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Effect of biochar on yield of watermelon (*Citrullus lanatus* Thunb.) and physico-chemical properties of soil in alfisols of konkan

RR Banpatti, RV Dhopavkar, SS More, AR Raut, Kanchan Ingle, YR Parulekar, VG Chavan and SB Dodake

Abstract
A field and laboratory study entitled "Effect of biochar on yield of watermelon and physico-chemical properties of soil in Alfisols of Konkan during *rabi* season in Konkan region" was conducted at the College of Horticulture, Dapoli, 2021- 22 using biochar and inorganic fertilizers at various rates of application. The experiment comprised of fourteen treatments viz., RDF (150:50:50) N: P_2O_5:K_2O kgha^{-1} (T_1); 100% RDF + CHB @ 2 t ha^{-1} (T_2); 75% RDF + CHB @ 2 t ha^{-1} (T_3); 100% RDF + CHB @ 4 t ha^{-1} (T_4); 75% RDF + CHB @ 4 t ha^{-1} (T_5); 100% RDF + CHB @ 6 t ha^{-1} (T_6); 75% RDF + CHB @ 6 t ha^{-1} (T_7); 100% RDF + RHB @ 2 t ha^{-1} (T_8); 75% RDF + RHB @ 2 t ha^{-1} (T_9); 100% RDF + RHB @ 4 t ha^{-1} (T_{10}); 75% RDF + RHB @ 4 t ha^{-1} (T_{11}); 100% RDF + RHB @ 6 t ha^{-1} (T_{12}); 75% RDF + RHB @ 6 t ha^{-1} (T_{13}); Absolute Control (T_{14}) laid in RBD with three replications. The experimental soil was sandy loam in texture, moderately acidity in reaction, low electrical conductivity, very high level of organic carbon, medium in available nitrogen, low in available phosphorus, high in potassium and low in cation exchange capacity. The biochar was prepared by subjecting rice husk and coconut husk to low heat (300-600 °C) pyrolysis in biochar kiln. The properties of rice husk and coconut husk biochar *viz.* pH is 9.34 and 9.05 respectively, EC is 0.321 dSm^{-1} and 0.143 dSm^{-1} respectively and nutrients include, nitrogen (0.184% and 0.156% respectively), phosphorus (0.153% and 0.077% respectively), potassium (0.15% and 0.13% respectively) and total carbon (83.54% and 74.50%).
Biochar at various rates @ 2t ha^{-1}, 4 t ha^{-1} and 6 t ha^{-1} was applied to the respective plots one week before sowing. Nitrogen was applied in the form of urea at different levels as per the treatments in 2 splits (at basal dose and at 30 DAS). Entire phosphorus and potassium were applied as basal dose in the form of SSP and MOP. The effect of biochar on soil properties and performance of watermelon at different stages was determined by following standard procedures.
The fruit yield was significantly enhanced under treatment with 100% RDF + RHB (6 t ha^{-1}) and at par with 100% RDF + CHB (6 t ha^{-1}) and 100% RDF + CHB (6 t ha^{-1}). Significant increase in porosity and maximum water holding capacity was noticed in the biochar applied treatments. However, the influence of treatments on soil particle density and bulk density was not significant.
The chemical properties like CEC and Organic carbon were significantly increased with biochar application. The available N, P_2O_5, K_2O were high in 100% RDF and biochar applied treatments than in 75% RDF and biochar applied treatments. However, the influence of treatments on soil pH and EC was not significant.

Keywords: Watermelon, bio char, pyrolysis, konkan

1. Introduction
Watermelon fruit is a pepo type, according to horticulture. It is very nutritious and low in calories. It is delicious and refreshing (Mangila *et al.*, 2007) [7]. Per 100 gm of edible watermelon, there are around 26 kcal of calories, 0.61gm of protein, 0.15gm of fat, 0.25gm of ash, 7.55gm of carbohydrates, 0.4gm of fibre, 7 mg of calcium, 0.24 mg of Iron, 10 mg of Magnesium, 11 mg of Phosphorus, and 112 mg of Potassium. It comprises 91.45 per cent water by weight. There are lots of phenolic, citrulline, lycopene, and carotene antioxidants in it. Due to their high fat and protein content, watermelon seeds are used to produce oil. Compared to the flesh, the watermelon peel contains more citrulline. Triterpene and anti-inflammatory phytonutrient, is also found, along with very high concentrations of citrulline and cucurbitacin E (Anon *et al.*, 2014) [3].
The narrow region of Konkan has a warm, humid climate and is located between the Western Ghats and the Arabian Sea. A distinguishing aspect of the region from June to September is its high rainfall (4748 mm).

