, T_9 consisting 75% RDF + 4 t ha^{-1} of rice husk biochar (RHB) at 81.58 mg kg^{-1}, T_{12} containing 100% RDF + 4 t ha^{-1} of areca nut husk biochar (AHB) at 81.96 mg kg^{-1}, and T_{13} receiving 75% RDF + 4 t ha^{-1} of areca nut husk biochar AHB at 80.63 mg kg^{-1}. The treatment T_{14}, which served as the absolute control, recorded the lowest value of 53.76 mg kg^{-1} of WSC at the harvest stage.

Table 4.2: Effect of application of biochar on water soluble carbon (WSC) of soil at different growth stages of watermelon

Tr no.	Treatment details	WSC (mg kg^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	61.00	60.47	60.23
T_2	100% RDF + CHB (2 t ha^{-1})	69.23	69.88	70.51
T_3	75% RDF + CHB (2t ha^{-1})	68.48	69.13	69.75
T_4	100% RDF + CHB (4t ha^{-1})	80.48	81.22	81.82
T_5	75% RDF + CHB (4 t ha^{-1})	79.27	79.90	80.62
T_6	100% RDF + RHB (2 t ha^{-1})	71.48	72.16	72.73
T_7	75% RDF + RHB (2 t ha^{-1})	69.33	69.97	70.59
T_8	100% RDF + RHB (4 t ha^{-1})	80.85	81.56	82.24
T_9	75% RDF + RHB (4 t ha^{-1})	80.31	80.94	81.58
T_{10}	100% RDF + AHB (2 t ha^{-1})	70.31	70.94	71.55
T_{11}	75% RDF + AHB (2 t ha^{-1})	68.40	69.07	69.67
T_{12}	100% RDF + AHB (4 t ha^{-1})	80.58	81.31	81.96
T_{13}	75% RDF + AHB (4 t ha^{-1})	79.35	80.00	80.63
T_{14}	Absolute control	54.85	54.08	53.76
	S.E. (±)	3.19	3.19	3.26
	CD (P=0.05)	9.26	9.28	9.46

Water soluble carbon (WSC) is an active and mobile form of soil organic carbon which helps in the immediate conversion of organic substrate for microbes and hence acts as an energy source as well as a mineral nutrient sink (Tao *et al.* 1999)

Water soluble carbon (WSC) significantly improved due to the application of biochar and RDF including FYM. As the rate of biochar improved content of WSC also increased. WSC was found to be highest in treatment (100% RDF + RHB 4 t ha^{-1})

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 form by the processes of decomposition, microbial transformation as well as enzymatic transformation. Sandhu *et al.*, (2017) recorded application of corn stover biochar @ 10 mg ha^{-1} increased WSC, similarly, Xing *et al.*, (2015) observed improvement in WSC by the addition of bamboo and rice biochar at 50%.

Findings supported by Arun Kumar *et al.*, (2019), Nandini *et al.*, (2022), Panda (2020), and Mavi *et al.*, (2021).

4.1.3 Effect of various crop residue biochar on labile carbon

The results about the effect of various crop residue biochar on labile carbon were presented in Table 4.3. Labile carbon pool ranged from 280.67 mg kg^{-1} to 347.19 mg kg^{-1} at 30 DAS, 276.67 mg kg^{-1} to 351.98 mg kg^{-1} at 60 DAS and 268.81 mg kg^{-1} to 358.22 mg kg^{-1} at harvest.

- **At 30 DAS**

The data indicated that the highest value of labile carbon (347.19 mg kg^{-1}) was observed in treatment T_8, which contained 100% recommended dose of fertilizer along with 4 t ha^{-1} of rice husk biochar. This value was at par to treatments T_4 (100% RDF + 4t ha^{-1} of coconut husk biochar) at 337.72 mg kg^{-1}, T_9 (75% RDF + 4 t ha^{-1} of rice husk biochar) at 339.87 mg kg^{-1}, and T_{12} (100% RDF + 4 t ha^{-1} of areca nut husk biochar) at 342.05 mg kg^{-1}, and significantly superior to all other treatments. The absolute control (T_{14}) recorded the lowest value of labile carbon at 30 DAS, which was 280.67 mg kg^{-1}.

- **At 60 DAS**

The highest recorded labile carbon content was 351.98 mg kg^{-1} in treatment T_8, which had received 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB). This value was statistically similar to the labile carbon content in treatments T_4 100% RDF + 4 t ha^{-1} of coconut husk biochar (CHB) at 342.67 mg kg^{-1} and T_{12} 100% RDF + 4 t ha^{-1} of areca nut husk biochar (AHB) at 346.81 mg kg^{-1}. The absolute control exhibited the lowest labile carbon value at 276.67 mg kg^{-1}.

- **At harvest**

The highest labile carbon (351.98 mg kg^{-1}) was found in treatment T_8 receiving 100% RDF along with 4 t ha^{-1} RHB at harvest stage. But statistically treatment T_8 receiving 100% RDF along with 4 t ha^{-1} RHB was found at par with T_4 (348.75 mg kg^{-1}) and T_{12} (353.05 mg kg^{-1}) treatments in which 4 ton of CHB and RHB with 100 percent RDF was applied respectively.

Table 4.3: Effect of application of biochar on labile carbon (LC) of soil at different growth stages of watermelon

Tr no.	Treatment details	Labile carbon (mg kg^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	284.33	281.33	279.33
T_2	100% RDF + CHB (2 t ha^{-1})	315.55	320.34	326.54
T_3	75% RDF + CHB (2t ha^{-1})	305.44	310.24	316.44
T_4	100% RDF + CHB (4t ha^{-1})	337.72	342.67	348.75
T_5	75% RDF + CHB (4 t ha^{-1})	327.48	332.01	338.47
T_6	100% RDF + RHB (2 t ha^{-1})	323.15	327.94	334.15
T_7	75% RDF + RHB (2 t ha^{-1})	332.05	316.82	323.33
T_8	100% RDF + RHB (4 t ha^{-1})	347.19	351.98	358.22
T_9	75% RDF + RHB (4 t ha^{-1})	335.33	339.87	346.00
T_{10}	100% RDF + AHB (2 t ha^{-1})	320.00	324.82	331.33
T_{11}	75% RDF + AHB (2 t ha^{-1})	310.00	314.80	321.00
T_{12}	100% RDF + AHB (4 t ha^{-1})	342.05	346.81	353.05
T_{13}	75% RDF + AHB (4 t ha^{-1})	330.37	335.82	342.00
T_{14}	Absolute control	280.67	276.67	268.81
	S.E. (±)	4.05	4.91	4.15
	CD (P=0.05)	11.78	14.28	12.05

Labile carbon is 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 to changes 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 biochar rates into the soil (Tirol *et al.* 2004).

Arun Kumar *et al.*, (2019) found labile carbon was positively affected by the application of biochar. Murthy (2020) recorded that biochar prepared at 500 °C and applied at 10 t ha^{-1} showed the highest labile carbon. Shilpa (2019) found the highest labile carbon in the cob rind biochar treated plot. Results were supported by Nandini *et al.*, (2022).

4.1.4 Effect of various crop residue biochar on microbial biomass carbon

Microbial biomass carbon was found to be increased with an increase in the rate of biochar which was presented in Table 4.4. MBC ranged between 197.67 to 274.95 mg kg^{-1}, 204.88 to

282.12 mg kg^{-1} and 200.55 to 279.88 mg kg^{-1} at 30 DAS, 60 DAS and at harvest respectively. The MBC increased from 30 DAS to 60 DAS and then decreased at the harvest stage which was discussed as under,

- **At 30 DAS**

The data showed that maximum microbial biomass carbon was noticed in treatment T_8 consisting of 100% RDF + RHB 4 t ha^{-1} 274.95 mg kg^{-1} which was recorded at par with treatments T_4 and T_{12} consisting 100% RDF along with 4 t ha^{-1} of coconut husk biochar and areca nut husk biochar respectively. Significantly superior over all other remaining treatments. The lowest value of MBC was recorded (197.67 mg kg^{-1}) in the treatment (T_{14}) which was absolute control.

- **At 60 DAS**

At 60 days after sowing, the treatment T_8, which received 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB), exhibited the highest microbial biomass carbon status of 282.12 mg kg^{-1}. It was at par to treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (270.33 mg kg^{-1}) and T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (276.51 mg kg^{-1}), and significantly superior to all other remaining treatments. The lowest value of microbial biomass carbon (204.88 mg kg^{-1}) was recorded in treatment T_{14}, which was absolute control.

- **At harvest**

The results revealed that the application of treatment T_8, 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 par to treatments T_4, which consisted of 100% RDF with coconut husk biochar (CHB) at 4 t ha^{-1} (268 mg kg^{-1}), T_9 containing 75% RDF with RHB at 4 t ha^{-1} (266.92 mg kg^{-1}), and T_{12} receiving 100% RDF with areca nut husk biochar (AHB) at 4 t ha^{-1} (274.18 mg kg^{-1}). The absolute control, represented by treatment T_{14}, showed the lowest value of microbial biomass carbon (200.55 mg kg^{-1}) at the harvest stage.

Microbial biomass carbon (MBC) measures biological activity and carbon contained in living components of soil organic matter within the soil. MBC indicate the response of soil microbes within the soil to changes occurring in the soil system which affects the turnover of soil organic matter. MBC acts as a source as well as the sink of available nutrients in the soil.

In the present investigation, it was found that due to a considerable increase in microbial population after addition of biochar in soil as it improves chemical and physical properties within soil such as pH, CEC, porosity, water holding capacity, and surface area which led to increased MBC.

Table 4.4: Effect of application of biochar on microbial biomass carbon (MBC) of soil at different growth stages of watermelon

Tr no.	Treatment details	MBC (mg kg^{-1})		
		30DAS	**60DAS**	**Harvest**
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	206.04	213.47	208.75
T_2	100% RDF + CHB (2 t ha^{-1})	240.97	248.18	245.84
T_3	75% RDF + CHB (2 t ha^{-1})	218.19	225.37	223.05
T_4	100% RDF + CHB (4 t ha^{-1})	263.06	270.33	268.00
T_5	75% RDF + CHB (4 t ha^{-1})	252.91	260.14	257.73
T_6	100% RDF + RHB (2 t ha^{-1})	248.59	255.80	253.42
T_7	75% RDF + RHB (2 t ha^{-1})	227.12	234.34	231.96
T_8	100% RDF + RHB (4 t ha^{-1})	274.95	282.12	279.88
T_9	75% RDF + RHB (4 t ha^{-1})	260.45	267.62	266.92
T_{10}	100% RDF + AHB (2 t ha^{-1})	245.48	252.66	250.29
T_{11}	75% RDF + AHB (2 t ha^{-1})	224.67	231.85	229.53
T_{12}	100% RDF + AHB (4 t ha^{-1})	269.33	276.51	274.18
T_{13}	75% RDF + AHB (4 t ha^{-1})	256.45	263.65	261.32
T_{14}	Absolute control	197.67	204.88	200.55
	S.E. (±)	4.57	4.60	4.47
	CD (P=0.05)	13.29	13.38	13.00

Hale *et al.*, (2015) concluded that microbial biomass carbon in soil increases after the application of biochar which might be due to properties of biochar such as large surface area and high porosity which provide the best habitat for microbes by maintaining water and air. Biochar itself acts as a good carbon source for the growth of microbes (Fowles 2007). Knicker *et al.*, (2013) concluded biochar helps in the development of new microbial colonies due to the presence of its aromatic structures. Bera *et al.*, (2016) showed that mixed oak biochar and maple with dairy manure improved MBC in soil.

Similar findings were also recorded by Masto *et al.*, (2013), Panda (2020), Shilpa (2019), Mavi *et al.*, and Nandini *et al.*, (2022).

4.1.5 Effect of various crop residue biochar on soil inorganic carbon (SIC)

Soil inorganic carbon at 30 DAS, 60 DAS and at harvest did not differ significantly. Soil inorganic carbon ranged between 1.20 to 1.49 g kg^{-1} in case of 30 DAS, 1.23 to 1.52 g kg^{-1} at 60 days after sowing and 1.22 to 1.56 g kg^{-1} at harvest and revealed in Table 4.5.

The highest value of soil inorganic carbon was recorded about 1.49 g kg^{-1} at 30 DAS, 1.52 g kg^{-1} at 60 days after sowing and 1.56 g kg^{-1} at harvest of watermelon. The lowest value of soil inorganic carbon was recorded in treatment (T_{14}) which was absolute control and found to be 1.20 g kg^{-1},1.23 g kg^{-1} and 1.22 g kg^{-1} at 30, 60 and at harvest respectively.

Table 4.5: Effect of application of biochar on soil inorganic carbon (SIC) of soil at different growth stages of watermelon

Tr no.	Treatment details	SIC (g kg^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	1.26	1.29	1.25
T_2	100% RDF + CHB (2 t ha^{-1})	1.34	1.36	1.41
T_3	75% RDF + CHB (2 t ha^{-1})	1.28	1.31	1.35
T_4	100% RDF + CHB (4 t ha^{-1})	1.43	1.46	1.50
T_5	75% RDF + CHB (4 t ha^{-1})	1.39	1.41	1.46
T_6	100% RDF + RHB (2 t ha^{-1})	1.37	1.40	1.44
T_7	75% RDF + RHB (2 t ha^{-1})	1.33	1.36	1.40
T_8	100% RDF + RHB (4 t ha^{-1})	1.49	1.52	1.56
T_9	75% RDF + RHB (4 t ha^{-1})	1.41	1.44	1.48
T_{10}	100% RDF + AHB (2 t ha^{-1})	1.35	1.37	1.42
T_{11}	75% RDF + AHB (2 t ha^{-1})	1.32	1.35	1.39
T_{12}	100% RDF + AHB (4 t ha^{-1})	1.46	1.49	1.53
T_{13}	75% RDF + AHB (4 t ha^{-1})	1.40	1.43	1.47
T_{14}	Absolute control	1.20	1.23	1.22
	S.E. (±)	0.22	0.05	0.08
	CD (P=0.05)	NS	NS	NS

4.1.6 Effect of various crop residue biochar on soil total carbon (TC)

The data regarding total carbon in the Table 4.6 revealed range of total carbon which was 15.26 to 18.19 g kg^{-1} at 30 days after sowing, 15.31 to 18.40 g kg^{-1} at 60 DAS and 15.33 to 18.72 g kg^{-1} at harvest.

- **At 30 DAS**

Treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} (18.19 g kg^{-1}) had the highest total carbon which was recorded at par with treatments T_4 receiving 100% RDF + CHB 4t ha^{-1} (17.77 g kg^{-1}) T_{12} receiving 100% RDF + AHB 4 t ha^{-1} (17.91 g kg^{-1}), T_9 receiving 75% RDF + RHB 4 t ha^{-1}(17.41 g kg^{-1}), T_{13} receiving 75% RDF + AHB 4 t ha^{-1} (17.34 g kg^{-1}) and it was significantly superior over all other treatments. The lowest value of total carbon was (15.26 g kg^{-1}) found in the treatment absolute control.

