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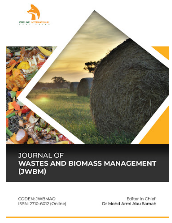

RESEARCH ARTICLE

EFFECT OF BIOCHAR AND VERMICOMPOST AS AN ORGANIC SOIL AMENDMENT IN SWEET ORANGE

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ABSTRACT

A Field experiment on sweet orange (*Citrus sinensis L.*) plant was conducted in Regional Agricultural Research Station (RARS), Jamalpur during 2017-2020 with the objectives to investigate the effect of biochar and vermicompost on growth and fruit yield of sweet orange and to develop soil fertility through inclusion of biochar and vermicompost. There were four treatments comprising T_1: Biochar + IPNS based Chemical fertilizer,T_2: Vermicompost + IPNS based chemical ferrtilizer, T_3: Biochar + vermicompost + IPNS based Chemical fertilizer and T_4: Chemical fertilizer All the treatments were significantly different from the control on all the growth and yield parameters. Data revealed that, T_3 treatment i.e; Biochar + vermicompost + IPNS based chemical fertilizer showed its best results with respect to vegetative and fruit characters of sweet orange plant. Among the four treatments, the highest average fruit yield (8.10 t ha^{-1}) was recorded in T_3 treatment (biochar-vermicompost combination treatment) and the lowest (5.38 t ha^{-1}) was found in control T_4 (chemical fertilizer) treatment. Soil organic carbon (SOC), total N, available P, K and S contents in post-harvest soil were also highest in T_3 treatment. The overall results indicate that application of biochar @ 4 kg tree^{-1} in combination with vermicompost @ 2 kg tree^{-1} and IPNS based Chemical fertilizer was most effective in increasing sweet orange yield and carbon accumulation in soil than sole application of biochar or vermicompost in combination with recommended doses of chemical fertilizers.

KEYWORDS

Biochar, vermicompost, biochar-vermicompost complex, chemical fertilizer, sweet orange, yield and carbon accumulation.

1. INTRODUCTION

Soil fertility degradation, caused by erosion and depletion or imbalance of organic matter/nutrients, is affecting world agricultural productivity. Inorganic fertilizers have played a significant role in increasing crop production since the "green revolution"; however, they are not a sustainable solution for maintenance of crop yields. Organic amendments, such as compost and biochar, could therefore be useful tools to sustainably maintain or increase soil organic matter, preserving and improving soil fertility and crop yield. Biochar is a carbon-rich material obtained from thermo chemical conversion of biomass in an oxygen-limited environment. Biochar has been described as a possible tool for soil fertility improvement, potential toxic element adsorption, and climate change mitigation (Malghani et al., 2013; Stewart et al., 2013). Some recent studies have indicated that combined applications of biochar with organic or inorganic fertilizers could lead to enhanced soil physical, chemical, and biological properties, as well as plant growth. A group researcher showed that the combined application of compost and biochar had a positive synergistic effect on soil nutrient contents and water-holding capacity under field conditions (Liu et al., 2012).

Malta or sweet orange (*Citrus sinensis L.*) is a nutritious and popular citrus fruit crops of the world, occupied third position among the sub-tropical fruits. It has a great nutritional role in our daily food requirements, being a rich source of vitamin C. In our climatic condition, Malta can easily be grown under the ago-economic edaphic condition of Bangladesh. The popularity and demand of Malta is increasing day by day but farmers do not use balance fertilizer for its cultivation, which cause serious nutritional disorders. However, it has a scope to ensure the yield and quality of BARI Malta-1 checking the deficiency of nutrients. Under such situation, integrated plant nutrient system (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity. With the above point of view, the present study was carried out to determine the effect of biochar application alone or combined with vermicompost on (i) plant growth and yield ii) physical, chemical and biological properties of soil.

2. MATERIALS AND METHODS

The experiment on impact of biochar and vermicompost on sweet orange plant was started at Regional Agricultural Research Station (RARS), Jamalpur during 2017-2018. Sweet orange (*Citrus sinensis L.*) (*BARI Malta-1*) was used for the study. The initial soil samples of the experimental field were collected and analyzed following standard methods. Soil chemical properties have been presented in Table 1.

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Table 1: Chemical properties of initial experimental soil at RARS, Jamalpur

Location	pH	OC (%)	OM (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
				meq 100g^{-1}				µg g^{-1}						
RARS, Jamalpur	6.4	0.77	1.32	6.5	2.2	0.109	0.041	5.1	15	0.24	2.2	20	1.2	0.9
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

A total of 20 sweet orange plants (3 years old) were selected from HRC, RARS, Jamalpur and included in the study. Growth characteristics of plants prior to fertilization have been presented in Table 2.