The *Rabi* season in the Konkan region is ideal for producing watermelons. Watermelon is a major crop during *Rabi* in the Konkan region due to its short growing season. The climate in this area is ideal for cultivating watermelon, with moderate temperatures during the growth period and warm temperatures during the fruiting stage.

When plant biomass has been converted thermo chemically by a process known as pyrolysis at high temperature of 350 to 600 °C in atmosphere with little to no oxygen, the resulting product is called biochar. Biochar is a porous, fine-grained substance that is rich in carbon (Amonette and Joseph, 2009) [2]. It can be produced in many different ways, including the heap, drum, and pit methods.

Biochar is a suitable choice in this scenario for preserving both soil quality and crop productivity. A variety of charcoal termed biochar is applied to soil as a soil amendment to improve soil health and carbon sequestration. Biochar is being researched as a viable technique for carbon sequestration due to its potential to reduce climate change and global warming. Biochar has the potential to be a vital tool for the agricultural industry because of its distinctive ability to contribute to soil growth, water saving, the creation of renewable energy, and carbon sequestration. To address this expanding problem, researchers suggested enhancing the condition of degraded soils with biochar.

2. Materials and Methods

The field experiment was carried out in the *Rabi* season of 2021-2022 at the College of Horticulture in Dapoli (M. S.). The experimental plot's soil was lateritic loamy and had good drainage, making it ideal for cultivating watermelons. Ayesha variety of watermelon was used for present investigation. The experimental plot's soil had a sandy loam texture, a moderately acidity in reaction (5.37), poor electrical conductivity (0.096 dS m^{-1}), a very high level of organic carbon (14.13 g kg^{-1}) and a low cation exchange capacity (10.68 Cmol (p^+) kg^{-1}). It had a medium available nitrogen content (294.62 kg ha^{-1}), a low available phosphorous content (11.58 kg ha^{-1}), and a high available potassium level (284.26 kg ha^{-1}). In general, the soil at the trial site resembled typical lateritic soil from the Konkan region.

The field experiment was laid out in a Randomized block design comprising of fourteen treatments with three replications during *Rabi* 2021, College of Horticulture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The recommended dose of fertilizers (150: 50: 50 kg N, P_2O_5 and K_2O kg ha^{-1}). The treatments details are as given in table 1

Table 1: Treatment details for the field experiment

Treatment No.	Treatment details
T_1	RDF (150:50:50) N: P_2O_5:K_2O kgha^{-1}
T_2	100% RDF + CHB (2 t ha^{-1})
T_3	75% RDF + CHB (2 t ha^{-1})
T_4	100% RDF + CHB (4 t ha^{-1})
T_5	75% RDF + CHB (4 t ha^{-1})
T_6	100% RDF + CHB (6 t ha^{-1})
T_7	75% RDF + CHB (6 t ha^{-1})
T_8	100% RDF + RHB (2 t ha^{-1})
T_9	75% RDF + RHB (2 t ha^{-1})
T_{10}	100% RDF + RHB (4 t ha^{-1})
T_{11}	75% RDF + RHB (4 t ha^{-1})
T_{12}	100% RDF + RHB (6 t ha^{-1})
T_{13}	75% RDF + RHB (6 t ha^{-1})
T_{14}	Absolute control

*Note: FYM @ 15-ton ha^{-1} to all treatments
CHB: Coconut Husk Biochar, RHB: Rice Husk Biochar

3. Results and Discussion

In watermelon (*Citrullus lanatus* Thunb) var. Ayesha, the Crop yield, nutrient content and physico-chemical properties of soil were influenced by application of combination of biochar with inorganic fertilizer.