- **At 60 DAS**

Similarly, in case of 60 DAS, a higher value of total carbon was recorded (18.40 g kg^{-1}) in Treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} and It was at par with treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) at 18.01 g kg^{-1}, T_5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) at 17.39 g kg^{-1}, T_9 with 75% RDF and 4 t ha^{-1} of rice husk biochar (RHB) at 17.69 g kg^{-1}, T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) at 18.19 g kg^{-1}, and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) at 17.54 g kg^{-1}. The absolute control showed the lowest value of total carbon at 60 days after sowing, measuring 15.31 g kg^{-1}.

- **At harvest**

At the harvest of watermelon, the highest total carbon of soil was recorded (18.72 g kg^{-1}) in treatment T_8, which consisted of 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB). It was at par with treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (18.30 g kg^{-1}), T5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (17.39 g kg^{-1}), T9 with 75% RDF and 4 t ha^{-1} of rice husk biochar (RHB) (17.97 g kg^{-1}), T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (18.50 g kg^{-1}), and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (17.81 g kg^{-1}). The absolute control showed the lowest total carbon (15.33 g kg^{-1}) at harvest.

Table 4.6: Effect of application of biochar on total carbon (TC) of soil at different growth stages of watermelon

Tr no.	Treatment details	TC (g kg^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	15.37	15.42	15.41
T_2	100% RDF + CHB (2 t ha^{-1})	16.45	16.66	16.75
T_3	75% RDF + CHB (2 t ha^{-1})	15.63	15.83	16.10
T_4	100% RDF + CHB (4 t ha^{-1})	17.77	18.01	18.30
T_5	75% RDF + CHB (4 t ha^{-1})	16.91	17.11	17.39
T_6	100% RDF + RHB (2 t ha^{-1})	16.69	16.90	17.17
T_7	75% RDF + RHB (2 t ha^{-1})	16.17	16.38	16.63
T_8	100% RDF + RHB (4 t ha^{-1})	18.19	18.40	18.72
T_9	75% RDF + RHB (4 t ha^{-1})	17.41	17.69	17.97
T_{10}	100% RDF + AHB (2 t ha^{-1})	16.58	16.78	17.06
T_{11}	75% RDF + AHB (2 t ha^{-1})	15.94	16.15	16.42
T_{12}	100% RDF + AHB (4 t ha^{-1})	17.91	18.19	18.50
T_{13}	75% RDF + AHB (4 t ha^{-1})	17.34	17.54	17.81
T_{14}	Absolute control	15.26	15.31	15.33
	S.E. (±)	0.41	0.45	0.46
	CD (P=0.05)	1.20	1.30	1.34

Total carbon content in soil was significantly increased after the application of biochar and RDF along with FYM. There was a significant improvement in soil organic carbon which led to an increase in TC. This might be due to the increased level of biochar and RDF along with FYM which increased the carbon status in the soil which was due to the high carbon content present in biochar. The functional groups present in biochar such as phenolic and carbonyl carbon helped to adsorb organic compounds.

Similar results were recorded by Madhupriya (2019), Panda (2020), Shilpa (2019), Mavi *et al.*, (2021), and Nandini *et al.*, (2022).

4.2 Effect of various crop residue biochar on properties of soil

4.2.1 Effect of various crop residue biochar on chemical properties of soil

4.2.1.1 Effect of various residue biochar on soil pH

The results pertaining to the status of soil pH were presented in Table 4.7. The results recorded that there was no significant difference in soil pH due to the application of biochar, however, an increase in soil pH compared to absolute control was observed. Soil pH ranged from 5.35 to 5.59 at 30 DAS, 5.37 to 5.63 at 60 DAS and 5.44 to 5.69 at harvest.

Table 4.7: Effect of application of biochar on pH of soil at different growth stages of watermelon

Tr no.	Treatment details	pH (1:2.5)		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O kgha^{-1})	5.37	5.40	5.47
T_2	100% RDF + CHB (2 t ha^{-1})	5.43	5.47	5.51
T_3	75% RDF + CHB (2 t ha^{-1})	5.39	5.41	5.45
T_4	100% RDF + CHB (4 t ha^{-1})	5.55	5.59	5.64
T_5	75% RDF + CHB (4 t ha^{-1})	5.50	5.53	5.58
T_6	100% RDF + RHB (2 t ha^{-1})	5.47	5.51	5.55
T_7	75% RDF + RHB (2 t ha^{-1})	5.41	5.45	5.48
T_8	100% RDF + RHB (4 t ha^{-1})	5.59	5.63	5.69
T_9	75% RDF + RHB (4 t ha^{-1})	5.53	5.57	5.61
T_{10}	100% RDF + AHB (2 t ha^{-1})	5.45	5.49	5.53
T_{11}	75% RDF + AHB (2 t ha^{-1})	5.40	5.42	5.46
T_{12}	100% RDF + AHB (4 t ha^{-1})	5.57	5.61	5.67
T_{13}	75% RDF + AHB (4 t ha^{-1})	5.52	5.55	5.59
T_{14}	Absolute control	5.35	5.37	5.44
	S.E. (±)	0.08	0.07	0.08
	CD (P=0.05)	NS	NS	NS

The highest values of soil pH were observed 5.59, 5.63 and 5.69 at 30 DAS, 60 DAS and at harvest in treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} respectively. However, the lowest values of soil pH observed 5.35 at 30 days after sowing, 5.37 at 60 days after sowing and 5.44 at harvest in absolute control.

4.2.1.1 Effect of various residue biochar on electrical conductivity

Application of biochar at different rates along with different rates of RDF had no significant difference in electrical conductivity presented in Table 4.8. However, there was a marginal increment in electrical conductivity at 30 DAS, 60 DAS and at harvest. Electrical conductivity ranged from 0.086 to 0.108 dS m^{-1} at 30 DAS, 0.077 to 0.101 dS m^{-1} at 60 DAS and 0.069 to 0.096 dS m^{-1} at harvest.

Table 4.8: Effect of application of biochar on Electrical conductivity of soil at different growth stages of watermelon

Tr no.	Treatment details	Electrical conductivity (EC) (dS m^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	0.087	0.078	0.072
T_2	100% RDF + CHB (2 t ha^{-1})	0.096	0.082	0.080
T_3	75% RDF + CHB (2 t ha^{-1})	0.090	0.077	0.074
T_4	100% RDF + CHB (4 t ha^{-1})	0.105	0.097	0.092
T_5	75% RDF + CHB (4 t ha^{-1})	0.098	0.087	0.085
T_6	100% RDF + RHB (2 t ha^{-1})	0.097	0.085	0.082
T_7	75% RDF + RHB (2 t ha^{-1})	0.093	0.080	0.078
T_8	100% RDF + RHB (4 t ha^{-1})	0.108	0.101	0.096
T_9	75% RDF + RHB (4 t ha^{-1})	0.101	0.093	0.090
T_{10}	100% RDF + AHB (2 t ha^{-1})	0.096	0.083	0.081
T_{11}	75% RDF + AHB (2 t ha^{-1})	0.091	0.079	0.076
T_{12}	100% RDF + AHB (4 t ha^{-1})	0.106	0.098	0.093
T_{13}	75% RDF + AHB (4 t ha^{-1})	0.100	0.088	0.087
T_{14}	Absolute control	0.086	0.077	0.069
	S.E. (±)	**0.01**	**0.01**	**0.01**
	CD (P=0.05)	**NS**	**NS**	**NS**

4.2.1.1 Effect of various residue biochar on available nitrogen content in the soil

The data pertaining to available nitrogen of soil at 30 DAS, 60 DAS and at harvest was shown in Table 4.9. Available nitrogen ranged from 286.67 to 340.19 kg ha^{-1} at 30 DAS, 271.31 to 318.29 kg ha^{-1} at 60 DAS and 258.58 to 303.10 kg ha^{-1} at harvest.

- **At 30 DAS**

At 30 DAS, among all the treatments, treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} showed the highest value of available nitrogen which was 340.19 kg ha^{-1}. The highest treatment was at par with treatments T_4 containing 100% RDF + CHB 4t ha^{-1} (334.15 kg ha^{-1}), T_5 consisting of 75% RDF + CHB 4 t ha^{-1} (324.46 kg ha^{-1}), T_6 receiving 100% RDF + RHB 2 t ha^{-1}(320.24 kg ha^{-1}), T_9 containing 75% RDF + RHB 4 t ha^{-1} (332.16 kg ha^{-1}), T_{12} with 100% RDF + AHB 4 t ha^{-1}) (338.45 kg ha^{-1}), T_{13} with 75% RDF + AHB 4 t ha^{-1} (330.10 kg ha^{-1}). Absolute control showed the lowest value of available nitrogen in soil (286.67 kg ha^{-1}) at 30 days after sowing.

- **At 60 DAS**

At 60 days after sowing, the available nitrogen of the soil decreased compared to 30 DAS. The data indicated that the highest value of available nitrogen, at 318.29 kg ha^{-1}, was recorded in treatment T_8 with 100% recommended dose of fertilizer (RDF) and 4 t ha^{-1} of rice husk biochar (RHB). Treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (334.15 kg ha^{-1}), T_5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (324.46 kg ha^{-1}), T_6 with 100% RDF and 2 t ha^{-1} of rice husk biochar (RHB) (301.25 kg ha^{-1}), T_9 with 75% RDF and 4 t ha^{-1} of rice husk biochar (RHB) (332.16 kg ha^{-1}), T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (338.45 kg ha^{-1}), and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (330.10 kg ha^{-1}) were found to be at par with the highest treatment. The highest treatment was significantly superior to all other treatments. The lowest value of soil available nitrogen, about 271.31 kg ha^{-1}, was recorded in treatment T_{14}, which served as the absolute control.

- **At harvest**

At the harvest stage of watermelon, the available nitrogen of the soil reduced compared to 30 and 60 DAS, with the maximum value recorded at 303.10 kg ha^{-1} in treatment T_8 with 100% recommended dose of fertilizer (RDF) and 4 t ha^{-1} of rice husk biochar. It was found to be at par with treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (298.08 kg ha^{-1}), T_5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (292.18 kg ha^{-1}), T_6 with 100% RDF and 2 t ha^{-1} of rice husk biochar (RHB) (286.04 kg ha^{-1}), T_9 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (294.38 kg ha^{-1}), T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (300.24 kg ha^{-1}), and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (293.04 kg ha^{-1}), being the highest value superior to other treatments. The lowest value of 258.58 kg ha^{-1} was recorded in treatment T_{14}, which served as the absolute control.

Table 4.9: Effect of application of biochar on available nitrogen content in soil at different growth stages of watermelon

Tr no.	Treatment details	Available nitrogen (kg ha^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	291.43	275.25	263.19
T_2	100% RDF + CHB (2 t ha^{-1})	314.22	294.17	278.10
T_3	75% RDF + CHB (2 t ha^{-1})	301.44	285.18	271.31
T_4	100% RDF + CHB (4 t ha^{-1})	334.15	311.03	298.08
T_5	75% RDF + CHB (4 t ha^{-1})	324.46	304.56	292.18
T_6	100% RDF + RHB (2 t ha^{-1})	320.24	301.25	286.04
T_7	75% RDF + RHB (2 t ha^{-1})	311.16	288.15	273.29
T_8	100% RDF + RHB (4 t ha^{-1})	340.19	318.29	303.10
T_9	75% RDF + RHB (4 t ha^{-1})	332.16	310.13	294.38
T_{10}	100% RDF + AHB (2 t ha^{-1})	317.36	296.37	281.37
T_{11}	75% RDF + AHB (2 t ha^{-1})	308.23	286.29	271.31
T_{12}	100% RDF + AHB (4 t ha^{-1})	338.45	315.18	300.24
T_{13}	75% RDF + AHB (4 t ha^{-1})	330.10	307.01	293.04
T_{14}	Absolute control	286.67	271.31	258.58
	S.E. (±)	7.58	9.26	7.23
	CD (P=0.05)	22.04	26.92	21.02

The present investigation found that various levels of biochar improved the available nitrogen content in soil at 30, and 60 DAS and harvest of watermelon crop. The reason behind that was biochar provides microhabitat for nitrogen fertilizers as the added nitrogenous fertilizers are trapped by the pores present in biochar. Slowly release of nitrogen from applied biochar enhanced the availability of nitrogen in the soil and minimized loss of nitrogen. Biochar improved water holding capacity as well as cation exchange capacity within soil which helped to increase available nitrogen Steiner *et al.*, (2008). Nelissen *et al.*, (2012) also concluded that biochar absorbs nitrification inhibitors present in soil (monoterpenes and phenolic compounds) which leads to higher nitrification which can cause an increase in available nitrogen. Application of biochar into soil improves chemical and biological properties in soil which can cause protection of nitrogen from loss and higher availability.

Application of biochar along with mineral nitrogen led to an increased N mineralization rate compared with the control, biochar only or urea only treatment which was probably by stimulating microbial activity within the soil (Amonette and Joseph, 2009). Widowati *et al.*, (2014) recorded the highest amount of nitrogen and potassium content in maize crop which might be due to their retention in biochar. The significant effect of the application of biochar on available nitrogen content in soil was also recorded by Novak *et al.*, (2009), Venkatesh *et al.*, (2012), Zhang *et al.*, (2017) Xingfan *et al.*, (2023).

4.2.1.1 Effect of various residue biochar on available phosphorus content in soil

The results pertaining to the available phosphorus of soil at 30 DAS, 60 DAS and harvest were shown in Table 4.10. Available phosphorus varies from 11.24 to 16.08 kg ha^{-1} at 30 DAS, in case of 60 DAS and harvest it ranged from 8.75 to 13.10 kg ha^{-1} and 7.56 to 11.85 kg ha^{-1} respectively.

- **At 30 DAS**

The maximum available phosphorus in the soil was 16.08 kg ha^{-1} in treatment T_8, which received 100% RDF + RHB 4 t ha^{-1}. This treatment was on par with T_4, which received 100% RDF + CHB 4 t ha^{-1} at 15.02 kg ha^{-1}, T_5 with 75% RDF + CHB 4 t ha^{-1} (4.40 kg ha^{-1}), T_9 with 75% RDF + RHB 4 t ha^{-1} (4.90 kg ha^{-1}), T_{12} with 100% RDF + AHB 4 t ha^{-1} (15.61 kg ha^{-1}), and T13 with 75% RDF + AHB 4 t ha^{-1} at 14.70 kg ha^{-1}. It was also superior to the other treatments. The minimum available phosphorus was 9.41 kg ha^{-1} recorded in the absolute control treatment.

- **At 60 DAS**

At 60 DAS, the maximum available phosphorus in the soil was 13.10 kg ha^{-1} in treatment T_8, which received 100% RDF + RHB 4 t ha^{-1}. This treatment, at par with T_4 with 100% RDF + CHB 4 t ha^{-1} at 12.04 kg ha^{-1}, T_5 with 75% RDF + CHB 4 t ha^{-1} at 11.42 kg ha^{-1}, T_9 with 75% RDF + RHB 4 t ha^{-1} at 14.90 kg ha^{-1}, T_{12} with 100% RDF + AHB 4 t ha^{-1} at 15.61 kg ha^{-1}, and T_{13} with 75% RDF + AHB 4 t ha^{-1} at 14.70 kg ha^{-1}, was also superior to the other treatments. The minimum available phosphorus was 9.41 kg ha^{-1} recorded in the absolute control treatment.