Table 2: Initial morphological characteristics of sweet orange plant

Treatment	Plant height (m)	Base girth (cm)	Canopy spreading (m)		No. of branch plant^{-1}	Tree volume (m^3)
			EW	NS		
T_1	1.97	15.51	1.42	1.51	15.02	2.21
T_2	1.92	16.82	1.39	1.44	14.79	2.01
T_3	1.95	16.41	1.45	1.48	12.33	2.18
T_4	1.87	16.01	1.47	1.52	13.55	2.17

Note : T_1 : Biochar + chemical fertilizer, T_2 : Vermicompost + chemical fertilizer, T_3: Biochar + Vermicompost + chemical fertilizer, T_4: Control (chemical fertilizer).

The chemical compositions (such as organic carbon, N, P, K, S, B, Cu, Fe, Mn, Zn, Mg, Ca and pH) of biochar and vermicompost were determined in the Soil Science Laboratory, BARI, Gazipur. (Table 3 and Table 4)

Table 3: Chemical composition of biochar used for the experiment

Properties	pH	OC (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			meq 100g^{-1}				µg g^{-1}						
Biochar	10.4	36.0	1.25	0.92	0.91	0.90	0.74	0.23	0.008	0.0012	0.12	0.03	0.010

Table 4: Chemical composition of vermicompost used for the experiment

Properties	pH	OC %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq 100g^{-1}				µg g^{-1}					
Vermicompost	6.2	14.9	1.45	0.83	0.85	1.51	0.87	0.39	0.008	0.001	0.50	0.014

The experiment was conducted to determine the impact of biochar and vermicompost for quality sweet orange production during the fruiting season of 2017-18. The, study was undertaken followed by Randomized Complete Block (RCB) design with 5 replications. The plants were fertilized in 16 November, 2019.Recommended Dose of Chemical Fertilizer of fertilizer for the sweet orange plant was $N_{169}P_{79}K_{88}S_{18}Zn_3B_1$ (3 years old tree). Urea, TSP, MoP, Gypsum, Zinc sulphate and boric acid were used as a source of N, P, K, S and B, respectively. All other chemical fertilizers were applied as a initial blanket dose through IPNS basis. Biochar @ 8 kg plant^{-1} and vermicompost @ 4 kg plant^{-1} and biochar-vermicompost combination @ (4+ 2) kg plant^{-1} was applied as per treatment. All fertilizer and manure were applied as ring method around the plant and exclude 1m distance from the tree base. Other intercultural operations were done as per requirement. Imidachloprid (Imitaf @ 0.25 ml L^{-1}) was applied to reduce leaf miner infestation when new leaf emerged.

Treatments were as follows:

T_1 = Biochar + IPNS based Chemical fertilizer ($N_{97}P_{20}K_{15}S_{18}Zn_3B_1$)
T_2 = Vermicompost + IPNS based Chemical fertilizer $N_{108}P_{45}K_{54}S_{18}Zn_3B_1$)
T_3 = Biochar + Vermicompost + IPNS based Chemical fertilizer ($N_{103}P_{32}K_{34}S_{18}Zn_3B_1$)
T_4 = Chemical fertilizer ($N_{169}P_{79}K_{88}S_{18}Zn_3B_1$)

Table 5: Treatments combinations for sweet orange plant

Treatments	Treatment combination							
	Chemical fertilizer (g/tree/year)						Organic manure (kg /tree/year)	
	N	P	K	S	Zn	B	Biochar	Vermicompost
T_1	97	20	15	18	3.2	1	8	0
T_2	108	45	54	18	3.2	1	0	4
T_3	103	32	34	18	3.2	1	4	2
T_4	169	79	88	18	3.2	1	0	0

Note: T_1 : Biochar + chemical fertilizer, T_2 : Vermicompost + chemical fertilizer, T_3: Biochar + Vermicompost + chemical fertilizer, T_4: Control (chemical fertilizer).

Data on vegetative and fruit characters were recorded and analyzed statistically using statistical software STAR which was developed by IRRI. After two years, post harvest soil samples were collected from 0-15cm depth and analyzed following standard procedures.

Carbon stock and Carbon accumulation were calculated using following formula.