3.1 Effect of biochar on fruit yield of watermelon

The data regarding yield of watermelon influenced by different levels of recommended dose of fertilizers with different biochar are presented in Table 2 and figure. 1

Table 2: Effect of application of biochar on fruit 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}	28.85
T_2	100% RDF + CHB (2 t ha^{-1})	37.00
T_3	75% RDF + CHB (2 t ha^{-1})	35.25
T_4	100% RDF + CHB (4 t ha^{-1})	46.50
T_5	75% RDF + CHB (4 t ha^{-1})	46.20
T_6	100% RDF + CHB (6 t ha^{-1})	49.12
T_7	75% RDF + CHB (6 t ha^{-1})	47.33
T_8	100% RDF + RHB (2 t ha^{-1})	38.55
T_9	75% RDF + RHB (2 t ha^{-1})	36.43
T_{10}	100% RDF + RHB (4 t ha^{-1})	46.75
T_{11}	75% RDF + RHB (4 t ha^{-1})	45.78
T_{12}	100% RDF + RHB (6 t ha^{-1})	51.15

T_{13}	75% RDF + RHB (6 t ha^{-1})	48.10
T_{14}	Absolute control	23.27
	S.E. (±)	1.17
	CD (P = 0.05)	3.39

Fruit yield of watermelon per ha (t ha^{-1}) varies significantly between treatments, ranging from 23.27 t ha^{-1} to 51.15 t ha^{-1}.The result revealed that the treatment T_{12} with 100% RDF + RHB (6 t ha^{-1}) recorded the highest fruit yield (51.15 t ha^{-1}) which was found to be highly significant and was at par with the treatments T_6 (49.12 t ha^{-1}) and T_{13} (48.10 t ha^{-1})

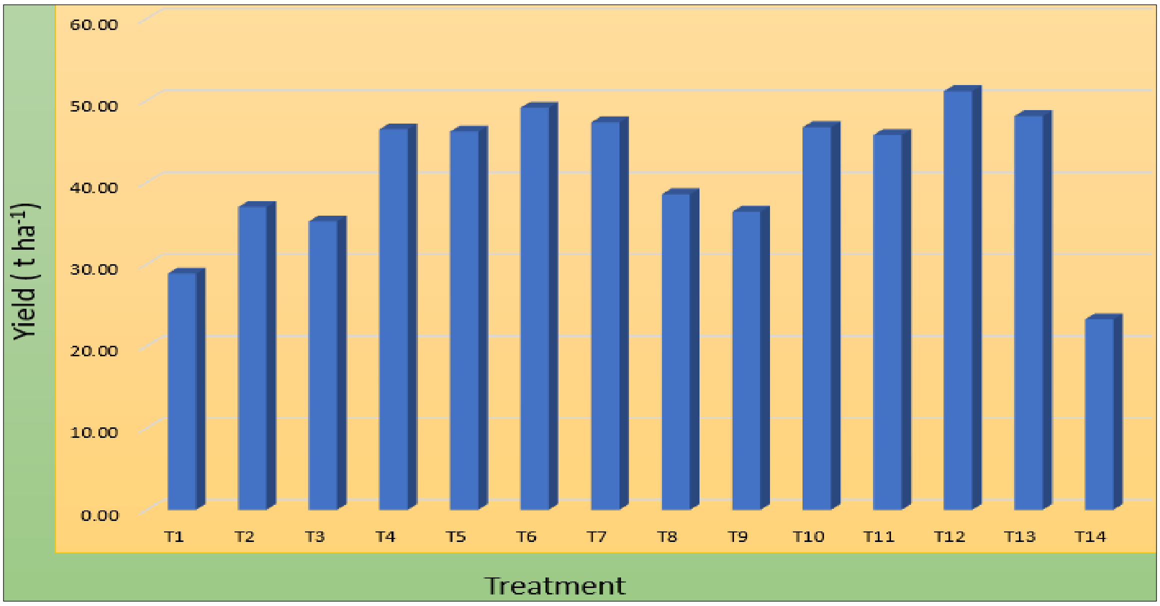

Fig 1: Effect of application of biochar on fruit yield of watermelon

The application of biochar has a considerable impact on the fruit girth of watermelons, according to the results. This may be achieved as a result of the release of macro- and micronutrients as well as the beneficial microorganism activity that may enhance fruit development characteristics.

In okra, Edward *et al*. (2013) [4] found comparable significant results. Similar significant results were found by Lal (2016) [6] and Almaroai and Eissa (2017) [1] in sweet corn and tomato, respectively.

3.2 Effect of biochar on physical properties of soil
3.2.1 Effect of biochar on bulk density and particle density of soil.