- **At harvest**

In the case of the harvest stage of watermelon, the highest value was obtained in treatment T_8, consisting of 100% RDF + RHB 4 t ha^{-1}, which measured 11.85 kg ha^{-1}. It was on par with T_4, 100% RDF + CHB 4 t ha^{-1} (10.79 kg ha^{-1}), T_5 with 75% RDF + CHB 4 t ha^{-1} (10.17 kg ha^{-1}), T_9 with 75% RDF + CHB 4 t ha^{-1} (11.92 kg ha^{-1}), T_{12} with 100% RDF + AHB 4 t ha^{-1} (12.63 kg ha^{-1}) and T_{13} with 75% RDF + AHB 4 t ha^{-1} (11.72 kg ha^{-1}). The minimum recorded value of available phosphorus was 8.75 kg ha^{-1} in the absolute control treatment.

Table 4.10: Effect of application of biochar on available phosphorous content in soil at different growth stages of watermelon

Tr no.	Treatment details	Available P_2O_5 (kg ha^{-1})		
		30DAS	**60DAS**	**Harvest**
T_1	RDF (150:50:50) N: P_2O_5: K_2O kgha^{-1})	11.43	9.20	8.00
T_2	100% RDF + CHB (2 t ha^{-1})	13.51	10.53	9.28
T_3	75% RDF + CHB (2 t ha^{-1})	12.21	9.23	7.98
T_4	100% RDF + CHB (4 t ha^{-1})	15.02	12.04	10.79
T_5	75% RDF + CHB (4 t ha^{-1})	14.40	11.42	10.17
T_6	100% RDF + RHB (2 t ha^{-1})	14.31	11.33	10.08
T_7	75% RDF + RHB (2 t ha^{-1})	13.12	10.14	8.89
T_8	100% RDF + RHB (4 t ha^{-1})	16.08	13.10	11.85
T_9	75% RDF + RHB (4 t ha^{-1})	14.90	11.92	10.67
T_{10}	100% RDF + AHB (2 t ha^{-1})	14.02	11.04	9.79
T_{11}	75% RDF + AHB (2 t ha^{-1})	12.85	9.87	8.62
T_{12}	100% RDF + AHB (4 t ha^{-1})	15.61	12.63	11.38
T_{13}	75% RDF + AHB (4 t ha^{-1})	14.70	11.72	10.47
T_{14}	Absolute control	11.24	8.75	7.56
	S.E. (±)	0.59	0.58	0.58
	CD (P=0.05)	1.72	1.70	1.69

Significantly higher available phosphorus in soil was found in treatment in which a full dose of RDF and a higher level of biochar was used which was (100% RDF + RHB 4 t ha^{-1}). Thus, the available phosphorus status in soil was affected by the application of biochar. The lowest status of available phosphorus was observed in absolute control at all the stages of the watermelon crop. It might be due to direct supply of soluble phosphorus through chemical fertilizer with biochar which leads to a significant increase in available phosphorus in soil caused by the property of biochar to hold anions.

According to Atkinson *et al*. (2010) biochar enhanced availability and plant uptake of phosphorus after addition to soil attributed to its role as source of soluble phosphorus salts and exchangeable phosphorus forms, it avoids phosphorus precipitation by modifying soil pH (bonding or sorbing elements which precipitate phosphorus) or enhances microbial activity leading to changes in phosphorus availability. Opala *et al.*, (2012) reported microbes carried out the conversion of soil phosphorus to available phosphorus. Mukherjee *et al.*, (2011) concluded when pH increases the amount of free phosphorus also increases in the soil system. Similar results were found by Cao *et al.*, (2017) in watermelon, Husien *et al.*, (2017), and Venkatesh *et al.*, (2012).

4.2.1.1 Effect of various residue biochar on available potassium content in soil

Results presented in Table 4.11 showed the effect of various residue biochar on available potassium content in soil at 30 DAS, 60 DAS and harvest. It ranged from 283.67 to 350.19 kg ha^{-1} at 30 DAS, 275.33 to 332.20 kg ha^{-1} at 60 DAS and 268.47 to 323.51 kg ha^{-1} at harvest.

- **At 30 DAS**

It was observed from the data that at 30 DAS, treatment T_8 (100% RDF + RHB 4 t ha^{-1}) recorded the maximum value of available potassium, which was 350.19 kg ha^{-1}. It was on par with T_4 receiving 100% RDF + CHB 4t ha^{-1} at 340.71 kg ha^{-1}, T_5 receiving 75% RDF + CHB 4 t ha^{-1} (330.48 kg ha^{-1}), T_9 receiving 75% RDF + CHB 4 t ha^{-1} (338.48 kg ha^{-1}) T_{12} (100% RDF + AHB 4 t ha^{-1}) (345 kg ha^{-1}), and T_{13} receiving 75% RDF + AHB 4 t ha^{-1} (334.15 kg ha^{-1}). It was significantly superior to the remaining treatments. The lowest value of available potassium (283.67 kg ha^{-1}) was observed in the case of the absolute control (T_{14}).

- **At 60 DAS**

At 60 days after sowing, the higher available potassium content of the soil was registered with the application of treatment T_8 100% RDF + RHB 4 t ha^{-1} was (332.20 kg ha^{-1}). Treatments which were at par with the highest treatment were T_4 with 100% RDF + CHB 4 t ha^{-1} (322.49 kg ha^{-1}), T_5 with 75% RDF + CHB 4 t ha^{-1} (312.19 kg ha^{-1}), T_9 with 75% RDF + RHB 4 t ha^{-1} (320.48 kg ha^{-1}), T_{12} with 100% RDF + AHB 4 t ha^{-1} (327.67 kg ha^{-1}), T_{13} with 75% RDF + AHB 4 t ha^{-1} (316.08 kg ha^{-1}) and the highest treatment was superior with remaining treatment. Lower available potassium of soil at 60 days after sowing was observed in absolute control (275.33 kg ha^{-1}).

- **At harvest**

Results revealed that treatment T_8 100% RDF + RHB 4 t ha^{-1}) showed the maximum value of available potassium (323.51 kg ha^{-1}) at the harvest stage. This treatment also at par with T_4 100% RDF along with 4 t ha^{-1}CHB (313.33 kg ha^{-1}), T_5 consisting 75% RDF with 4 t ha^{-1}CHB (303.33 kg ha^{-1}), T_9 containing 75% RDF with RHB 4 t ha^{-1} (311.50 kg ha^{-1}), T_{12} receiving 100% RDF along with AHB 4 t ha^{-1} (318.64 kg ha^{-1}), T_{13} (75% RDF + AHB 4 t ha^{-1}) (307.67 kg ha^{-1}) and minimum value was found in absolute control was (268.47 kg ha^{-1}).

Available potassium in soil was significantly increased as the rate of biochar addition increased. In the present investigation, the highest available potassium was found in treatment (T_8) 100% RDF + RHB (4 t ha^{-1}) and the lowest was found in absolute control.

A direct supply of soluble potassium fertilizers along with biochar was done which improved the available potassium in soil considerably. Chan *et al.*, (2007) found that high potassium in soil was due to the high concentration of potassium found in biochar. While considering many biochars high availability of potassium in soil might be due to the reduction of leaching of potassium by biochar (Laird *et al.*, 2010; Martinsen et al, 2014). Bindu *et al.*, (2016) found that carbonate and carboxylate functional groups of biochar help to retain potassium and other nutrients.

Higher K availability after biochar application was also reported by Major *et al.*, (2010), Cao *et al.*, (2017), Deepak Kumar (2017), Wangmo *et al.*, (2022)

Table 4.11: Effect of application of biochar on available potassium content in soil at different growth stages of watermelon

Tr no.	Treatment details	Available K_2O (kg ha^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	287.33	279.33	274.71
T_2	100% RDF + CHB (2 t ha^{-1})	318.53	301.41	293.41
T_3	75% RDF + CHB (2 t ha^{-1})	308.44	291.33	283.36
T_4	100% RDF + CHB (4 t ha^{-1})	340.71	322.49	313.33
T_5	75% RDF + CHB (4 t ha^{-1})	330.48	312.19	303.33
T_6	100% RDF + RHB (2 t ha^{-1})	326.15	309.21	301.67
T_7	75% RDF + RHB (2 t ha^{-1})	315.33	298.33	290.43
T_8	100% RDF + RHB (4 t ha^{-1})	350.19	332.20	323.51
T_9	75% RDF + RHB (4 t ha^{-1})	338.48	320.48	311.50
T_{10}	100% RDF + AHB (2 t ha^{-1})	323.33	306.33	298.33
T_{11}	75% RDF + AHB (2 t ha^{-1})	313.29	296.07	289.71
T_{12}	100% RDF + AHB (4 t ha^{-1})	345.00	327.67	318.64
T_{13}	75% RDF + AHB (4 t ha^{-1})	334.15	316.08	307.67
T_{14}	Absolute control	283.67	275.33	268.47
	S.E. (±)	7.98	7.71	7.37
	CD (P=0.05)	23.21	22.42	21.43

4.2.2 Effect of various crop residue biochar on biological properties of soil

4.2.2.1 Effect of application of biochar on the microbial count of soil

The application of various rates of biochar along with different rates of RDF affected the microbial population significantly. Biochar application enhanced bacterial, fungal and actinomycetes population in the soil at 30 DAS, 60 DAS and harvest.

1) Effect of biochar application on bacteria population (CFU g^{-1} soil)

The perusal of the data in Table 4.12 showed that bacterial population ranged between 46.31 to 61.44 CFU×10^7 at 30 DAS, 47.63 to 64.41 CFU×10^7 at 60 DAS and 46.02 to 63.08 CFU×10^7 at harvest. In general, the bacterial population increased from 30 DAS to 60 DAS and then decreased at the harvest stage.

❖ **At 30 DAS**

At 30 DAS, data revealed that the highest number of bacterial populations found in treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} was 61.44 CFU×10^7. Treatments T_4 receiving 100% RDF + CHB 4t ha^{-1} (58.56 CFU×10^7) and T_{12} receiving 100% RDF + AHB 4 t ha^{-1} (59.45 CFU×10^7) were recorded at par with the highest treatment. The highest treatment T_8 found to be significantly superior to other treatments. The lowest bacterial count (46.31 CFU×10^7) was observed in absolute control.

Table 4.12: Effect of biochar application on bacteria population (CFU g^{-1} soil)

Tr no.	Treatment details	Bacteria population CFU×10^7		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O kgha^{-1})	48.63	50.11	49.00
T_2	100% RDF + CHB (2 t ha^{-1})	52.66	55.32	53.98
T_3	75% RDF + CHB (2 t ha^{-1})	50.22	52.88	51.54
T_4	100% RDF + CHB (4 t ha^{-1})	58.56	61.55	60.21
T_5	75% RDF + CHB (4 t ha^{-1})	55.00	57.66	59.32
T_6	100% RDF + RHB (2 t ha^{-1})	54.63	57.29	55.95
T_7	75% RDF + RHB (2 t ha^{-1})	51.36	54.03	52.68
T_8	100% RDF + RHB (4 t ha^{-1})	61.44	64.41	63.08
T_9	75% RDF + RHB (4 t ha^{-1})	57.26	59.92	58.58
T_{10}	100% RDF + AHB (2 t ha^{-1})	53.70	56.36	55.02
T_{11}	75% RDF + AHB (2 t ha^{-1})	50.87	53.53	52.29
T_{12}	100% RDF + AHB (4 t ha^{-1})	59.45	62.35	61.01
T_{13}	75% RDF + AHB (4 t ha^{-1})	56.24	58.90	57.56
T_{14}	Absolute control	46.31	47.63	46.02
	S.E. (±)	1.05	1.25	1.20
	CD (P=0.05)	3.07	3.62	3.49

- **At 60 DAS**

While considering data regarding 60 DAS, it was revealed that the maximum count of the bacterial population (64.41 CFU×10^7) observed in treatment (T_8) receiving 100% RDF + RHB 4 t ha^{-1}. This treatment was at par with T_4 containing 100% RDF + CHB 4 t ha^{-1} (61.55 CFU×10^7) and T_{12} receiving 100% RDF + AHB 4 t ha^{-1} (62.35 CFU×10^7) and significantly superior over the remaining treatment. A minimum count of bacteria (47.63 CFU×10^7) was seen in the absolute control treatment.

- **At harvest**

In case of the harvest stage of watermelon, the highest bacterial population seen in treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} was 63.08 CFU×10^7. Treatment T_4 containing 100% RDF + CHB 4t ha^{-1} (60.21 CFU×10^7) and T_{12} with 100% RDF + AHB 4 t ha^{-1}) (61.01 CFU×10^7) Were at par with treatment T_8. Absolute control recorded the lowest bacterial count about 46.02 CFU×10^7.

The application of biochar significantly improved the bacterial population. The largest population was found in the treatment (T_8) 100% RDF + RHB (4 t ha^{-1}) as well as lowest was found in absolute control.

The beneficial properties of biochar after addition in soil allowed better development of bacteria in soil as compared to control (Atkinson *et al.*, 2010). Chen *et al.*, (2013) observed that due to the favourable properties of biochar, it improves soil pH and other soil properties which helps in the growth of bacteria. Ming *et al.*, (2016) recorded that due to the higher availability of organic carbon for bacterial proliferation, a higher bacterial population was found in biochar treated soil. Bacteria were not only able to colonise the surfaces of porous biochar materials but also avoid being dominated by fungi due to their small size. The same results were found in Pandian *et al.*, (2016), Siva Devika *et al.*, (2018), Gowthami (2019) and Manasi *et al.*, (2021)

2) Effect of biochar application on fungi population (CFU g^{-1} soil)

The fungal population enhanced from 30 DAS up to 60 DAS and then after declined towards harvest and that data was presented in Table 4.13. Fungal count ranged from 4.28 to 5.82 CFU×10^4 at 30 DAS, 4.31 to 8.24 CFU×10^4 at 60 DAS and 4.30 to 7.06 CFU×10^4 at harvest.

- **At 30 DAS**

While studying data at 30 DAS, it was found that treatment T_8 100% RDF + RHB 4 t ha^{-1}) was significantly the highest fungal count (5.82 CFU×10^4) and at par with treatment T_4 100% RDF + CHB 4t ha^{-1}) (5.74 CFU×10^4) and T_{12} 100% RDF + AHB 4 t ha^{-1}) (5.78 CFU×10^4) and also significantly superior over other treatments. The lowest fungal count was observed in absolute control which was (4.28 CFU×10^4).

❖ **At 60 DAS**

Similarly, at 60 DAS treatment, T_8 100% RDF + RHB 4 t ha^{-1}) showed the largest fungal population which was (8.24 CFU×10^4). It was at par with treatments T_4 100% RDF + CHB 4t ha^{-1}) (8.16 CFU×10^4) and T_{12} 100% RDF + AHB 4 t ha^{-1}) (8.20 CFU×10^4). It was superior over all remaining treatments. The lowest fungal population (4.31 CFU×10^4) was seen in treatment T_{14} which was absolute control.

❖ **At harvest**

Treatment T_8 100% RDF + RHB 4 t ha^{-1}) recorded the highest fungal population which was (7.06 CFU×10^4). It was at par with treatments T_4 with 100% RDF + CHB 4 t ha^{-1} (6.96 CFU×10^4) and T_{12} containing 100% RDF + AHB 4 t ha^{-1} (7.00 CFU×10^4) at harvest. The minimum fungal count was observed in treatment T_{14} which was absolute treatment (4.30 CFU×10^4) at harvest.