Carbon stock (t ha^{-1}) = Carbon concentration (%) x bulk density (gcm^{-3}) x depth (cm)

Carbon accumulation (t ha^{-1}) = Final C stock (t ha^{-1}) - Initial C stock (t ha^{-1})

3. Result and Discussion

3.1 Effect of organic amendment on vegetative characters of sweet orange

The results of organic amendment treatments indicated significant increase in plant height, base girth and canopy spreading of sweet orange plant. Plant height varies from 2.77 m to 3.26 m. Among the treatments, T_3 (biochar-vermicompost combination) treatment exhibited the highest base girth (34.63 cm) compared to the least in T_4 treatment (28.53 cm). Maximum canopy spread both East-West direction (3.15m) and North-South direction (2.90 m) was observed in treatment T_3 treatment. This value was minimum (2.37m x 2.23 m) under control treatment. The plant height, base girth and canopy spreading were taken as indicators for the growth of sweet orange plant. Significant increase in tree volume from 7.66 m^3 to 15.58 m^3 was found in different organic amendment treatments. Biochar –vermicompost complex can be attributed to the availability of nutrients to the plants due to the retention of the nutrients in the soil which led to enhance plant height, leaf number and leaf area (Rodriguez et al., 2009).

Table 6: Vegetative characteristics of sweet orange plant as influence by organic amendment, 2019-2020

Treatment	Plant height (m)	Base girth (cm)	Canopy spreading (m)		Number of branch plant^{-1}	Tree volume (m^3)
			EW	NS		
T_1	2.99 b	31.41 b	2.75 b	2.59 b	28.97 b	11.15 b
T_2	2.85 c	30.21 bc	2.68 b	2.57 b	26.82 c	10.25 b
T_3	3.26 a	34.63 a	3.15 a	2.90 a	31.68 a	15.58 a
T_4	2.77 c	28.53 c	2.37 c	2.23 c	23.60 d	7.66 c
CV (%)	6.18	5.10	3.82	3.11	9.21	6.71
LSD (0.05)	0.09	1.93	0.029	0.15	1.95	1.21

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Note: T_1 : Biochar + chemical fertilizer, T_2 : Vermicompost + chemical fertilizer, T_3: Biochar + Vermicompost + chemical fertilizer, T_4: Control (chemical fertilizer).

3.2 Effect of organic amendment on fruit characters and yield of sweet orange

A significant variation was observed for sweet orange yield when different organic amendment were applied. Maximum fruit length (8.10 cm) and fruit breadth (6.39 cm) were recorded from T_3 treatment and the minimum were found in T_4 treatment. No. of fruits/plant varies from 56.34 to 37.89. The highest individual fruit wt. (202.08 g) was recorded in the T_3 (biochar-vermicompost combination) treatment followed by T_1 (189.54 g) and the lowest wt. (137.48 g) recorded in the control treatment comprises with recommended chemical fertilizers. These results are in agreement with the findings of Mohideen who also reported improvement in average fruit weight of chilli with the application of Gliciridia biochar + 100% urea over sole applications (Mohideen, 2018). In 2019-2020, the highest fruit yield (7.98 t ha^{-1}) was found in T_3 treatment (biochar-vermicompost combination) treatment compared to only biochar applied (7.08 t ha^{-1}) or only vermicompost applied (6.93 t ha^{-1}) where as the lowest fruit yield (4.92 t ha^{-1}) was noticed in T_4 treatment (only chemical fertilizers). The higher average fruit yield recorded with the dual application of biochar and vermicompost is possibly due to improvement in soil properties and increased nutrient availability (Deluca et al., 2009). TSS ranged from 9.90% to 8.42% in different treatments. Soluble solids content markedly increased in response to biochar application; this contributed to higher sweetness than that of fruit from biochar-free plants (Villocino et al., 2015).

Table 7: Fruit characteristics of sweet orange plant as influence by organic amendment, 2019-2020

Treat.	Fruit length	Fruit diameter	No. of fruits/plant	Individual fruit wt. (g)	Fruit yield (t ha^{-1})		Average yield (t ha^{-1})	TSS (%)
	(cm)				2018-2019	2019-2020		
T_1	7.51 b	6.03 b	51.32 b	189.54 b	7.47 b	7.08 b	7.27	9.32 a
T_2	7.16 c	5.90 b	48.78 b	172.14 c	7.07 b	6.93 b	7.00	9.28 a
T_3	8.10 a	6.39 a	56.34 a	202.08 a	8.23 a	7.98 a	8.10	9.90 a
T_4	6.85 d	5.42 c	37.89 c	137.48 d	5.85 c	4.92 c	5.38	8.42 b
CV (%)	2.15	3.49	4.12	3.96	7.50	7.12	-	2.59
LSD (0.05)	0.025	0.043	3.8	48.111	0.65	0.85	-	0.67

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Note: T_1 : Biochar + chemical fertilizer, T_2 : Vermicompost + chemical fertilizer, T_3: Biochar + Vermicompost + chemical fertilizer, T_4: Control (chemical fertilizer).