The perusal of data to the bulk density and particle density as influenced by different levels of recommended dose of fertilizers with biochar are presented in Table 3

The data related to bulk density and particle density of soils showed a statistically non-significant results through different treatment.

Table 3: Effect of application of biochar on bulk density and particle density of soil at harvest watermelon

Tr no.	Treatment Details	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})
		At harvest	At harvest
T_1	RDF (150:50:50) N: P_2O_5:K_2O kg ha^{-1}	1.48	2.60
T_2	100% RDF + CHB (2 t ha^{-1})	1.45	2.63
T_3	75% RDF + CHB (2 t ha^{-1})	1.47	2.60
T_4	100% RDF + CHB (4 t ha^{-1})	1.43	2.65
T_5	75% RDF + CHB (4 t ha^{-1})	1.43	2.63
T_6	100% RDF + CHB (6 t ha^{-1})	1.38	2.66
T_7	75% RDF + CHB (6 t ha^{-1})	1.40	2.66
T_8	100% RDF + RHB (2 t ha^{-1})	1.44	2.63
T_9	75% RDF + RHB (2 t ha^{-1})	1.45	2.62
T_{10}	100% RDF + RHB (4 t ha^{-1})	1.41	2.66
T_{11}	75% RDF + RHB (4 t ha^{-1})	1.43	2.64
T_{12}	100% RDF + RHB (6 t ha^{-1})	1.37	2.69
T_{13}	75% RDF + RHB (6 t ha^{-1})	1.40	2.66
T_{14}	Absolute control	1.51	2.60
	S.E. (±)	0.04	0.07
	CD (P = 0.05)	NS	NS

Soil application at different levels of recommended fertilizer doses with biochar reduces soil bulk density. Biochar addition directly leads to a decrease in the bulk density of soils because biochar has a lower density than mineral soils and induces soil aggregation, making the soil more porous.

The effects of various levels of recommended fertilizer doses on soil application with biochar show no significant results through various treatments because particle density, which is primarily dependent on soil separates and cannot be altered through fertilizer variation, is primarily dependent on soil separates and cannot be altered through fertilizer variation.

3.2.2 Effect of biochar on porosity and maximum water holding capacity of soil.

The data on soil porosity and maximum water holding capacity of soil as affected by various treatments was presented in Table 4 and Figure 2

At harvest, the highest value of porosity measured was 49% in treatment T_{12}, which received 100% RDF + RHB (6 t ha^{-1}) and it was at par with treatments T_{13} (47.43%), T_4 (45.97%), T_6 (48.19%), T_7 (47.30%), T_{10} (46.55%) and T_{11} (45.39%) and significantly superior over rest of treatments. The absolute control (T_{14}) treatment had the lowest porosity recorded at 41.84%

At harvest, the highest value of Maximum water holding capacity recorded was 55.70% in treatment T_{12} receiving 100% RDF + RHB (6 t ha^{-1}) and It was at par with treatments T_6 (54.93%), T_{13} (54.31%), T_7 (53.93%) and T_{10} (53.43%) and significantly superior than the other treatments. The absolute control (T_{14}) treatment has the lowest value of Maximum water holding capacity (44.22%).

Table 4: Effect of application of biochar on soil porosity and maximum water holding capacity of soil at harvest watermelon

Tr no.	Treatment Details	Porosity (%)	Maximum water holding capacity (%)
		At harvest	At harvest
T_1	RDF (150:50:50) N: P_2O_5:K_2O kg ha^{-1}	42.76	45.30
T_2	100% RDF + CHB (2 t ha^{-1})	44.41	49.78
T_3	75% RDF + CHB (2 t ha^{-1})	43.53	46.84
T_4	100% RDF + CHB (4 t ha^{-1})	45.97	51.37
T_5	75% RDF + CHB (4 t ha^{-1})	45.31	50.61
T_6	100% RDF + CHB (6 t ha^{-1})	48.18	54.91
T_7	75% RDF + CHB (6 t ha^{-1})	47.30	53.93
T_8	100% RDF + RHB (2 t ha^{-1})	44.79	50.21
T_9	75% RDF + RHB (2 t ha^{-1})	44.20	48.22
T_{10}	100% RDF + RHB (4 t ha^{-1})	46.55	53.43
T_{11}	75% RDF + RHB (4 t ha^{-1})	45.38	51.22
T_{12}	100% RDF + RHB (6 t ha^{-1})	49.00	55.70
T_{13}	75% RDF + RHB (6 t ha^{-1})	47.43	54.31
T_{14}	Absolute control	41.84	44.22
	S.E. (±)	1.26	1.42
	CD (P = 0.05)	3.65	4.11