Table 4.13: Effect of biochar application on fungi population (CFU g^{-1} soil)

Tr no.	Treatment details	Fungi population CFU×10^4		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	4.30	4.50	4.44
T_2	100% RDF + CHB (2 t ha^{-1})	4.33	6.75	5.55
T_3	75% RDF + CHB (2 t ha^{-1})	4.02	6.44	5.24
T_4	100% RDF + CHB (4 t ha^{-1})	5.74	8.16	6.96
T_5	75% RDF + CHB (4 t ha^{-1})	4.41	6.83	5.63
T_6	100% RDF + RHB (2 t ha^{-1})	4.40	6.82	5.62
T_7	75% RDF + RHB (2 t ha^{-1})	4.10	6.52	5.32
T_8	100% RDF + RHB (4 t ha^{-1})	5.82	8.24	7.06
T_9	75% RDF + RHB (4 t ha^{-1})	4.50	6.92	5.72
T_{10}	100% RDF + AHB (2 t ha^{-1})	4.36	6.78	5.58
T_{11}	75% RDF + AHB (2 t ha^{-1})	4.06	6.48	5.28
T_{12}	100% RDF + AHB (4 t ha^{-1})	5.78	8.20	7.00
T_{13}	75% RDF + AHB (4 t ha^{-1})	4.46	6.88	5.68
T_{14}	Absolute control	4.28	4.31	4.30
	S.E. (±)	0.31	0.32	0.35
	CD (P=0.05)	0.89	0.94	1.02

The application of biochar along with RDF including FYM significantly enhanced the fungal population in soil. Treatment (T_8) 100% RDF + RHB (4 t ha^{-1}) showed a maximum fungal population and absolute control showed a lower population of fungus.

Gowthami (2019) concluded that the increase in the population of fungi with biochar rate was due to the availability of optimum energy sources and food in the form of soil organic carbon. Due to the application of biochar in soil some of the secretions of flavonoids, sesquiterpenes and strigolactones induced by plant roots improved colonization of arbuscular mycorrhiza fungi in plant roots as well as increased not only spore germination but also hyphal branching of AM fungi (Zhang *et al.*, 2018). The same results were found in Siva Devika *et al.*, (2018).

3) Effect of biochar application on Actinomycetes population (CFU g^{-1} soil)

The data represented in Table 4.14 indicated that the actinomycetes count enhanced from 30 DAS up to 60 DAS and then declined towards harvest. Actinomycetes count varies from 8.83 to 18.03 CFU×10^5 at 30 DAS, 9.24 to 19.27 CFU×10^5 at 60 DAS and 8.84 to 18.60 CFU×10^5 at harvest.

- **At 30 DAS**

At 30 DAS, the highest count for actinomycetes was observed in treatment T_8 100% RDF + RHB 4 t ha^{-1}) which was (18.03 CFU×10^5). This treatment was at par with treatments T_4 and T_{12} containing 100% RDF along with CHB (16.81 CFU×10^5) and AHB (17.00 CFU×10^5) at 4 t ha^{-1} it was superior overall remaining treatment. The minimum actinomycetes population (8.83 CFU×10^5) resulted in treatment T_{14} which was absolute control.

- **At 60 DAS**

Similarly, in case of 60 days after sowing, treatment T_8 consisting of 100% RDF + RHB 4 t ha^{-1}) showed maximum actinomycetes count (19.27 CFU×10^5) and the same treatment was at par with the treatment T_4 and T_{12} consisting of 100% RDF + CHB (17.90 CFU×10^5) and AHB 4 t ha^{-1}) (18.67 CFU×10^5) and significantly superior on other treatment. Absolute control which was treatment T_{14} showed the lowest count about 9.24 CFU×10^5.

- **At harvest**

At the harvest stage of watermelon, the highest actinomycetes count was recorded at about (18.60 CFU×10^5) in treatment T_8 containing 100% RDF + RHB 4 t ha^{-1}. The same treatment was at par with T_4 100% RDF + CHB 4t ha^{-1}) (17.16 CFU×10^5) and T_{12} consisting 100% RDF + AHB 4 t ha^{-1} (17.70 CFU×10^5) and superior to other treatments. The lowest count of actinomycetes was (8.84 CFU×10^5) found in treatment T_{14} which was absolute control.

Actinomycetes population influenced by the application of biochar. There was a significant improvement in population by application of biochar, FYM along with RDF. The lowest actinomycetes population was found in absolute control whereas, the highest population was recorded in treatment (T_8) 100% RDF + RHB (4 t ha^{-1}).

An increase in the actinomycetes population was found in biochar added soil (Yun *et al.*, 2017). Watzinger *et al.*, (2014) reported that the actinomycetes population is sensitive to low pH hence increase in soil pH due to the application of biochar increased the actinomycetes population. Similarly, Johnsen *et al.*, (2002) concluded that actinomycetes have the ability to degrade resistant and complex substances such as biochar present in soil hence their population was increased after the addition of biochar. The same results were found by Pandian *et al.*, (2016), Siva Devika *et al.*, (2018), Gowthami (2019), Manasi *et al.*, (2021).

Table 4.14: Effect of biochar application on actinomycetes population (CFU g^{-1} soil)

Tr no.	Treatment details	Actinomycetes population CFU×10^5		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	8.86	9.86	8.88
T_2	100% RDF + CHB (2 t ha^{-1})	10.44	12.08	10.77
T_3	75% RDF + CHB (2 t ha^{-1})	9.37	11.05	9.70
T_4	100% RDF + CHB (4 t ha^{-1})	16.81	17.90	17.16
T_5	75% RDF + CHB (4 t ha^{-1})	13.24	14.92	13.57
T_6	100% RDF + RHB (2 t ha^{-1})	11.75	13.43	12.08
T_7	75% RDF + RHB (2 t ha^{-1})	9.86	11.86	10.19
T_8	100% RDF + RHB (4 t ha^{-1})	18.03	19.27	18.60
T_9	75% RDF + RHB (4 t ha^{-1})	15.22	16.87	15.55
T_{10}	100% RDF + AHB (2 t ha^{-1})	11.40	13.07	11.73
T_{11}	75% RDF + AHB (2 t ha^{-1})	9.56	11.23	9.89
T_{12}	100% RDF + AHB (4 t ha^{-1})	17.00	18.67	17.70
T_{13}	75% RDF + AHB (4 t ha^{-1})	13.42	15.09	13.75
T_{14}	Absolute control	8.83	9.24	8.84
	S.E. (±)	0.42	0.50	0.50
	CD (P=0.05)	1.22	1.45	1.45

4.2.2.1 Effect of application of biochar on dehydrogenase activity of soil (µg $TPFg^{-1}$ 24 hr^{-1})

A significant increase in dehydrogenase activity within soil was found in biochar applied treatments shown in Table 4.15. Dehydrogenase activity ranges from 7.48 to 13.83 µg TPF g^{-1} 24

hr^{-1} at 30 DAS, 7.82 to 14.60 µg TPF g^{-1} 24 hr^{-1} at 60 DAS and 9.14 to 15.68 µg TPF g^{-1} 24 hr^{-1} at harvest.

- **At 30 DAS**

In general, at 30 DAS, the highest dehydrogenase activity was recorded in treatment T_8 consisting of 100% RDF along with RHB 4 t ha^{-1} (13.83 µg TPF g^{-1} 24 hr^{-1}) which was found at par with treatments T_4(12.53 µg TPF g^{-1} 24 hr^{-1}) and T_{12} (13.45 µg TPF g^{-1} 24 hr^{-1}) consisting of 100% RDF along with CHB and AHB at 4 t ha^{-1} respectively. The lowest dehydrogenase activity was seen in treatment T_{14} (absolute control) which was (7.48 µg TPF g^{-1} 24 hr^{-1}).

- **At 60 DAS**

Treatment T_8 comprising 100% RDF + RHB 4 t ha^{-1} reported maximum value of dehydrogenase activity (14.60 µg TPF g^{-1} 24 hr^{-1}) which was at par with two treatments which were T_4 100% RDF + CHB 4t ha^{-1}) (13.58 µg TPF g^{-1} 24 hr^{-1}) and T_{12} containing 100% RDF + AHB 4 t ha^{-1} (14.28 µg TPF g^{-1} 24 hr^{-1}). A minimum value was found (7.82 µg TPF g^{-1} 24 hr^{-1}) in absolute control.

- **At harvest**

At harvest, the highest value of dehydrogenase activity was recorded as 15.68 µg TPF g^{-1} 24 hr^{-1} in treatment T_8 (100% RDF + RHB 4 t ha^{-1}). It was on par with T_4 (14.60 µg TPF g^{-1} 24 hr^{-1}) and T_{12} (15.28 µg TPF g^{-1} 24 hr^{-1}) consisting of 100% recommended dose of fertilizers along with CHB and AHB respectively. Treatment T_8 was significantly superior to the remaining treatments. The absolute control showed the lowest value of dehydrogenase activity, which was 9.14 µg TPF g^{-1} 24 hr^{-1}.

The result of the present investigation found that dehydrogenase activity significantly increased with an increased rate of biochar. Treatment (T_8) 100% RDF + RHB (4 t ha^{-1}) recorded the highest dehydrogenase activity within soil and the lowest was found in absolute control.

Manasi *et al.*, (2021) concluded increase in dehydrogenase activity with an increase in organic carbon through biochar and FYM addition was due to the high surface area and porous nature of biochar leading to the retention of soluble organic matter and inorganic nutrient content in the soil helps in providing suitable habitat for enzymes and microbes. Marinara *et al.*, (2006) concluded that higher dehydrogenase activity was due to increased metabolic activity of microbes in biochar applied treatment. Enhanced dehydrogenase activity was recorded to be correlated with the availability of organic matter content in the soil (Serra-Wittling *et al.*, 1995) Similar results were also found by Masto *et al.*, (2013), Ouyang *et al.*, (2014), Gowthami (2019).

Table 4.15: Effect of biochar application on dehydrogenase enzyme activity of soil at different stages of watermelon

Tr no.	Treatment details	Dehydrogenase activity (μg TPF g^{-1} 24 hr^{-1})		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	7.63	7.96	8.61
T_2	100% RDF + CHB (2 t ha^{-1})	10.58	11.02	11.84
T_3	75% RDF + CHB (2 t ha^{-1})	8.90	9.61	10.43
T_4	100% RDF + CHB (4 t ha^{-1})	12.53	13.58	14.60
T_5	75% RDF + CHB (4 t ha^{-1})	11.75	12.42	13.24
T_6	100% RDF + RHB (2 t ha^{-1})	11.24	11.91	12.73
T_7	75% RDF + RHB (2 t ha^{-1})	10.18	10.85	11.67
T_8	100% RDF + RHB (4 t ha^{-1})	13.83	14.60	15.68
T_9	75% RDF + RHB (4 t ha^{-1})	12.32	12.99	13.81
T_{10}	100% RDF + AHB (2 t ha^{-1})	11.00	11.67	12.49
T_{11}	75% RDF + AHB (2 t ha^{-1})	9.86	10.53	11.35
T_{12}	100% RDF + AHB (4 t ha^{-1})	13.45	14.28	15.28
T_{13}	75% RDF + AHB (4 t ha^{-1})	12.08	12.75	13.57
T_{14}	Absolute control	7.48	7.82	9.14
	S.E. (±)	0.50	0.50	0.38
	CD (P=0.05)	1.47	1.45	1.45

4.3 Influence of various crop residue biochar on Nutrient content in leaves of watermelon

4.3.1 Effect of various crop residue biochar on total nitrogen content in plant at different stages of watermelon

Results on the effect of biochar levels and RDF levels on nitrogen content in leaves of watermelon at 30 DAS, 60 DAS and harvest were shown in Table 4.16. It varied from 1.39 to 2.02 % at 30 days after sowing, 1.36 to 1.85 % at 60 days after sowing and 1.33 to 1.82 % at harvest.

- **At 30 DAS**

Among all the treatments, the highest nitrogen content in leaves of watermelon was seen in treatment T_8 with 100% RDF + RHB 4 t ha^{-1} (2.02%) and was at par with T_{12} containing 100% RDF + AHB 4 t ha^{-1} (1.95 %), T_4 with 100% RDF + CHB 4t ha^{-1} (1.90%) and was significantly higher compared to rest of the treatments. The lowest total nitrogen content percentage in leaves was (1.39%) in absolute control.

- **At 60 DAS**

Treatment receiving T_8 with 100% RDF + RHB 4 t ha^{-1} recorded the highest nitrogen content (1.85%) and found at par with T_{12} containing 100% RDF + AHB 4 t ha^{-1} (1.80%), T_4 receiving 100% RDF + CHB 4t ha^{-1} (1.77%) it also superior over rest of the treatments. Absolute control (T_{14}) reported the lowest nitrogen content which was (1.36%).

- **At harvest**

The highest nitrogen content was recorded in T_8 with 100% RDF + RHB 4 t ha^{-1} (1.82%). It was at par with T_{12} consisting 100% RDF + AHB 4 t ha^{-1} (1.77%), T_4 containing 100% RDF + CHB 4t ha^{-1} (1.74%) and significantly superior over the remaining treatment. The lowest nitrogen % in the leaves of watermelon showed by Absolute control (T_{14}) (1.33%).

Table 4.16: Effect of application of biochar on total nitrogen content in plant at different stages of watermelon

Tr no.	Treatment details	Nitrogen content %		
		30DAS	**60DAS**	**Harvest**
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	1.42	1.38	1.36
T_2	100% RDF + CHB (2 t ha^{-1})	1.67	1.52	1.49
T_3	75% RDF + CHB (2 t ha^{-1})	1.46	1.34	1.31
T_4	100% RDF + CHB (4 t ha^{-1})	1.90	1.77	1.74
T_5	75% RDF + CHB (4 t ha^{-1})	1.80	1.65	1.62
T_6	100% RDF + RHB (2 t ha^{-1})	1.78	1.63	1.60
T_7	75% RDF + RHB (2 t ha^{-1})	1.63	1.47	1.44
T_8	100% RDF + RHB (4 t ha^{-1})	2.02	1.85	1.82
T_9	75% RDF + RHB (4 t ha^{-1})	1.86	1.71	1.68
T_{10}	100% RDF + AHB (2 t ha^{-1})	1.72	1.56	1.53
T_{11}	75% RDF + AHB (2 t ha^{-1})	1.55	1.42	1.39
T_{12}	100% RDF + AHB (4 t ha^{-1})	1.95	1.80	1.77
T_{13}	75% RDF + AHB (4 t ha^{-1})	1.82	1.67	1.64
T_{14}	Absolute control	1.39	1.36	1.33
	S.E. (±)	0.06	0.05	0.05
	CD (P=0.05)	0.16	0.15	0.14

Application of various rates of biochar with two different levels of RDF was done during the investigation and the result found that as the rate of biochar increases, nitrogen content in leaves of watermelon also increased. The highest percentage of nitrogen content in leaves was found in treatment (T_8) 100% RDF + RHB (4 t ha^{-1}) whereas, the lowest nitrogen content was found in control.

Glaser *et al.*, (2002) reported an increase in nitrogen concentration after the addition of biochar. The increase in nitrogen percentage in the biochar applied plot was higher than control as there is minimum loss as well as slow release of nitrogen. The addition of biochar to tomatoes increased nitrogen content significantly (Almaroai and Eissa 2017). The same result was also found by Agegnehu *et al.*, (2016).