3.3 Nutrient status of post-harvest soil

Table 8 presents nutrient status of soil after completion of the experiment. Application of soil amendments produced significant variations in the chemical properties of the soil. The highest pH value was observed in the trial treated with biochar-vermicompost combined application, while the lowest values were recorded in the chemical fertilizer (control) trial. Under T_3 (biochar-vermicompost complex) treatment, about 60 % increases was observed in the available N content of the soil compared to control. Application of sole biochar and sole vermicompost also increased the available N over control. Likewise; remarkable increases of about 67.28 % and 46.15 % were recorded for P and K respectively in the T_3 in comparison to the control. It has been suggested that biochar – vermicompost complex amendment could lead to a change in the microbial community in soils, both in structure, abundance and activity (Lehmann, 2007). These changes could improve bioavailability of nutrients to the plants and even stimulate the release of plant growth promoting hormones. Beside these, other soil nutrient status was increased due to application of organic amendment compared to that of initial soil. In the present study, application of organic amendment recorded an improvement in soil nutrient status over control.

Table 8: Nutrient status of post harvest soil under sweet orange plant, 2019-2020

Treatments	pH	SOC (%)	Total N%	K	P	S	B	Zn
				meq 100g^{-1}	µg g^{-1}			
T_1	6.78	0.83	0.056	0.18	11.55	19.73	0.41	1.97
T_2	6.65	0.82	0.053	0.15	10.82	19.25	0.39	1.73
T_3	6.83	0.86	0.064	0.19	13.60	21.61	0.45	2.53
T_4	6.47	0.76	0.040	0.13	8.13	18.58	0.26	1.43
Initial soil	6.4	0.77	0.041	0.109	5.1	15	0.24	0.9

Note: T_1 : Biochar + chemical fertilizer, T_2 : Vermicompost + chemical fertilizer, T_3: Biochar + Vermicompost + chemical fertilizer, T_4: Control (chemical fertilizer).

3.4 Soil carbon accumulation under organic amendment under sweet orange plant

Table 9 presents the data pertaining to the organic amendment application on soil carbon accumulation under sweet orange plant. Organic amendment application had positive effect on carbon stock and carbon accumulation after two years experiment. The initial soil organic carbon, bulk density and carbon stock in soil were 0.77%, 1.48 gcm^{-3} and 17.09 tha^{-1}, respectively. After two years, bulk density varied from 1.44-1.49 gcm^{-3}. Post harvest SOC concentration was found to be high (0.86%) in Biochar-vermicompost complex (T_3 treatment), which was about 13.15 % more than the control treatment (0.76%).The SOC concentration (%) ranged in the order: Biochar-vermicompost complex (0.86%) > sole biochar (0.83%) >sole vermicompost (0.82%) and control (0.76%). Result revealed that, the treatment with a chemical fertilizer (control) showed the lowest SOC concentration. Highest SOC concentration was observed in organic amendment treatment. Irrespective of treatments, maximum SOC was recorded in soil treated with biochar- vermicompost complex. This hence shows the highest soil carbon sequestration potential.

Table 9: Soil fertility attributes under organic amendment under sweet orange plant, 2019-2020

Treatments	Initial soil			Post harvest soil			Carbon accumulation (t ha^{-1})
	SOC (%)	BD (gcm^{-3})	C Stock (t ha^{-1})	SOC (%)	BD (gcm^{-3})	C Stock (t ha^{-1})	
T_1	0.77	1.48	17.09	0.83	1.46	18.17	1.08
T_2	0.77	1.48	17.09	0.82	1.47	18.08	0.99
T_3	0.77	1.48	17.09	0.86	1.44	18.57	1.48
T_4	0.77	1.48	17.09	0.76	1.49	16.98	0

Note: T_1 : Biochar + chemical fertilizer, T_2 : Vermicompost + chemical fertilizer, T_3: Biochar + Vermicompost + chemical fertilizer, T_4: Control (chemical fertilizer).

4. Conclusion

From three years experimental results, it can be concluded that, T_3 treatment (Biochar + Vermicompost + IPNS based chemical fertilizer) was found to be the most effective in increasing sweet orange yield, improved carbon accumulation and nutrient availability. So, combined use of biochar and vermicompost along with chemical fertilizer plays an important role in both short-term yield increase and long-term maintenance of soil organic matter compared to sole chemical fertilizer.

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