The increase in porosity caused by biochar addition might be attributed to a decrease in soil bulk density as well as the diluting impact of biochar in soil. Herath *et al.* (2013) [5] reported that applying biochar to soil improves total pore volume, which was mostly due to the diluting impact of biochar, which caused a drop in bulk density of soil Biochar is porous in nature and has a high specific surface area; when added to soil, it enhances porosity and water holding capacity. Verheijen *et al.*, 2010 [11] reported an increase in MWHC of soil with biochar addition because biochar addition enhances soil specific surface.

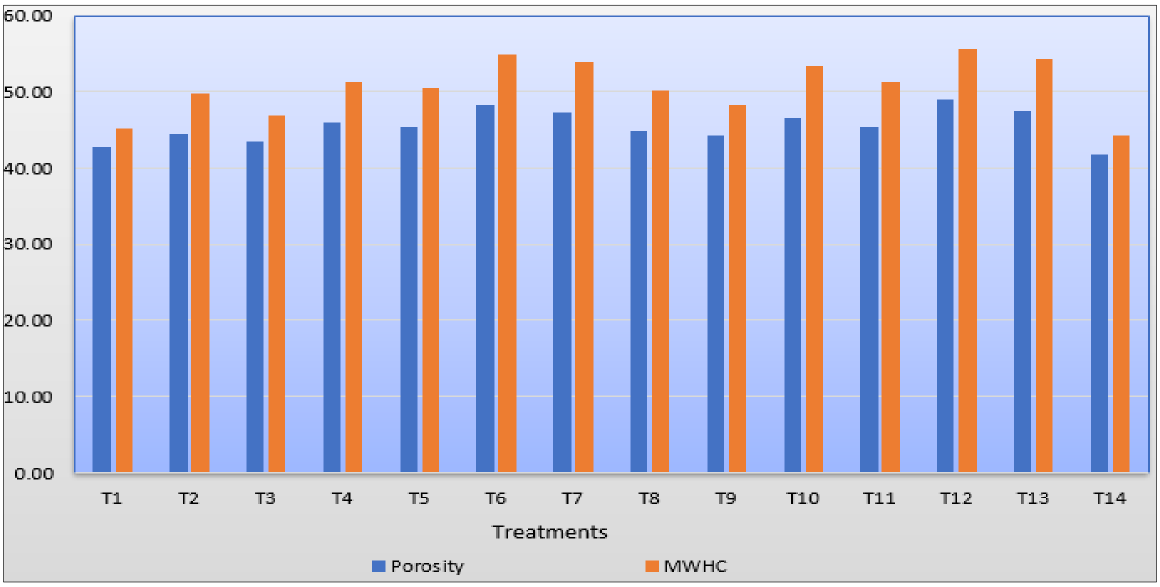

Fig 2: Effect of application of biochar on soil porosity and maximum water holding capacity of soil at harvest watermelon

3.3 Effect of biochar on chemical properties of soil.

3.3.1 Effect of biochar on soil pH and Electrical conductivity (E.C) of soil.

The data in respect of soil pH and electrical conductivity due to different levels of recommended fertilizer doses with biochar are presented in Table 5

It was revealed that the varied treatments had no significant effect on soil pH and EC.

Table 5: Effect of application of biochar on Soil pH and Electrical conductivity of soil at harvest watermelon

Tr no.	Treatment Details	pH	Electrical conductivity (dS m^{-1})
		At harvest	At harvest
T_1	RDF (150:50:50) N: P_2O_5:K_2O kg ha^{-1}	5.46	0.072
T_2	100% RDF + CHB (2 t ha^{-1})	5.50	0.079
T_3	75% RDF + CHB (2 t ha^{-1})	5.48	0.075
T_4	100% RDF + CHB (4 t ha^{-1})	5.57	0.088
T_5	75% RDF + CHB (4 t ha^{-1})	5.55	0.083
T_6	100% RDF + CHB (6 t ha^{-1})	5.63	0.091
T_7	75% RDF + CHB (6 t ha^{-1})	5.58	0.089
T_8	100% RDF + RHB (2 t ha^{-1})	5.52	0.081
T_9	75% RDF + RHB (2 t ha^{-1})	5.48	0.077
T_{10}	100% RDF + RHB (4 t ha^{-1})	5.58	0.089
T_{11}	75% RDF + RHB (4 t ha^{-1})	5.56	0.087
T_{12}	100% RDF + RHB (6 t ha^{-1})	5.65	0.094
T_{13}	75% RDF + RHB (6 t ha^{-1})	5.61	0.091
T_{14}	Absolute control	5.45	0.069
	S.E. (±)	0.09	0.01
	CD (P=0.05)	NS	NS