4.3.2 Effect of various crop residue biochar on total phosphorus content in plant at different stages of watermelon

The result on the effect of various crop residue biochar on total phosphorus content in plant at different stages of watermelon was resented in Table 4.17.

- **At 30 DAS**

Treatment receiving T_8 with 100% RDF + RHB 4 t ha^{-1} showed the highest value of total phosphorus content (0.42%) at par with treatments T_{12} and T_4 receiving 100% RDF along with AHB (0.40 %) and CHB (1.90%) at 4t ha^{-1} respectively and it was significantly superior over rest of all the treatments. The lowest phosphorus content was found in absolute control which was (0.15%).

Table 4.17: Effect of application of biochar on total phosphorus content in plant at different stages of watermelon

Tr no.	Treatment details	Phosphorous content %		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	0.18	0.15	0.14
T_2	100% RDF + CHB (2 t ha^{-1})	0.29	0.25	0.23
T_3	75% RDF + CHB (2 t ha^{-1})	0.24	0.23	0.18
T_4	100% RDF + CHB (4 t ha^{-1})	0.37	0.36	0.34
T_5	75% RDF + CHB (4 t ha^{-1})	0.33	0.31	0.29
T_6	100% RDF + RHB (2 t ha^{-1})	0.32	0.30	0.28
T_7	75% RDF + RHB (2 t ha^{-1})	0.28	0.26	0.21
T_8	100% RDF + RHB (4 t ha^{-1})	0.42	0.40	0.38
T_9	75% RDF + RHB (4 t ha^{-1})	0.35	0.33	0.31
T_{10}	100% RDF + AHB (2 t ha^{-1})	0.30	0.26	0.24
T_{11}	75% RDF + AHB (2 t ha^{-1})	0.27	0.24	0.20
T_{12}	100% RDF + AHB (4 t ha^{-1})	0.40	0.38	0.36
T_{13}	75% RDF + AHB (4 t ha^{-1})	0.34	0.32	0.30
T_{14}	Absolute control	0.15	0.12	0.11
	S.E. (±)	0.02	0.02	0.01
	CD (P=0.05)	0.06	0.05	0.04

- **At 60 DAS**

A similar trend was observed at 60 DAS, T_8 containing 100% RDF + RHB 4 t ha^{-1} showed the highest percentage of total phosphorus content which was (0.40%) and this was also at par with T_{12} consisting 100% RDF + AHB 4 t ha^{-1} (0.38 %), T_4 with 100% RDF + CHB 4t ha^{-1} (0.36). Absolute control showed the lowest percentage of phosphorus which was (0.12%).

- **At harvest**

At harvest, the total phosphorus content in the leaves of watermelon was the highest in T_8 receiving 100% RDF + RHB 4 t ha^{-1} which was (0.38%). T_{12} with 100% RDF + AHB 4 t ha^{-1} (0.36 %), T_4 with 100% RDF + CHB 4t ha^{-1} (0.34%) treatments were at par with treatment (T_8). Minimum phosphorus content was found in absolute control (0.11%).

Application of biochar showed the highest phosphorus percentage as compared to control. The reason behind it was more phosphorus availability to crops due to the application of biochar. The properties of soil were also improved by biochar. Results were supported by Banpatti (2022) found increased phosphorus content in watermelon after the addition of biochar. The same results were also obtained by Villocino and Quevedo (2015).

4.3.2 Effect of various crop residue biochar on total potassium content in plant at different stages of watermelon

The total potassium content percentage in leaves of watermelon ranged from 1.11 to 1.40 % at 30 DAS, 1.07 to 1.37 % at 60 DAS and 1.03 to 1.33 % at harvest. It was shown in Table 4.18.

- **At 30 DAS**

At 30 DAS, the results demonstrated significantly higher potassium levels in the leaves of watermelon, reaching 1.40% in treatment T_8 (100% RDF + RHB 4 t ha^{-1}). It was on par with treatments T_{12} (100% RDF + AHB 4 t ha^{-1}) at 1.39% and T_4 (100% RDF + CHB 4t ha^{-1}) at 1.36%. The lowest potassium content was observed in treatment T_{14} (absolute control), which measured 1.11%.

- **At 60 DAS**

A similar trend was observed at 60 DAS, treatment T_8 with 100% RDF + RHB 4 t ha^{-1} showed total potassium content of about 1.37 % which was significantly higher. This treatment was at par with treatments T_{12} with 100% RDF + AHB 4 t ha^{-1} (1.36 %), T_4 receiving 100% RDF + CHB 4t ha^{-1} (1.34 %). Absolute control showed the lowest value of total potassium content in leaves content which was (1.07 %).

❖ **At harvest**

The highest percentage of total potassium content was observed in treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} (1.33%) and at par with T_{12} receiving 100% RDF + AHB 4 t ha^{-1} (1.31 %), T_4 receiving 100% RDF + CHB 4 t ha^{-1} (1.30 %) and T_8 consisting 100% RDF + RHB 4 t ha^{-1}. The results indicated that absolute control showed a total potassium content of 1.03 % which was the lowest among all the treatments.

Biochar application enhanced potassium content in leaves of watermelon as ash in biochar released mineral nutrients like potassium for crop uptake. The water holding capacity of soil was improved by the application of biochar which increased the availability of nutrients such as nitrogen and potassium which are taken by plants for use. Biochar also improves cation exchange capacity within soil which helps to hold K and makes it available for plant use. The same result was obtained by Villocino and Quevedo (2015), Banapatti (2022), and Kanchan (2022) in watermelon crop.

Table 4.18: Effect of application of biochar on total potassium content in plant at different stages of watermelon

Tr no.	Treatment details	Potassium content %		
		30DAS	60DAS	Harvest
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	1.14	1.09	1.04
T_2	100% RDF + CHB (2 t ha^{-1})	1.24	1.22	1.19
T_3	75% RDF + CHB (2 t ha^{-1})	1.19	1.14	1.09
T_4	100% RDF + CHB (4 t ha^{-1})	1.36	1.34	1.30
T_5	75% RDF + CHB (4 t ha^{-1})	1.31	1.30	1.23
T_6	100% RDF + RHB (2 t ha^{-1})	1.30	1.27	1.22
T_7	75% RDF + RHB (2 t ha^{-1})	1.22	1.20	1.18
T_8	100% RDF + RHB (4 t ha^{-1})	1.40	1.37	1.33
T_9	75% RDF + RHB (4 t ha^{-1})	1.34	1.32	1.28
T_{10}	100% RDF + AHB (2 t ha^{-1})	1.28	1.25	1.21
T_{11}	75% RDF + AHB (2 t ha^{-1})	1.20	1.18	1.16
T_{12}	100% RDF + AHB (4 t ha^{-1})	1.39	1.36	1.31
T_{13}	75% RDF + AHB (4 t ha^{-1})	1.33	1.31	1.25
T_{14}	Absolute control	1.11	1.07	1.03
	S.E. (±)	0.02	0.02	0.01
	CD (P=0.05)	0.05	0.04	0.03

4.4 Effect of various crop residue biochar on the yield of watermelon

The fruit yield of watermelon was affected by the application of different rates of biochar and different rates of RDF. Fruit yield ranged from 48.85 to 22.85 t ha^{-1}. Fruit yield was presented in Table 4.19 and Figure 4.2.

The result revealed that treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} recorded the highest fruit yield (48.85 t ha^{-1}) This value was statistically at par to treatments T_{12} receiving 100% RDF with AHB 4 t ha^{-1} (48.58 t ha^{-1}), T_4 containing 100% RDF with CHB 4 t ha^{-1} (48.58 t ha^{-1}). T_5 containing 75% RDF with 4 t ha^{-1} of coconut husk biochar (47.25 t ha^{-1}), T_9 consisting of 75% RDF with 4 t ha^{-1} of rice husk biochar (47.60 t ha^{-1}), T_{12} containing 100% RDF with 4 t ha^{-1} of areca nut husk biochar (48.58 t ha^{-1}), and T_{13} comprising of 75% RDF with 4 t ha^{-1} of areca nut husk biochar (47.35 t ha^{-1}), while significantly exceeding remaining treatments. The lowest fruit yield was observed in treatment (T_{14}) absolute control was (19.01 t ha^{-1}).

Table 4.19: Effect of various crop residue biochar on yield of watermelon

Tr no.	Treatment details	Fruit yield (t ha^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1}	29.00
T_2	100% RDF + CHB (2 t ha^{-1})	37.32
T_3	75% RDF + CHB (2 t ha^{-1})	35.36
T_4	100% RDF + CHB (4 t ha^{-1})	48.48
T_5	75% RDF + CHB (4 t ha^{-1})	47.25
T_6	100% RDF + RHB (2 t ha^{-1})	39.50
T_7	75% RDF + RHB (2 t ha^{-1})	37.24
T_8	100% RDF + RHB (4 t ha^{-1})	48.85
T_9	75% RDF + RHB (4 t ha^{-1})	47.60
T_{10}	100% RDF + AHB (2 t ha^{-1})	38.30
T_{11}	75% RDF + AHB (2 t ha^{-1})	36.48
T_{12}	100% RDF + AHB (4 t ha^{-1})	48.58
T_{13}	75% RDF + AHB (4 t ha^{-1})	47.35
T_{14}	Absolute control	19.01
	S.E. (±)	0.68
	CD (P=0.05)	2.04

The yield of crops depends on the production and mobilization of carbohydrates, intake of water and nutrients from the soil. It is also affected by the environment during growth. The application of biochar showed an increase in fruit yield of watermelon as compared to control. It may be due to intake of nutrients through a combination of biochar, FYM and inorganic fertilizers (Shilpa, 2019). Masto *et al.* (2013) found a significant increase in maize grain yield with the application of biochar 4 t ha^{-1}. Similar results were found by Lal (2016) in sweet corn, Almaroai and Eissa (2017) in tomato and Edward *et al.*, (2013) in okra. Similar results were found in Zhai *et al.*, (2016), Agbna *et al.*, (2017), and Surve *et al.*, (2021).

4.5 Influence of various crop residue biochar on quality attributes of watermelon fruits

The data pertaining to total soluble solids (TSS), reducing sugar, total sugar and lycopene content of watermelon fruit. TSS, reducing sugar, total sugar and lycopene content were presented in Table 4.20.

4.5.1. Effect of application of biochar on total soluble solids (TSS) of watermelon fruit

TSS content in watermelon fruit ranged from about 9.83 to 10.82 °B. The highest total soluble solids (TSS) were observed in Treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} (10.82 °B). This treatment was at par with T_4 receiving 100% RDF + CHB 4 t ha^{-1} (10.76 °B), T_5 (75% RDF + CHB 4 t ha^{-1}) (10.62°B), T_9 (75% RDF + RHB 4 t ha^{-1}) (10.66 °B), T_{12} receiving 100% RDF + AHB 4 t ha^{-1}) (10.79 °B), T_{13} (75% RDF + AHB 4 t ha^{-1}) (10.64 °B) and significantly superior over rest of treatment. The lowest TSS was observed in treatment (T_{14}) absolute control was (9.83 °B).

The combination of biochar, FYM and inorganic fertilizers significantly increased TSS content in watermelon fruit, as there was an increase in the availability of nutrients in the soil led to maximum plant absorption.

Similar results were obtained by Villocino and Quevedo (2015) that biochar had a significant effect on watermelon, resulting in a greater sweetness as compared to melons grown on plants in control. Nair and Lawson (2015) and Almaroai and Eissa (2017) found similar results. Nagula *et al.*, (2021) found the highest TSS in bananas grown in a coconut husk biochar treated plot.

4.5.2 Effect of application of biochar on reducing sugar of watermelon fruit

Reducing sugar content in watermelon fruit was the highest in treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} and ranged from 4.77 to 5.52 %. Treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} was found to be at par with T_4 receiving 100% RDF + CHB 4t ha^{-1} (5.35%), T_5 (75% RDF + CHB 4 t ha^{-1}) (5.24%), T_9 (75% RDF + RHB 4 t ha^{-1}) (5.32 %), T_{12} with 100% RDF + AHB 4 t ha^{-1} (5.41%), T_{13} (75% RDF + AHB 4 t ha^{-1}) (5.27%). Treatment (T_8) was found significantly superior over remaining treatments. The lowest value of reducing sugar was found in absolute control (4.77%).

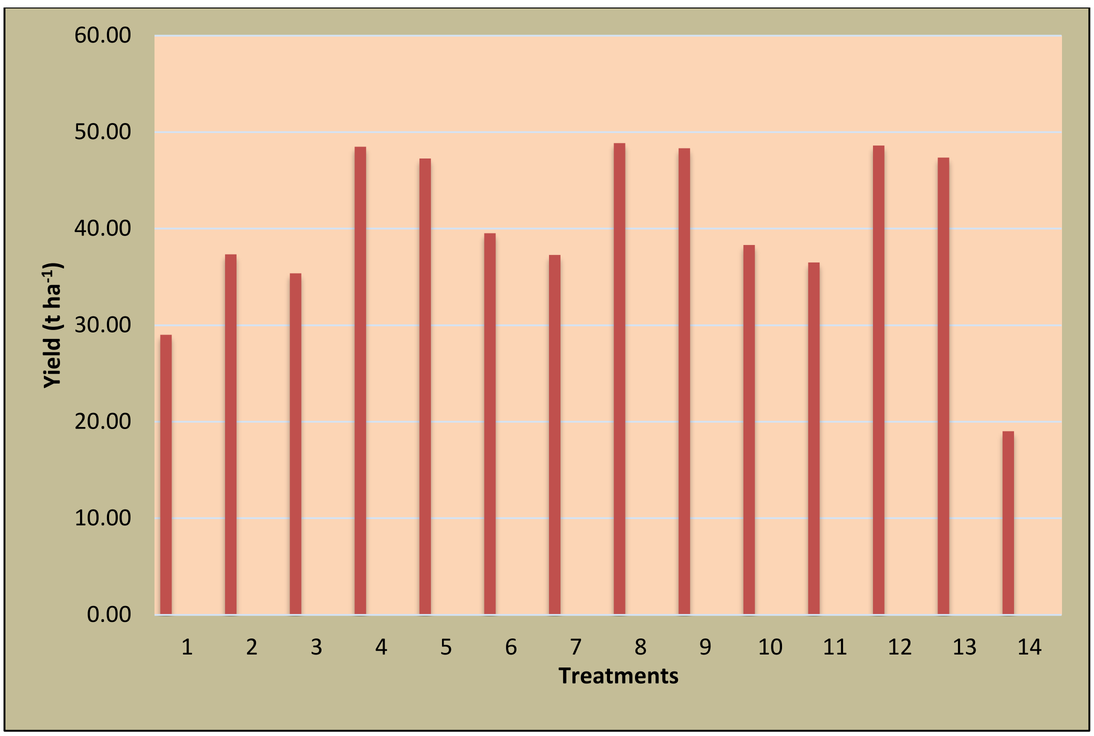


Fig 4.2 : Effect of various crop residue biochar on yield of watermelon

Due to the application of biochar in soil, the availability of nutrients required by plants improved which led to the enhancement of sugar content in fruits. Reducing and total sugar was affected due to the various rates of biochar with two different levels of RDF as well as environmental factors also affected. The control showed the lowest sugar percentage.

4.5.3 Effect of application of biochar on total sugar of watermelon fruit

The total sugar percentage in watermelon fruit was affected due to different rates of biochar along with different rates of RDF and it varied from 7.37 to 8.52%. The highest total sugar percentage(8.52%) was observed in treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} and at par with T_4 with 100% RDF + CHB 4t ha^{-1} (8.35%), T_5 with75% RDF + CHB 4 t ha^{-1} (8.05%), T_9 with 75% RDF + RHB 4 t ha^{-1} (8.12 %), T_{12} with 100% RDF + AHB 4 t ha^{-1}) (8.45 %), T_{13} (75% RDF + AHB 4 t ha^{-1}) (8.07 %) and the lowest total sugar was observed 7.37 % in absolute control treatment.

Table 4.20: Effect of application of biochar on total soluble solids (TSS), reducing sugar, total sugar and lycopene content of watermelon

Tr. No.	Treatment details	TSS (°B)	Reducing Sugars (%)	Total Sugar (%)	Lycopene Content (mg lycopene in 100 g sample)
T_1	RDF (150:50:50) N: P_2O_5: K_2O $kgha^{-1}$)	9.94	4.82	7.42	4.94
T_2	100% RDF + CHB (2 t ha^{-1})	10.36	5.11	7.90	5.24
T_3	75% RDF + CHB (2 t ha^{-1})	10.27	4.93	7.63	5.05
T_4	100% RDF + CHB (4 t ha^{-1})	10.76	5.35	8.35	5.48
T_5	75% RDF + CHB (4 t ha^{-1})	10.62	5.24	8.05	5.36
T_6	100% RDF + RHB (2 t ha^{-1})	10.38	5.22	8.01	5.34
T_7	75% RDF + RHB (2 t ha^{-1})	10.29	5.08	7.88	5.20
T_8	100% RDF + RHB (4 t ha^{-1})	10.82	5.52	8.52	5.68
T_9	75% RDF + RHB (4 t ha^{-1})	10.66	5.32	8.12	5.44
T_{10}	100% RDF + AHB (2 t ha^{-1})	10.37	5.18	7.95	5.30
T_{11}	75% RDF + AHB (2 t ha^{-1})	10.28	4.98	7.78	5.10
T_{12}	100% RDF + AHB (4 t ha^{-1})	10.79	5.41	8.45	5.56
T_{13}	75% RDF + AHB (4 t ha^{-1})	10.64	5.27	8.07	5.41
T_{14}	Absolute control	9.83	4.77	7.37	4.89
	S.E. (±)	0.13	0.09	0.16	0.09
	CD (P=0.05)	0.36	0.28	0.47	0.26

4.5.4 Effect of application of biochar on lycopene content of watermelon fruit

Lycopene content in watermelon fruit varied from 4.89 to 5.68 mg lycopene in 100 g sample. The highest lycopene content (10.82 68 mg lycopene in 100 g sample) in watermelon was found in treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1}. Treatment (T_8) was recorded at par with T_4 (5.48 mg) and T_{12} (5.56 mg), receiving 100% RDF along with CHB and AHB at 4 t ha^{-1} respectively. Absolute control showed the lowest lycopene content was about 4.89 mg lycopene in 100 g sample.

Lycopene content in watermelon was significantly affected by the application of biochar with RDF along with FYM. Melissa et. al., (2022) found an increase in lycopene content in cherry tomatoes in biochar treated plots compared to those without biochar treated plot.

4.5.5 Sensory evaluation of watermelon fruit

The results obtained from the sensory evaluation of watermelon fruit by a panel of 12 judges who used the 9-point Hedonic scale of sensory evaluation were presented in Table 4.21. Sensory qualities of watermelon fruit like colour, flavour as well as texture were evaluated by them.

4.5.5.1 Colour of watermelon fruit

The data indicated that treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} recorded the highest colour score (6.89) while absolute control showed the lowest colour score (5.18).

4.5.5.2 Taste of watermelon fruit

The taste of watermelon is also affected by the application of biochar along with RDF. Results in Table 4.21 showed that treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} had the highest taste score (7.11) and the lowest taste score (5.50) found in treatment (T_{14}) which was absolute control.

4.5.5.3 Texture of watermelon fruit

The highest score for texture was shown by treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} which was (6.80) and the lowest score in absolute control (5.20) was reported in Table 4.21

4.5.5.4 Average sensory score

The overall average sensory score was recorded in Table 4.21 which showed that treatment T_8 receiving 100% RDF + RHB 4 t ha^{-1} had a maximum score (6.93) and absolute control had a minimum score (5.28).

The highest score in case of colour, taste and overall acceptance was recorded in fruits of biochar treated plot compared to without biochar treated plot by Villcocino and Quevedo (2015) in watermelon.

Table 4.21: Effect of application biochar on sensory evaluation of watermelon fruit

Tr. No.	Treatment details	colour	Taste	Texture	Average sensory evaluation
T_1	RDF (150:50:50) N: P_2O_5: K_2O kgha^{-1})	5.30	5.52	5.21	5.34
T_2	100% RDF + CHB (2 t ha^{-1})	5.81	6.03	5.72	5.85
T_3	75% RDF + CHB (2 t ha^{-1})	5.46	5.68	5.37	5.50
T_4	100% RDF + CHB (4 t ha^{-1})	6.70	6.92	6.61	6.74
T_5	75% RDF + CHB (4 t ha^{-1})	6.18	6.40	6.09	6.22
T_6	100% RDF + RHB (2 t ha^{-1})	5.89	6.11	5.80	5.93
T_7	75% RDF + RHB (2 t ha^{-1})	5.66	5.88	5.57	5.70
T_8	100% RDF + RHB (4 t ha^{-1})	6.89	7.11	6.80	6.93
T_9	75% RDF + RHB (4 t ha^{-1})	6.39	6.61	6.30	6.43
T_{10}	100% RDF + AHB (2 t ha^{-1})	5.85	6.07	5.76	5.89
T_{11}	75% RDF + AHB (2 t ha^{-1})	5.62	5.84	5.53	5.66
T_{12}	100% RDF + AHB (4 t ha^{-1})	6.85	7.07	6.76	6.89
T_{13}	75% RDF + AHB (4 t ha^{-1})	6.35	6.57	6.26	6.39
T_{14}	Absolute control	5.18	5.50	5.20	5.28

4.6 Chemical Characterisation of biochars prepared from rice husk, areca nut and coconut husk

Biochars were prepared from various crop residues such as rice husk, coconut husk and areca nut husk which available locally in the Konkan area. Then biochar passed through a 2mm sieve and analysed for different parameters such as pH, electrical conductivity, total carbon, total N, P and K. Results obtained after analysis were represented in Table 4.22.

Analysis of biochars recorded alkaline pH of about 9.34, 9.05 and 9.21 for rice husk, coconut husk and areca nut husk biochar respectively. Similarly, electrical conductivity was found 0.321 dSm^{-1} in RHB, 0.143 dSm^{-1} in CHB and 0.289 dSm^{-1} in AHB. Total carbon percentage recorded 83.54 in RHB, 74.50% in CHB and 80.20 % in AHB. Total nitrogen content was found the highest in RHB (0.184%) followed by AHB (0.166%) and CHB (0.156%). Total phosphorus content in biochar was the highest in RHB (0.153%) at par with AHB (0.103%) and

CHB (0.077%). Total potassium content recorded up to 0.15 %, 0.13% and 0.14% in RHB, CHB and AHB respectively.

Table 4.22: Characterisation of biochars prepared from rice husk, areca nut and coconut husk

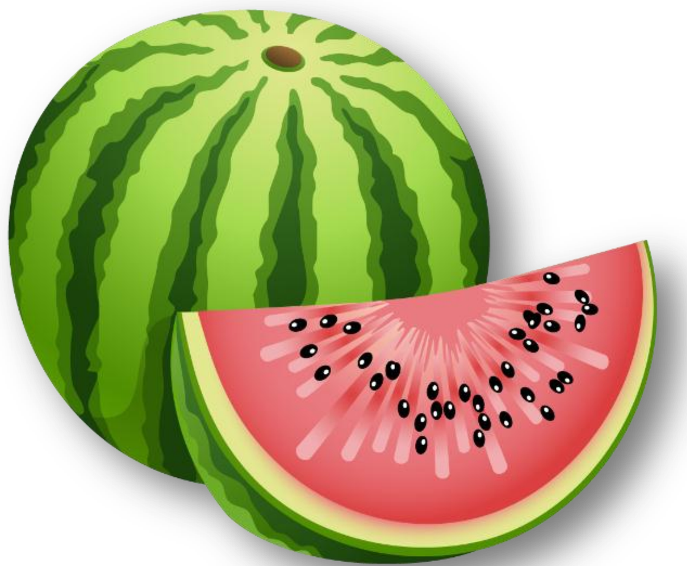
Sr. No.	Parameters	RHB	CHB	AHB
1	pH	9.34	9.05	9.21
2	EC (dSm^{-1})	0.321	0.143	0.289
3	Total Carbon (%)	83.54	74.50	80.20
4	Total nitrogen content (%)	0.184	0.156	0.166
5	Total Phosphorous (%)	0.153	0.077	0.103
6	Total potassium content (%)	0.15	0.13	0.14

Chemical characterisation of rice husk, coconut husk and areca nut husk biochar were done in the present investigation which found that the alkaline nature of biochar was due to biochar prepared at high temperature. The physical and chemical properties of biochar are influenced by different properties of feedstock used for pyrolysis and pyrolysis conditions such as high temperature (Downie *et al.*, 2009).

Srinivasarao *et al.*, 2013 recorded that high temperature (600 – 900ºC**)** produced biochar with alkaline pH and higher electrical conductivity as compared to lower temperature (400ºC & below). Xie *et al.*, (2015) also concluded that higher pH and electrical conductivity in coconut husk biochar was due to the presence of more soluble salts as well as greater alkali metal content present in coconut husk. The physical and chemical properties of biochar changes with pyrolytic temperature (Murty, 2020). Bera, *et al.*, (2014) concluded organic groups such as the –COO and –O groups are an important factor to improve the acid reaction and contribute to alkalinity of the biochars through association of these groups with H^+. Carbonates were the major alkaline compounds among the inorganic compounds leading to the alkaline pH of biochars. The relative contribution of the organic and inorganic compounds changes with changes in pyrolysis temperature.

Carbon percentage in biochar is affected by many factors such as temperature during pyrolysis, material used and method used in pyrolysis. Biochar produced by the drum method had the greatest carbon content as compared to the heap. Biochar produced at higher temperatures had higher carbon percentage and more stable carbon than biochar produced at lower temperatures (Srinivasarao *et al.*, 2013). According to Chun *et al.*, (2004) as the pyrolytic temperature rises carbon content increases whereas, oxygen and hydrogen content falls which shows intensifying carbonization of chars.

Srinivasarao *et al.*, (2013) concluded stable pyrolytic temperature produces biochar with the highest nitrogen, phosphorus and potassium content. Nutrient content in biochar is affected by the type of material brought for pyrolysis (Shenbagavalli 2012). Lower nitrogen content was found in biochar which might be due to losses of nitrogen through the burning of biomass carbon during the pyrolysis process. Ashworth *et al.*, (2014) found that due to volatilization of carbon during pyrolysis caused the cleaving of organic phosphorus bonds which led to highly soluble phosphorus salt associated with biochar. The phosphorus concentration in the biochar materials reduced as to the feedstock materials. potassium content was dependent on the feedstock used for pyrolysis. In the feedstock has high potassium then biochar receives high potassium %.



SUMMARY AND CONCLUSION

CHAPTER V
SUMMARY AND CONCLUSIONS

A field investigation on “Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan” was carried out at the College of Horticulture, Dapoli from November 2022 to March 2023 in which 14 treatments having a combination of two different rates of biochar (2 and 4 ton ha^{-1}) along with different rates of RDF was studied. In this investigation, three different types of crop residues were utilized which are rice husk, coconut husk and areca nut husk to prepare biochar. Before sowing split dose of urea and a full dose of SSP and MOP were applied and the remaining split doses of urea were applied at 30 and 60 days after sowing. Soil and plant samples were collected at 30 DAS, 60 DAS and at harvest and analysed. In the end, statistical analysis of all the data was done and the results obtained were summarized in this chapter as follows,

5.1 Effect of various crop residue biochar on soil carbon pools

5.2 Effect of various crop residue biochar on properties of soil

5.3 Influence of various crop residue biochar on nutrient content in leaves of watermelon

5.4 Effect of various crop residue biochar on the yield of watermelon

5.5 Influence of various crop residue biochar on quality attributes of watermelon fruits

5.1 Effect of various crop residue biochar on soil carbon pools

Various soil carbon pools such as water soluble carbon, labile carbon, microbial biomass carbon, organic carbon, inorganic carbon and total carbon were estimated at 30 DAS, 60 DAS and harvest. As the rate of biochar and recommended dose of fertilizers along with FYM was increased status of soil carbon pools in soil was also improved. An increasing trend was observed from 30 days after sowing to harvest.

1. Treatment (T_8) receiving 100% RDF along with RHB (4 t ha^{-1}) showed the highest value of soil organic carbon 16.71 g kg^{-1},16.88 g kg^{-1} and 17.16 g kg^{-1} at 30, 60 and harvest respectively and the lowest value was found in absolute control.

2. The highest water soluble carbon (WSC) was found in treatment (T_8) receiving 100% RDF along with RHB (4 t ha^{-1}) which was 80.85 mg kg^{-1}, 81.56 mg kg^{-1}, 82.24 mg kg^{-1} at 30, 60 and harvest respectively. Lowest value of water soluble carbon found in absolute control.

3. Labile carbon pool ranged from 280.67 mg kg^{-1} to 347.19 mg kg^{-1} at 30 DAS, 276.67 mg kg^{-1} to 351.98 mg kg^{-1} at 60 DAS and 268.81 mg kg^{-1} to 358.22 mg kg^{-1} at harvest. The maximum value of labile carbon at 30, 60 DAS and harvest was recorded 347.19 mg kg^{-1}, 351.98 mg kg^{-1} and 358.22 mg kg^{-1} respectively in treatment (T_8) 100% RDF along with RHB (4 t ha^{-1}).

4. Microbial biomass carbon (MBC) ranged from 197.67 to 274.95 mg kg^{-1}, 204.88 to 282.12 mg kg^{-1} and 200.55 to 279.88 mg kg^{-1} at 30 DAS, 60 DAS and at harvest respectively. The highest MBC was found 274.95 mg kg^{-1} at 30 DAS, 282.12 mg kg^{-1} at 60 DAS and 279.88 mg kg^{-1} at harvest in treatment (T_8) consisting of 100% RDF along with RHB (4 t ha^{-1})

5. It was observed that there was no significant difference in varied treatments in case of inorganic carbon (IC). But an increasing trend was found from 30 DAS to harvest.

6. Highest total carbon (TC) in the soil at 30, 60 DAS and harvest found 18.19 g kg^{-1},18.40 g kg^{-1} and 18.72 g kg^{-1} by application of treatment (T_8) containing 100% RDF along with RHB (4 t ha^{-1}) and lowest found in absolute control.