The increase in pH might be attributed to the basic nature of biochar, *i.e.*, its high pH. Yuan and Xu (2011) [12] reported increase in soil pH after adding biochar, which they attribute to the release of basic cations in the soil.

The increase in EC with biochar application might be attributed to ash residues in biochar that are dominated by carbonates of alkali and alkaline earth metals (Nigussie *et al*., 2012) [10].

3.3.2 Effect of biochar on organic carbon and Cation exchange capacity of soil.

At harvest stage the maximum value of available nitrogen in soil recorded was 398.29 kg ha^{-1}in treatment T_7 receiving 75% RDF + CHB (6 t ha^{-1}) and It was at par with treatment T_{10} (396.33 kg ha^{-1}) and significantly superior over rest of treatments. The significantly lowest reported value of soil available nitrogen was 260.20 kg ha^{-1} in absolute control (T_{14}) treatment.

Table 6: Effect of application of biochar on organic carbon and Cation exchange capacity of soil at harvest watermelon

Tr no.	Treatment Details	Organic carbon (g kg^{-1})	CEC (Cmol (p+) kg^{-1})
		At harvest	At harvest
T_1	RDF (150:50:50) N: P_2O_5:K_2O kg ha^{-1}	14.30	11.26
T_2	100% RDF + CHB (2 t ha^{-1})	15.69	12.88
T_3	75% RDF + CHB (2 t ha^{-1})	14.79	11.45
T_4	100% RDF + CHB (4 t ha^{-1})	16.69	15.53
T_5	75% RDF + CHB (4 t ha^{-1})	16.20	14.18
T_6	100% RDF + CHB (6 t ha^{-1})	17.89	17.81
T_7	75% RDF + CHB (6 t ha^{-1})	17.29	16.43
T_8	100% RDF + RHB (2 t ha^{-1})	15.90	13.41
T_9	75% RDF + RHB (2 t ha^{-1})	15.30	12.33
T_{10}	100% RDF + RHB (4 t ha^{-1})	16.86	15.92
T_{11}	75% RDF + RHB (4 t ha^{-1})	16.40	14.94
T_{12}	100% RDF + RHB (6 t ha^{-1})	18.20	18.32
T_{13}	75% RDF + RHB (6 t ha^{-1})	17.60	17.14
T_{14}	Absolute control	14.09	10.51
	S.E. (±)	0.46	0.40
	CD (P=0.05)	1.32	1.17

When biochar is applied to soil, its high organic carbon content causes carbon to be released into the soil system. Additionally, the mineralization of organic matter adsorbed by the biochar particles causes the organic carbon content of the soil to rise.

Masulili *et al* (2010) [8]. findings that the presence of strong carboxylic and phenolic functional groups in biochar resulting in high surface negative charge and causes better capacity to exchange cations further supported the significant rise in CEC with the addition of biochar.