5.2 Effect of various crop residue biochar on properties of soil

5.2.1 Effect of various crop residue biochar on chemical properties of soil

1. It was recorded that various treatments did not have any significant effect on pH at different stages of watermelon. However, an increase in soil pH compared to absolute control was observed. The highest values of soil pH were observed 5.59, 5.63 and 5.69 at 30DAS, 60 DAS and at harvest in treatment T_8 with 100% RDF along with RHB 4 t ha^{-1} respectively.

2. Application of biochar at different rates along with different rates of RDF had no significant influence on electrical conductivity at 30, 60 DAS and harvest. Electrical conductivity ranged from 0.086 to 0.108 dS m^{-1} at 30 DAS, 0.077 to 0.101 dS m^{-1} at 60 DAS and 0.069 to 0.096 dS m^{-1} at harvest.

3. Available nitrogen ranged from 286.67 to 340.19 kg ha^{-1} at 30 DAS, 271.31 to 318.29 kg ha^{-1} at 60 DAS and 258.58 to 303.10 kg ha^{-1} at harvest. Highest available nitrogen recorded 340.19 kg ha^{-1} at 30 DAS, 318.29 kg ha^{-1} at 60 DAS and 303.10 kg ha^{-1} at harvest and lowest value found in absolute control.

4. Available phosphorus in soil at 30, 60 and harvest was recorded 11.24 to 16.08 kg ha^{-1} at 30 DAS, in the case of 60 DAS and harvest it ranged from 8.75 kg ha^{-1} to 13.10 kg

ha^{-1} and 7.56 kg ha^{-1} to 11.85 kg ha^{-1} respectively. Highest available phosphorus was found in treatment T_8 receiving 100% RDF along with RHB 4 t ha^{-1}.

5. Effect of various residue biochar on available potassium was recorded that treatment T_8 (100% RDF along with RHB 4 t ha^{-1}) showed highest values of available potassium which was 350.19 kg ha^{-1} at 30 DAS, 332.20 kg ha^{-1} at 60 DAS and 323.51 kg ha^{-1} at harvest.

5.2.2Effect of various crop residue biochar on biological properties of soil

1. The microbial population was significantly affected by the application of various rates of biochar along with different rates of RDF. Fungal, bacterial and actinomycetes populations recorded significantly higher in treatment T_8 containing 100% recommended dose of fertilizers along with RHB 4 t ha^{-1}. The bacterial population was observed 61.44 CFU×10^7 at 30 DAS, 64.41 CFU×10^7 at 60 DAS and 63.08 CFU×10^7 at harvest by application of treatment T_8 (100% RDF along with RHB 4 t ha^{-1}). Fungal population at 30, 60 and harvest recorded 5.82 CFU×10^4, 8.24 CFU×10^4 and 7.06 CFU×10^4 respectively in treatment T_8 (100% RDF along with RHB 4 t ha^{-1}). Actinomycetes population was found 18.03 CFU×10^5 at 30 DAS, 19.27 CFU×10^5 at 60 DAS and 18.60 CFU×10^5 at harvest.

2. The significantly highest dehydrogenase activity of soil was recorded in treatment T_8 containing 100% RDF along with RHB 4 t ha^{-1} which was 13.83 µg TPF g^{-1} 24 hr^{-1}, 14.60 µg TPF g^{-1} 24 hr^{-1}and 15.68 µg TPF g^{-1} 24 hr^{-1} at 30, 60 and at harvest respectively. Soil dehydrogenase activity within soil was found to increase from 30 days after sowing to harvest.

5.3 Influence of various crop residue biochar on nutrient content in leaves of watermelon

1. Significantly highest nitrogen content in leaves of watermelon at 30, 60 and harvest was found by application of treatment T_8 receiving 100% RDF along with RHB 4 t ha^{-1} which was 2.02 %, 1.85 % and 1.82 % at 30, 60 and at harvest respectively. A decreasing trend was seen from 30 DAS to harvest.

2. Treatment T_8 receiving 100% RDF along with RHB 4 t ha^{-1} showed the highest percentage of phosphorus content in leaves of watermelon at three different stages of watermelon which was (0.42%), (0.40%) and (0.38%) at 30, 60 DAS and harvest respectively. Phosphorus percentage showed a decreasing trend up to harvest.

3. Potassium content is significantly affected by different levels of biochar along with RDF. The highest potassium content was recorded up to 1.40 % at 30 DAS, 1.37 % at 60 DAS and 1.33 % at harvest in treatment T_8 with 100% RDF along with RHB 4 t ha^{-1}.

5.4 Effect of various crop residue biochar on the yield of watermelon

Fruit yield was significantly influenced by the application of biochar levels. It was ranged from 48.85 to 22.85 t ha^{-1}. The highest fruit yield was seen in treatment T_8 receiving 100% RDF along with RHB 4 t ha^{-1} (48.85 t ha^{-1}). Treatment T_8 was at par with treatments T_{12} (48.58 t ha^{-1}), T_4 (48.58 t ha^{-1}). T_5 (47.25 t ha^{-1}), T_9 (47.60 t ha^{-1}), T_{12} (48.58 t ha^{-1}), and T_{13} (47.35 t ha^{-1}).

5.5 Influence of various crop residue biochar on quality attributes of watermelon fruits

1. Significantly higher total soluble solids (TSS) were found in treatment T_8 containing 100% RDF along with RHB 4 t ha^{-1} which was 10.82 °B. TSS ranged from about 9.83 to 10.82 °B.

2. The highest reducing sugar percentage was recorded in treatment T_8 with 100% RDF along with RHB 4 t ha^{-1} and ranged from 4.77 to 5.52 %.

3. Similar to reducing sugar, highest total sugar was also found in treatment T_8 with 100% RDF along with RHB 4 t ha^{-1} (8.52%). Total sugar was varying from 7.37 to 8.52%.

4. Lycopene content varies from 4.89 to 5.68 mg lycopene in a 100 g sample. Treatment T_8 containing 100% RDF along with RHB 4 t ha^{-1} was 10.82 68 mg lycopene in 100 g sample and lowest value found in absolute control.

5.6 Characterisation of biochars prepared from Rice husk, Coconut husk and Areca nut husk

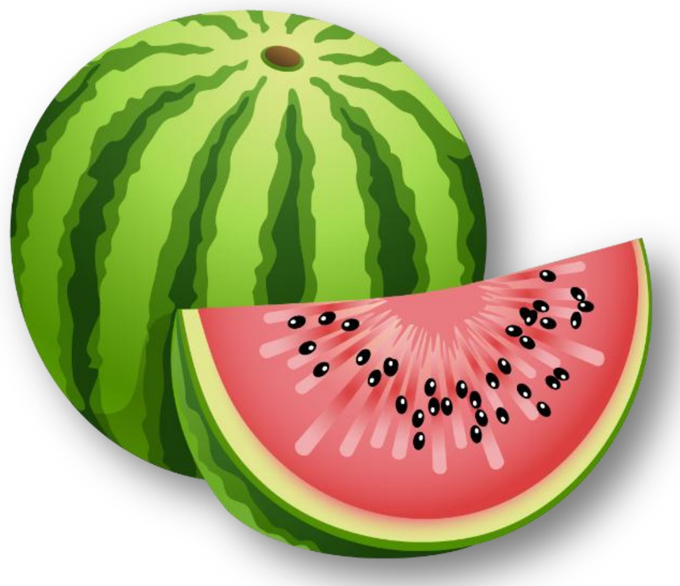
pH of biochars was found to be alkaline. Rice husk biochar showed about (9.34) followed by areca nut husk (9.21) and coconut husk (9.21). The electrical conductivity of all three biochars were rice husk biochar (0.321 dS m^{-1}), coconut husk biochar (0.143 dS m^{-1}) and areca nut husk biochar (0.289 dS m^{-1}). The total nitrogen content in rice husk biochar had 0.184 %, coconut husk biochar was 0.156% and areca nut husk biochar was 0.166%. Similarly, rice husk biochar, coconut husk biochar and areca nut husk biochar had total phosphorus percentages had 0.153%, 0.077% and 0.103 % respectively. Total potassium content was found 0.15%, 0.13% and 0.14 % in rice husk, coconut husk and areca nut husk biochar respectively. Total carbon percentages in rice husk, coconut husk and areca nut husk biochar were 83.54 %, 74.50 % and 80.20 % respectively.

Conclusion

The following conclusions were drawn as a result of the research:

- Results of the experiment entitled "Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan" showed that application of various rates of biochar along with two different rates of RDF recorded increased soil carbon pools, nutrient availability in soil and yield as compared to absolute control and RDF only at different stages of watermelon.
- From results it was concluded that application of 100% RDF along with RHB (4t ha^{-1}) significantly enhanced soil carbon pools such as soil organic carbon, soil total carbon, water soluble carbon, labile carbon and microbial biomass carbon. Inorganic carbon due to the application of biochar and RDF was recorded as non-significant but followed increasing trend at different stages of watermelon.
- Application of 100% RDF along with RHB (4 t ha^{-1}) also showed the highest pH and nutrient availability including available nitrogen, available phosphorus and available potassium within the soil at 30 DAS, 60 DAS and harvest.
- While considering biological properties in soil, the highest microbial count as well as dehydrogenase activity in soil was seen in treatment (T_8) 100% RDF along with RHB (4 t ha^{-1}).
- Nutrient content in leaves of watermelon was analyzed and results found that application of treatment (T_8) 100% RDF along with RHB (4 t ha^{-1}) had the highest nitrogen, phosphorus and potassium percentage.
- Application of treatment (T_8) 100% RDF along with RHB (4 t ha^{-1}) recorded maximum fruit yield of watermelon and also quality parameters of fruit such as reducing sugar, total sugar, total soluble solids (TSS) and lycopene content.

In general, application of biochar along with RDF and FYM helped to improve soil carbon fractions, chemical, biological properties of soil lead to improvement in yield, fruit quality. Result obtained during investigation showed that application of treatment (T_8) receiving 100% RDF along with RHB (4 t ha^{-1}) enhanced soil properties, carbon fractions, yield and quality parameters hence using biochar in agricultural systems is a practical way to decrease farm waste, enhance soil quality parameters such as soil chemical and biological characteristics, crop growth and yield.



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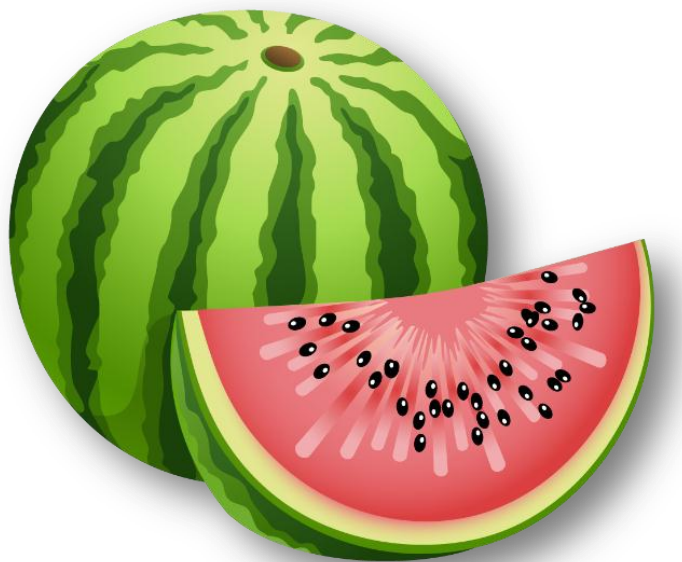

ABSTRACT

THESIS ABSTRACT

a) Title of the thesis : EFFECT OF VARIOUS FARM RESIDUE BIOCHAR ON YIELD OF WATERMELON (*Citrullus lanatus* Thunb.), SOIL CARBON POOLS AND SOIL PROPERTIES IN ALFISOLS OF KONKAN

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An investigation entitled "Effect of various farm residue biochar on yield of watermelon (*Citrullus lanatus* Thunb.), soil carbon pools and soil properties in Alfisols of Konkan" was undertaken at the College of Horticulture, Dapoli, during *Rabi* season 2022. During the investigation, three various biochars such as rice husk biochar (RHB), coconut husk biochar (CHB) and areca nut husk biochar (AHB) were prepared. In experiment 14 treatments in which a combination of two different levels of these biochars and two levels of RDF laid in RBD design with three replications were studied. The effect of different biochars with different levels of RDF on soil carbon pools, chemical and biological properties of soil, and leaves nutrient content in watermelon at different growth stages were studied. The experimental soil was sandy loam in texture, 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.

During the experiment, 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 0.321 dSm^{-1} in RHB, 0.143 dSm^{-1} in CHB and 0.289 dSm^{-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.

Biochar is highly recalcitrant in nature leads to carbon sequestration in soil. Application of biochar enhanced soil carbon pools such as organic carbon, water soluble carbon, labile carbon, microbial biomass carbon, inorganic carbon and total carbon at different stages of watermelon. Chemical and biological properties of soil positively affected by biochar application found in treatment T_8 containing 100% RDF along with rice husk biochar (RHB) 4ton ha^{-1}. The application of biochar improved the available nutrient content in the soil such as N, P and K. Due to the properties of biochar, it improves microbial population as well as dehydrogenase activity within the soil.

After analyzing the leaves of watermelon, it was found that nitrogen%, phosphorus % and potassium % were found maximum in biochar applied treatment as compared to control at different stages of watermelon. The yield of watermelon fruit was found significantly superior in biochar applied treatment T_8 receiving 100% RDF + RHB 4 ton ha^{-1} recorded 48.85 t ha^{-1} which was at par with treatments T_{12} (100% RDF + AHB 4 t ha^{-1}), T_4 (100% RDF + CHB 4t ha^{-1}). Similarly, fruit quality parameters such as reducing sugar, total sugar, TSS and lycopene content were improved by biochar application.

In general, the study indicated that application of 100% RDF + RHB 4ton ha^{-1} enhanced yield, quality parameters of watermelon fruit, soil carbon pools, nutrient availability within the soil and biological properties of soil.

Dr. Balasaheb Sawant Konkan Krishi Vidyaapeeth,

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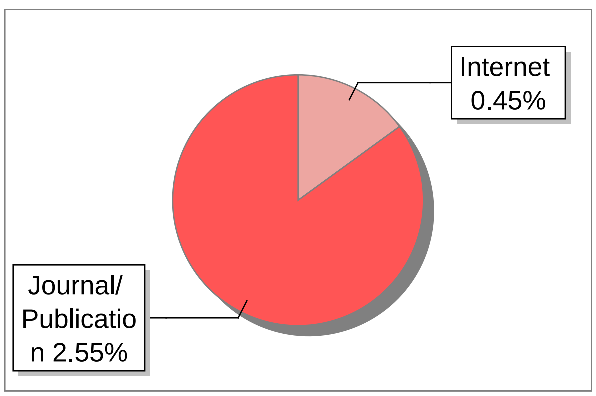

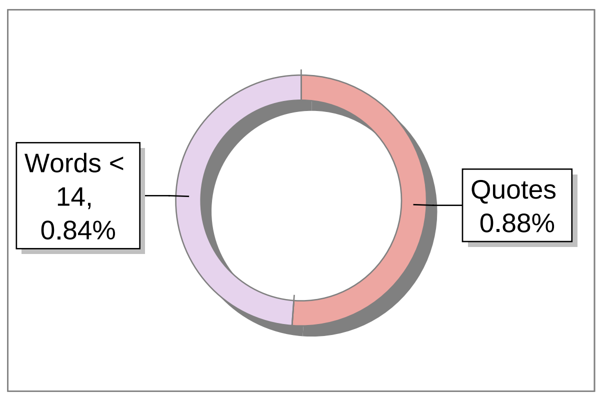

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Effect of various crop residue biochar on soil carbon pools and yield of watermelon in Alfisols of Konkan

JS Chavan, RV Dhopavkar, MC Kasture, YR Parulekar, VG More, SB Dodake, NA Meshram, SS More, BV Borane and NS Shinde

Abstract
The study on “Effect of various crop residue biochar on soil carbon pools and yield of watermelon in Alfisols of Konkan” conducted at the College of Horticulture, Dapoli, during the Rabi season 2022 focused on the impact of three biochars rice husk biochar (RHB), coconut husk biochar (CHB), and areca nut 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 fertilizer (100% and 75%) were examined using a randomized 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. Application of biochar, recognized for its recalcitrant nature, resulted in carbon sequestration in soil. 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, soil, Konkan etc.

Introduction
Crop residue management is a pressing issue in agriculture, with woody plant debris posing composting challenges. Instead, farmers often resort to burning, releasing greenhouse gases and losing valuable biomass. In India, converting millions of tons of unused crop leftovers into biochar could address this issue, providing a sustainable soil amendment to enhance carbon content and fertility. Modern agriculture's reliance on inorganic fertilizers has negatively impacted 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, aids nutrient retention, serves as a habitat for beneficial microbes, and promotes organic carbon storage in 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 an alternative to crop burning in India. The production of biochar is influenced by factors such as processing temperature, heating rate, reactor pressure, and biomass composition. The potential of biochar extends beyond soil enhancement, as it is studied for its role in combating climate change, 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 cucurbit crop 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 rice husk biochar (RHB), coconut husk biochar (CHB) and areca nut husk biochar (AHB) were prepared. 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 were studied. The treatment details were T_1- RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1}, T_2 -100% RDF + CHB (2 ton ha^{-1}), T_3 -75% RDF + CHB (2 ton ha^{-1}), T_4 -100% RDF + CHB (4 ton ha^{-1}), T_5 -75% RDF + CHB (4 ton ha^{-1}), T_6 - 100% RDF + RHB (2 ton ha^{-1}), T_7 -75% RDF + RHB (2 ton ha^{-1}), T_8 - 100% RDF + RHB (4 ton ha^{-1}), T_9 -75% RDF + RHB (4 ton ha^{-1}), T_{10} -100% RDF + AHB (2 ton ha^{-1}), T_{11} -75% RDF + AHB (2 ton ha^{-1}), T_{12} -100% RDF + AHB (4 ton ha^{-1}), T_{13} -75% RDF + AHB (4 ton ha^{-1}), T_{14} -Absolute control (RHB-Rice husk biochar, CHB- Coconut husk biochar, AHB- Areca nut husk biochar) and FYM @ 15 ton ha^{-1} applied to all treatments. Weight of each 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 0.321 dSm^{-1} in RHB, 0.143 dSm^{-1} in CHB and 0.289 dSm^{-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 loam in texture, 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. Ayesha variety of watermelon was used for investigation. Methodology used for analysis of soil carbon pools are as given in Table 1.

Table 1: Methodology used for soil carbon pools

Sr. No.	Soil Carbon Pools	Method	Reference
1.	Soil organic carbon	Walkley and Black's Wet oxidation method	Jackson (1973) [2]
2.	Water Soluble Carbon (WSC)	0.1 N $K_2Cr_2O_7$ and H_2SO_4 method	Chio *et al.* (1986) [1]
3.	Soil Inorganic Carbon (SIC)	Dry combustion method	Tiessen and Moir, (1993) [3]
4.	Labile Carbon (LC)	H_2SO_4 Method	Chan *et al.* (2001) [4]
5.	Soil Total Carbon (TC)	Dry combustion method	Tiessen and Moir, (1993) [3]
6.	Microbial biomass carbon	Chloroform fumigation method	Vance *et al.* (1987) [5].

Results and Discussion

The results of the effect 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), inorganic carbon (IC) and total carbon (TC) at harvest under watermelon crop presented in Table No. 2 and 3.

The changes in soil organic carbon of soil were due to the influence of different levels of recommended dose of fertilizers with various crop residue biochar. The results revealed that an increasing rate of biochar application influenced soil organic carbon considerably. Soil organic carbon ranged from 14.11 to 17.16 g kg^{-1} at harvest. During the harvest stage, the maximum organic carbon value was 17.16 g kg^{-1} in treatment T_8, which comprised 100% RDF with 4 t ha^{-1} of RHB. This value was on par with treatments T_4 containing 100% RDF + 4 t ha^{-1} of CHB) at 16.80 g kg^{-1}, T_5 containing 75% RDF + 4 t ha^{-1} of CHB at 15.93 g kg^{-1}, T_9 consisting 75% RDF + 4 t ha^{-1} of (RHB) at 16.49 g kg^{-1}, T_{12} containing 100% RDF + 4 t ha^{-1} of AHB at 16.97 g kg^{-1}, and T_{13} consisting 75% RDF with 4 t ha^{-1} of areca nut husk biochar (AHB) at 16.34 g kg^{-1}. The lowest organic carbon value at harvest was 14.11 g kg^{-1}, found in treatment T_{14}, which served as the absolute control.

Application of biochar and FYM along with inorganic 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 influenced.

Water soluble carbon affected positively by application of biochar, RDF and FYM. Application of 100% RDF along with 4 t ha^{-1} of rice husk biochar (T_8) resulted in a higher water-soluble carbon (WSC) content and it was at par with treatments T_4 (100% RDF + 4 t ha^{-1} of coconut husk biochar) at 81.82 mg kg^{-1}, T_5 receiving 75% RDF + 4 t ha^{-1} of coconut husk biochar (CHB) at 80.62 mg kg^{-1}, T_9 consisting 75% RDF + 4 t ha^{-1} of rice husk biochar (RHB) at 81.58 mg kg^{-1}, T_{12} containing 100% RDF + 4 t ha^{-1} of areca nut husk biochar (AHB) at 81.96 mg kg^{-1}, and T_{13} receiving 75% RDF + 4 t ha^{-1} of areca nut husk biochar AHB at 80.63 mg kg^{-1}.WSC ranged from 54.85 mg kg^{-1} to 80.85 mg kg^{-1} at harvest and 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 form by the processes of decomposition, microbial transformation as well as enzymatic transformation. Sandhu *et al.*, (2017) [7] recorded application of corn stover biochar @ 10 mg ha^{-1} increased WSC.

Labile carbon pool significantly affected by application of biochar. The highest labile carbon (351.98 mg kg^{-1}) was found in treatment T_8 receiving 100% RDF along with 4 t ha^{-1} RHB at harvest stage. But statistically treatment T_8 receiving 100% RDF along with 4 t ha^{-1} RHB was found at par with T_4 (348.75 mg kg^{-1}) and T_{12} (353.05 mg kg^{-1}) treatments in which 4 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 to changes 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 biochar 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 T_8, 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 par to treatments T_4, which consisted of 100% RDF with coconut husk biochar (CHB) at 4 t ha^{-1} (268 mg kg^{-1}), T_9 containing 75% RDF with RHB at 4 t ha^{-1} (266.92 mg kg^{-1}), and T_{12} receiving 100% RDF with areca nut husk biochar (AHB) at 4 t ha^{-1} (274.18 mg kg^{-1}). The absolute control, represented by treatment T_{14}, showed the lowest value of microbial biomass carbon (200.55 mg kg^{-1}) at the harvest stage. Microbial biomass carbon (MBC) measures biological activity and carbon contained in living components of soil organic matter within the soil. In the present investigation, it was found that due to a considerable increase in microbial population after addition of biochar in soil as it improves chemical and physical properties within soil such as pH, CEC, porosity, water holding capacity, and surface area which led to increased MBC. Hale *et al.*, (2015) [11] concluded that microbial biomass carbon in soil increases after the application of biochar which might be due to properties of biochar such as large surface area and high porosity which provide the best habitat for microbes by maintaining water and air. Biochar itself acts as a good carbon source for the growth of microbes (Fowles 2007) [6].

Soil inorganic carbon at harvest did not differ significantly. The highest value of soil inorganic carbon was recorded about 1.56 g kg^{-1} at harvest of watermelon. The lowest value of soil inorganic carbon was recorded in treatment (T_{14}) which was absolute control and found to be 1.22 g kg^{-1}.

At the harvest of watermelon, the highest total carbon of soil was recorded (18.72 g kg^{-1}) in treatment T_8, which consisted of 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB). It was at par with treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (18.30 g kg^{-1}), T5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (17.39 g kg^{-1}), T9 with 75% RDF and 4 t ha^{-1} of rice husk biochar (RHB) (17.97 g kg^{-1}), T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (18.50 g kg^{-1}), and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (17.81 g kg^{-1}). The absolute control showed the lowest total carbon (15.33 g kg^{-1}) at harvest. Total carbon content in soil was significantly increased after the application of biochar and RDF along with FYM. There was a significant improvement in soil organic carbon which led to an increase in TC. This might be due to the increased level of biochar and RDF along with FYM which increased the carbon status in the soil which was due to the high carbon content present in biochar. The functional groups present in biochar such as phenolic and carbonyl carbon helped to adsorb organic compounds.

Table 2: Effect of biochars on soil carbon pools under watermelon crop at harvest stage

Tr. No.	Treatment details	Soil Organic carbon (g kg^{-1})	Water Soluble Carbon (WSC) (mg kg^{-1})	Labile Carbon (LC) (mg kg^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	14.16	60.23	279.33
T_2	100% RDF + CHB (2 t ha^{-1})	15.54	70.51	326.54
T_3	75% RDF + CHB (2t ha^{-1})	14.75	69.75	316.44
T_4	100% RDF + CHB (4t ha^{-1})	16.80	81.82	348.75
T_5	75% RDF + CHB (4 t ha^{-1})	15.93	80.62	338.47
T_6	100% RDF + RHB (2 t ha^{-1})	15.73	72.73	334.15
T_7	75% RDF + RHB (2 t ha^{-1})	15.23	70.59	323.33
T_8	100% RDF + RHB (4 t ha^{-1})	17.16	82.24	358.22
T_9	75% RDF + RHB (4 t ha^{-1})	16.49	81.58	346.00
T_{10}	100% RDF + AHB (2 t ha^{-1})	15.64	71.55	331.33
T_{11}	75% RDF + AHB (2 t ha^{-1})	15.03	69.67	321.00
T_{12}	100% RDF + AHB (4 t ha^{-1})	16.97	81.96	353.05
T_{13}	75% RDF + AHB (4 t ha^{-1})	16.34	80.63	342.00
T_{14}	Absolute control	14.11	53.76	268.81
	S.E. (±)	0.43	3.26	4.15
	CD (P=0.05)	1.25	9.46	12.05
Initial Values		14.00	52.11	270.01

Table 3: Effect of various biochars on soil carbon pools under watermelon crop at harvest stage

Tr. no.	Treatment details	Microbial biomass carbon (MBC) (mg kg^{-1})	Soil inorganic carbon (IC) (g kg^{-1})	Total Carbon (TC) (g kg^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	208.75	1.25	15.41
T_2	100% RDF + CHB (2 t ha^{-1})	245.84	1.41	16.75
T_3	75% RDF + CHB (2t ha^{-1})	223.05	1.35	16.10
T_4	100% RDF + CHB (4t ha^{-1})	268.00	1.50	18.30
T_5	75% RDF + CHB (4 t ha^{-1})	257.73	1.46	17.39
T_6	100% RDF + RHB (2 t ha^{-1})	253.42	1.44	17.17
T_7	75% RDF + RHB (2 t ha^{-1})	231.96	1.40	16.63
T_8	100% RDF + RHB (4 t ha^{-1})	279.88	1.56	18.72
T_9	75% RDF + RHB (4 t ha^{-1})	266.92	1.48	17.97
T_{10}	100% RDF + AHB (2 t ha^{-1})	250.29	1.42	17.06
T_{11}	75% RDF + AHB (2 t ha^{-1})	229.53	1.39	16.42

T_{12}	100% RDF + AHB (4 t ha^{-1})	274.18	1.53	18.50
T_{13}	75% RDF + AHB (4 t ha^{-1})	261.32	1.47	17.81
T_{14}	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
Initial Values		184.12	1.15	15.15

Yield of watermelon

The result revealed that treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} recorded the highest fruit yield (48.85 t ha^{-1}) This value was statistically at par to treatments T_{12} receiving 100% RDF with AHB 4 t ha^{-1} (48.58 t ha^{-1}), T_4 containing 100% RDF with CHB 4 t ha^{-1} (48.58 t ha^{-1}). T_5 containing 75% RDF with 4 t ha^{-1} of coconut husk biochar (47.25 t ha^{-1}), T_9 consisting of 75% RDF with 4 t ha^{-1} of rice husk biochar (47.60 t ha^{-1}), T_{12} containing 100% RDF with 4 t ha^{-1} of areca nut husk biochar (48.58 t ha^{-1}), and T_{13} comprising of 75% RDF with 4 t ha^{-1} of areca nut husk biochar (47.35 t ha^{-1}), while significantly exceeding remaining treatments. The lowest fruit yield was observed in treatment (T_{14}) absolute control was (19.01 t ha^{-1}). The yield of crops depends on the production and mobilization of carbohydrates, intake of water and nutrients from the soil. It is also affected by the environment during growth. The application of biochar showed an increase in fruit yield of watermelon as compared to control. It may be due to intake of nutrients through a combination of biochar, FYM and inorganic fertilizers (Shilpa, 2019) [8].

Table 4: Effect of various crop residue biochar on yield of watermelon

Tr. No.	Treatment details	Fruit yield (t ha^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1}	29.00
T_2	100% RDF + CHB (2 t ha^{-1})	37.32
T_3	75% RDF + CHB (2 t ha^{-1})	35.36
T_4	100% RDF + CHB (4 t ha^{-1})	48.48
T_5	75% RDF + CHB (4 t ha^{-1})	47.25
T_6	100% RDF + RHB (2 t ha^{-1})	39.50
T_7	75% RDF + RHB (2 t ha^{-1})	37.24
T_8	100% RDF + RHB (4 t ha^{-1})	48.85
T_9	75% RDF + RHB (4 t ha^{-1})	47.60
T_{10}	100% RDF + AHB (2 t ha^{-1})	38.30
T_{11}	75% RDF + AHB (2 t ha^{-1})	36.48
T_{12}	100% RDF + AHB (4 t ha^{-1})	48.58
T_{13}	75% RDF + AHB (4 t ha^{-1})	47.35
T_{14}	Absolute control	19.01
	S.E. (±)	0.68
	CD (P=0.05)	2.04

Conclusion

The application of various rates of biochar along with inorganic fertilizers recorded enhanced soil carbon pools as well as yield of watermelon crop in Alfisols of Konkan. It was concluded that application of 100% RDF along with RHB (4t ha^{-1}) significantly improved soil carbon pools such as soil organic carbon, soil total carbon, water soluble carbon, labile carbon and microbial biomass carbon. Yield of watermelon crop also positively affected by biochar application. Overall results concluded that application inorganic fertilizers should be combined with biochar which help to achieve multiple benefits of carbon sequestration, environment protection.

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