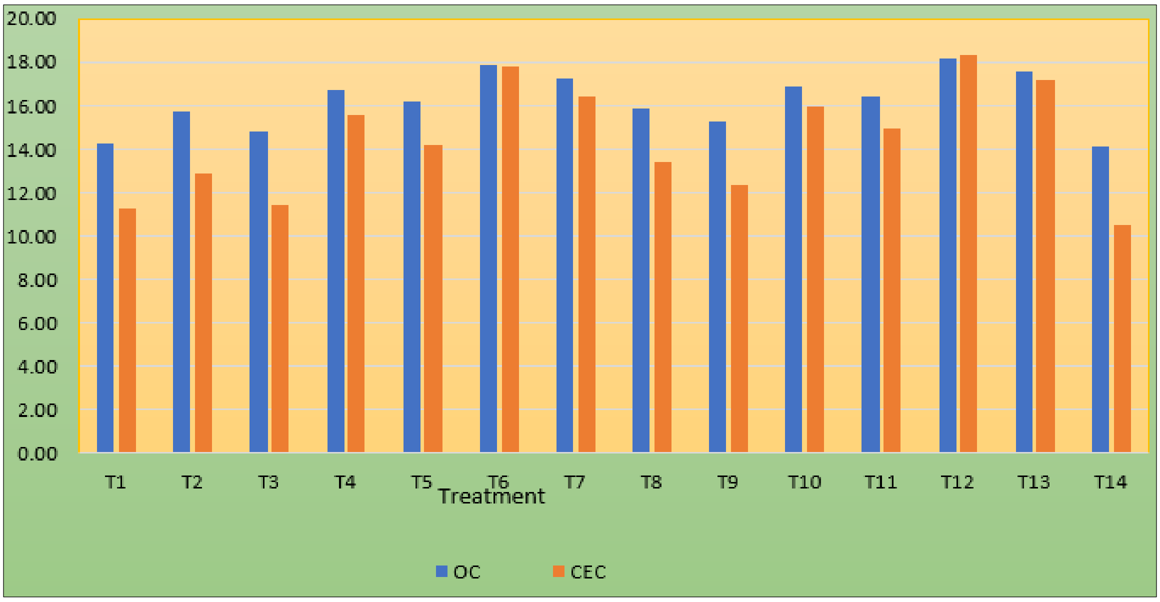

Fig 3: Effect of application of biochar on organic carbon and cation exchange capacity of soil at harvest watermelon

3.3.2 Effect of biochar on available nitrogen, available phosphorus, available potassium of soil.

The data on the effect of different levels of recommended fertilizer doses with biochar on available nitrogen, available phosphorus and available potassium in soil are presented in Table 7 and depicted in figure 4

while at harvest stage the maximum value of available nitrogen in soil recorded was 310.87 kg ha^{-1}in treatment T_{12} receiving 100% RDF + RHB (6 t ha^{-1}) and It was at par with treatments T_6 (307.41 kg ha^{-1}), T_{13} (303.44 kg ha^{-1}), T_7 (398.29 kg ha^{-1}) and T_{10} (396.33 kg ha^{-1}), T_4 (293.37 kg ha^{-1}), T_{11}(289.96 kg ha^{-1}) and T_5 (286.10 kg ha^{-1}) and significantly superior over rest of treatments. The significantly lowest reported value of soil available nitrogen was 260.20 kg ha-1 in absolute control (T_{14}) treatment.

At harvest, the highest available phosphorus in soil was 9.32 kg ha^{-1} in treatment T_{12} receiving 100% RDF + RHB (6 t ha^{-1}) and it was at par with treatments T_6 (9.21 kg ha^{-1}), T_{13} (9.18 kg ha^{-1}) and T_7 (9.12 kg ha^{-1}) and significantly superior over rest of treatments. The significantly lowest recorded value of soil available phosphorus was 7.93 kg ha^{-1} in absolute control (T_{14}) treatment.

At harvest, the maximum value of available potassium in soil was 323.62 kg ha^{-1} in treatment T_{12}, which received 100% RDF + RHB (6 t ha^{-1}) and it was at par with T_6 (328.10 kg ha^{-1}), T_{13} (321.52 kg ha^{-1}), T_7 (319.36 kg ha^{-1}), T_{10} (313.11 kg ha^{-1}) and T_4 (309.57 kg ha^{-1}) and significantly superior than the other treatments. The significantly lowest value of soil available potassium recorded was 276.81 kg ha^{-1} in absolute control (T_{14}) treatment.

Table 7: Effect of application of biochar on available nitrogen, available phosphorus and available potassium of soil at harvest watermelon

Tr no.	Treatment Details	Available nitrogen (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
		At harvest	At harvest	At harvest
T_1	RDF (150:50:50) N: P_2O_5:K_2O kg ha^{-1}	264.80	8.20	279.07
T_2	100% RDF + CHB (2 t ha^{-1})	275.60	8.37	288.67
T_3	75% RDF + CHB (2 t ha^{-1})	269.42	8.27	282.14
T_4	100% RDF + CHB (4 t ha^{-1})	293.37	8.59	309.57
T_5	75% RDF + CHB (4 t ha^{-1})	286.10	8.48	296.85
T_6	100% RDF + CHB (6 t ha^{-1})	307.41	9.21	328.10
T_7	75% RDF + CHB (6 t ha^{-1})	398.29	9.12	319.36
T_8	100% RDF + RHB (2 t ha^{-1})	282.70	8.63	291.85
T_9	75% RDF + RHB (2 t ha^{-1})	272.68	8.30	284.01
T_{10}	100% RDF + RHB (4 t ha^{-1})	396.33	8.60	313.11
T_{11}	75% RDF + RHB (4 t ha^{-1})	289.96	8.53	303.81
T_{12}	100% RDF + RHB (6 t ha^{-1})	310.87	9.32	332.62
T_{13}	75% RDF + RHB (6 t ha^{-1})	303.44	9.18	321.52
T_{14}	Absolute control	260.20	7.93	276.81
	S.E. (±)	8.70	0.23	8.36
	CD (P=0.05)	25.28	0.68	24.31

According to Nelissen *et al*. (2012) [9], the rise in nitrogen content caused by biochar addition is due to a higher nitrification rate because biochar absorbs potential nitrification inhibitors such as monoterpenes and other polyphenolic chemicals.

Due to the direct supply of soluble phosphorus in the soil that has been fertilized. The synergistic impact of biochar and fertilizer was noticed, and it boosted the amount of phosphorus that was available by applying them together. This was caused by the capacity of biochar to retain anions.

Due to the direct supply of mineral potassium by MOP, the available potassium was higher than control in 100% RDF applied treatments. Because biochar contains some ash that is rich in potassium, the quantity of potassium that is available in the soil increased with greater rates of biochar application.

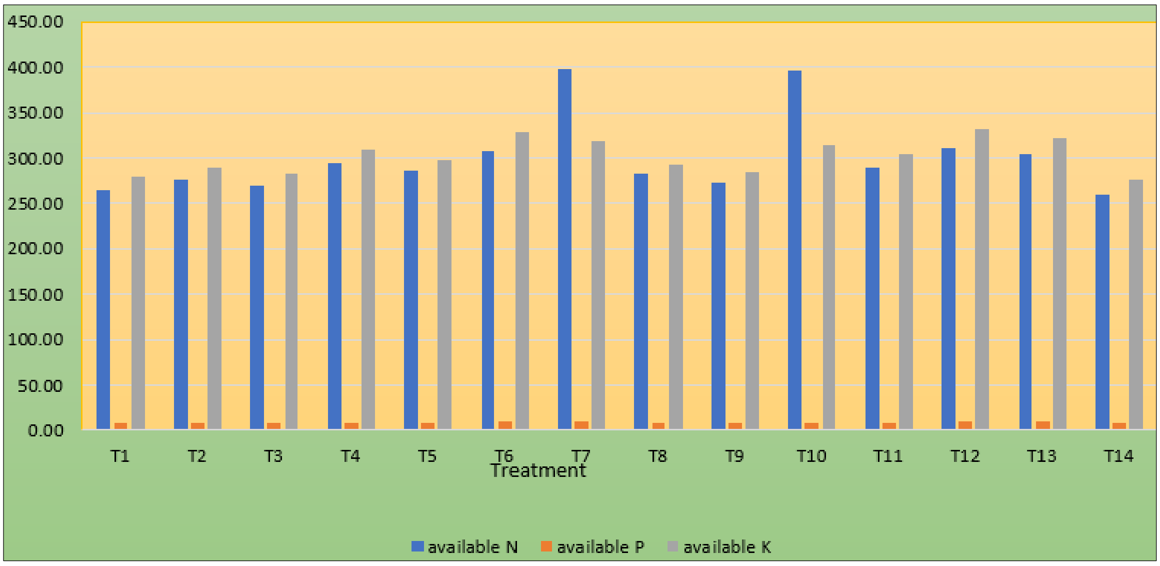

Fig 4: Effect of application of biochar on available N, available P and available K of soil at harvest watermelon

4. Conclusion

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

- Application of bio char to soil auspiciously improved soil physical properties (porosity and maximum water holding capacity) for watermelon growth and yield
- The application of bio char and inorganic fertilisers together improved the soil's chemical properties (organic carbon, available N, available P_2O_5, available K_2O, and CEC).
- When bio char was used in combination with inorganic fertilizers, watermelon yield increased.

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